

Prevention and Control of Infections in Hospitals

Practice and Theory

Bjørg Marit Andersen



Springer

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Original Norwegian edition published by Elefantus Forlag, Moss, 2016

ISBN 978-3-319-99920-3 ISBN 978-3-319-99921-0 (eBook)
<https://doi.org/10.1007/978-3-319-99921-0>

Library of Congress Control Number: 2018963171

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The registered company address is: Gwerbestrasse 11, 6330 Cham, Switzerland

Preface

Prevention and Control of Infections in Hospitals: Practice and Theory deal with infection control, surveillance and hygienic routines and key topics, both practical and theoretical. The book is adapted to a necessary level of infection prevention to cope with today's emerging and resistant microbes, hygienic challenges and emergency preparedness in practical work. It updates current knowledge about infection protection as basic for selecting routines and guidelines to prevent hospital infections.

Healthcare-associated infection (HAI) is primarily a patient safety issue, causing more than 90% of patient injuries. Leaders at all levels in the healthcare system are responsible for patient safety and infection control, from the director of the hospital to the health minister and government, and this should be warranted by law. Lack of management is associated with overcrowding, understaffing, corridor-beds, poor maintenance of buildings and equipment, inadequate cleaning and basic hygienic measures which often lead to HAIs. Hospital infections may occur in 5–20% or more of hospitalized patients. In Europe, at least 7.5 million patients acquire HAI each year, and more than 147,000 patients die directly or indirectly from HAIs each year in European hospitals.

Hospital infections are detected more often after discharge, due to shorter and shorter stay in hospitals. This may lead to spread of resistant bacteria between healthcare levels and less favourable outcome for the patient with infection. Virus like influenza and norovirus follow the patient and may spread like “fire in dry grass”. Entire departments with patients and personnel will be “sick-reported” and must shut down all activity for 2–3 weeks.

The spread of resistant and/or particularly pathogenic, contagious microbes poses a risk to patients, employees, visitors and society as a whole. Dangerous microbes often have a global spread pattern, which requires continuous readiness with effective, limiting measures against epidemics or pandemics.

The book is focused on practical measures against severe hospital infections such as postoperative wound infections; intravascular, blood-borne infections; infections in lower respiratory tract, urinary tract, skin and gastrointestinal tract; and infections in neonates and premature and in other patients with impaired infection defence.

A good hygiene is important to protect patients, visitors and employees against infections. Good hygiene routines, personal infection protection, cleanliness, textile

treatment, sterility, disinfection and high professional hygiene standards for patient care increase patient safety and protect the working environment. Daily infection surveillance, infection detection and adequate contraceptive measures and information are required to stop the spread of infection.

The book is intended to be an aid and an optimal standard in practical work to reduce the incidence of serious hospital infections and spread of infection. This increases the quality of patient treatment; patient safety is better taken care of, and infection control becomes a natural part of measures around hospital patients and employees.

Prevention and Control of Infections in Hospitals: Practice and Theory is updated from earlier (1996, 1999, 2003, 2008, 2016) Norwegian handbooks in infection control, lastly published in 2016 (Elefantus forlag, Moss). Each chapter has a practical part and a background information and documentation part.

Thanks to the following colleagues for professional advises and comments:

Infection control nurses, Mette Rasch and Kjersti Hochlin; chief physician, Kjell Olafsen; and professor in medicine, PhD, Inggard Lereim.

In addition, I am grateful to my family, friends and colleagues for friendly assistance and positive support during the writing period. However, my greatest and most enthusiastic fan, my dog, Tito, left forever in May 2018.

Target groups: health professionals; doctors, nurses and other health professionals; students in health-related subjects, hospital leaders and health agencies; and patients and their relatives.

Oslo, Norway
June 2018

Bjørg Marit Andersen

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Part I

Introduction (Surveillance, Microbes and Pathways, Tracing and Preventing)



Patient Protection Is Patient Safety

1

Abstract

Patient safety is dependent on the quality of care, treatment and protection against adverse events. Healthcare personnel should do their work in a good, safe and effective way. Hospital leaders have the responsibility to protect all patients against adverse events, like hospital infections, and ensure that hospital resources are sufficient.

Keywords

Healthcare-associated infections · HAI · Hospital infections · Patient safety · Overcrowding · Understaffing · Bed occupancy · Hygienic measures · Infection control · Leadership · Administration · Organization · Health resources

Lack of patient safety and protection in hospitals may result in adverse events and injuries. Hospital-associated infections (HAIs) cause more than 90% of all these adverse events [1, 2]. In US hospitals, it is estimated that more than 110,000 patients (ca. 37 million admissions) die from medical failures each year; and 99,000 of these deaths are attributed to HAIs [2, 3]. In Europe, HAIs may cause 37,000 attributable deaths, and contribute an additional 110,000 every year [1, 3]. It is estimated that HAIs may cost up to 16 million extra days in European hospitals each year [1, 3].

Patient safety is dependent on knowledge and skill of the personnel, proper use of guidelines, political choices and priorities, healthcare resources and a competent management.

Conditions associated with adverse events like HAIs are as follows: overcrowding of patients, high bed occupancy rates (more than 85%), too many beds in one room (single-bed room becomes two-bed room), corridor patients, transferring patients to another department that does not have the “right” speciality, too early discharges because of shortage of patient beds, understaffing, inadequate monitoring of sick patients and lack of hygiene and cleanliness. These are

well-known and well-documented causal factors for serious hospital infections and other injuries [1, 4–14].

Overcrowding and understaffing are associated with increased number of HAIs, especially among children and patients with immunodeficiency, often with repeated outbreaks in neonatal wards and in overcrowded departments [5–8].

In 2008, overcrowding at the NHS hospitals in England led to widespread resistant bacterial infections among the patients. The surgeons at the hospitals warned the patients against admissions in the hospitals with problems [9].

“Persistent overcrowding on NHS hospital wards is causing an uncontrollable spread of superbugs and other forms of infection, the Royal College of *Surgeons* warned last night. Its leaders called on the government to publish the bed occupancy rate-, *allowing patients to choose—where* conditions are safe. Surgeons should become whistle-blowers to alert the public to the risk of infection by overcrowding. Sixty percent of hospitals in England are failing to deal with superbug infections effectively. Wards where patients stay overnight should not have an occupancy rate of more than 82%. The staff-to-patient ratio should be high enough to ensure proper care in isolation beds” [9]. “Un-acceptable—to be infected by the NHS- hospitals” [9].

Poor maintenance and functionality of the hospital, like structural damage with leakages and growth of fungi and lack of single-bed rooms, toilets, bathrooms, isolates, etc., are associated with reduced patient safety with risk of spread of infections between patients and extra burden on the staff [1, 4–9, 15]. A rehabilitation effort must be made for hospital buildings, and the maintenance budget (10% of the budget) should be used as dedicated.

Inadequate cleaning, lack of basic hygiene measures and accumulation of resistant microbes and dirt in the environment may increase the risk of infections and carrier state [6–14]. Quality of cleaning is highly vulnerable when hospitals are going to save money [8, 10–16].

Infection control is very expensive for the hospital, patients and the society. Hospital infections such as pneumonia, sepsis, urinary tract infections, wound infections, etc. lead to prolonged stay—with occupancy of beds for 4–14 extra days—isolation costs, overuse of antibiotics and development of resistance [1–3, 15, 16]. This may slow the patient through-put, occupy the most expensive treatment beds on intensive care units (ICU) and even block the surgical activity.

1.1 Lack of Leader Competence and Responsibility

The hospital’s state of patient safety and prevalence of hospital infections reflect the leader competence. The responsibility for patient safety is on the leaders in all levels, from the head of the department and the hospital director all the way to the council of health and the government. Hospital injuries such as infections, invalidity and death should be prevented by good management, local and central. It is as important as ensuring good treatment of the patient’s actual disease. The management is also responsible for protecting personnel against infections and workplace injuries.

The incidence of healthcare-associated infections can be linked to management: [17]

- Too large span of control for managers
- A weak leadership with unclear routines and responsibilities
- Unclear roles and responsibilities for infection control personnel and the absence of infection control team
- Lack of active support from the management concerning infection control measures

Other aspects of leadership are of great importance:

- High personnel turnover
- Low personnel morale—“blindness to risk”
- High patient turnover
- Understaffing
- High patient bed occupancy rate $\geq 85\%$ [17]

Postoperative wound infections can be influenced by management factors at the hospital and used as a quality factor [18].

Incorrect savings—most determined by management—can lead to life-threatening hospital infections. For example, sharing of single-dose medicaments like propofol between several patients, with subsequent severe sepsis caused by contaminated dosing vessels [19].

Extreme leaders can be exemplified by savings that resulted in major infection outbreaks at Good Hope Hospital in England in 2007. Reuse of bed clothing by turning the bed linen between patients, to save annual wash costs of £ 500,000, promptly led to a sharp increase in MRSA and doubled the number of patients with *Clostridium difficile* infections [20]. The matter ended up in the house: “Is it all the safety of a patient’s life is worth? 0.275 pence?” [20].

Part-time work is a major management problem and results in increased spread of infections by personnel working at different healthcare institutions during the same period (hospitals and nursing homes), also in different countries [5–8, 21]. Neither hospital managers nor the Public Health Department seem to cope with this very important problem.

1.2 Hospital Organization Is Important for Hospital Infections and Patient Safety

The healthcare system has been through major changes during the last 50 years, all over the world. More patients are treated for more serious and life-threatening diseases, at higher ages and in more sophisticated and expensive ways, than ever, in the history. This health revolution has several weak sides that may increase the risk for patients and personnel concerning infections and other adverse incidents.

1.2.1 The Norwegian Example

Also Norway, with 5.5 million inhabitants, went through several major changes in the healthcare organization from the 1970s. At that time there were approximately 70 hospitals (30–1200 beds). The local hospitals, county hospitals, central hospitals and specialist hospitals served the communities in rural districts and cities [22]. Five university hospitals ensured the country's medical top specialities. With a few exceptions, all hospitals were public hospitals. Patients received treatment required according to "good medicine and present research" and usually without regard to costs. The patient was in focus. Few dangerous or resistant microbes threatened in the horizon and antibiotics worked. The staff generally followed good hygiene guidelines and had time for the patient who stayed often (too) long at the hospital.

Hospital management and leaders changes. In the 1980s, the doctors' "sole right" to lead hospitals and departments and corresponding power over financial resources weakened. The economic basis for hospital management was set under debate. Many physicians were ousted by nurses with education in leadership. Public wage levels disappeared, and the wage rise became a personal hassle between managers and employees. Business economists and other non-health professionals often became leaders for hospitals. The leadership prospered, and the economy came into focus, while the patient began to fall out of focus.

At the same time, many Norwegian hospitals developed a building-related decay and were in poorly maintained state because of lack of resources [23–26]. Most of the budget for repair and maintenance of hospital buildings was used for patient care, "firefighting measures" and ad hoc solutions [23–26]. Hospital budgets were often made during or after the actual budget year. This revealed a miserable financial planning and management of resources and poor leadership. The same problems are present today [25–28].

Economic savings. In the 1990s, economic savings came in response to rapid development in medical disciplines, new medical technology, increasing patient demand and increasing payroll costs in the form of "personal" salary. While the pay packet rose, the "factory patient" was established with cost analyses for the patient's diseases—from heart attack to ingrown toenails. It was done time-use-, ordering-, and cost analyses of many activities, resulting in a huge bureaucracy [25–28]. This resulted in many hospitals becoming introverted, self-centred, structural slums [23, 24]. The patient's role was on the way out;—first on the corridor, secondly, often prematurely discharged [1, 5, 6, 29].

New hospitals. A number of new hospitals were built in Norway, such as the regional hospital in Tromsø, children's hospital at Ullevål University Hospital, a new "Rikshospitalet" in Oslo, St. Olav's Hospital in Trondheim, Sørlandet Hospital in Kristiansand, Akershus University Hospital outside Oslo and Østfold Hospital. The huge expenses for new building usually went beyond the normal health budget.

Nevertheless, an unknown part was taken from the hospital's yearly health budget by retaining resources for maintenance, reconstruction and necessary new building in existing hospitals.

Reduced activity. Despite all seven new hospitals for the last 20 years, one fifth of all patient beds have been removed in Norwegian hospitals, to save money! From 1990 to 2017, 3840 somatic beds (22%), in Norwegian hospitals, disappeared completely (Fig. 1.1) [30].

Reduced treatment capacity. During the period from 1990 to 2017, the total number of patient beds was halved from 6 to 3 per 1000 inhabitants [30]. This caused a reduced processing capacity in Norwegian hospitals for both somatic and psychiatric patients. Somatic beds were reduced from 4 to 2.5 per 1000 inhabitants (Fig. 1.2). There is a significant lack of patient beds per 1000 inhabitants, in spite of an increasing number of inhabitants, more elderly people and patients with multiple complex diseases.

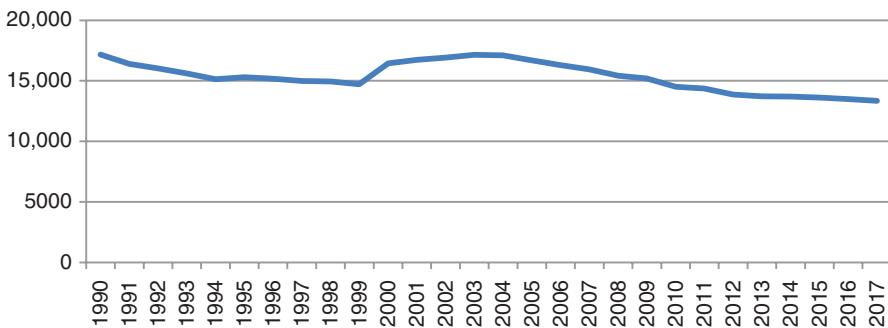


Fig. 1.1 Numbers of somatic patient beds in Norwegian hospitals, 1990–2017. (Source: Statistic Central Bureau, Norway)

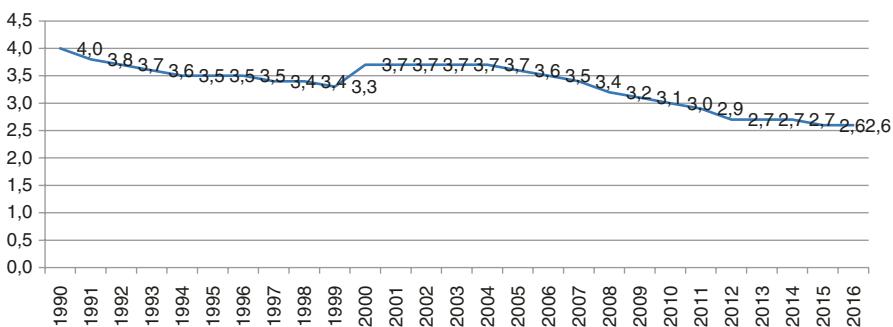


Fig. 1.2 The number of somatic patient beds per 1000 inhabitants in Norway, 1990–2017 (Source: Statistic Central Bureau, Norway)

New public management (NPM). In the last 20 years, Norway's health expenditure as a share of gross national product (GDP) has been on average—or below—compared to 35–40 other OECD countries (Table 1.1) [31]. Still, there has been a continuous misunderstanding among healthcare leaders that “Norwegian healthcare system is too expensive” [32–35]. This misinformation made the basis for the entrance of industry philosophy into the Norwegian healthcare system. NPM

Table 1.1 OECD results for Norway (2008–2012–2016)

Indicator	Norway	OECD mean	Comment
Bed occupancy rate, activity and employees (2009–2010)			
Hospital beds/1000 inhabitants	3.3	5.3	Norway has sixth lowest rate (29/35)
Occupancy of beds in acute medicine	91.6	76.1	Norway has third highest rate
Number of days per stay	4.5	6.9	Norway second shortest, only Turkey has shorter
Healthcare persons			
General practitioner per 1000 inhabitants	4.1	3.4	Norway is third after Greece and Austria
Specialists doctors as a percentage of total	40	62	Norway is the second lowest, 34/35, after Ireland
Doctor consultations per capita	5.2	6.3	19 out of 35 countries had more consultations than Norway
Practicing nurses per 1000 inhabitants	14.4	7.9	Norway at fifth place after Denmark, Belgium, Switzerland and Iceland
Ratio between nurses and doctors	3.5	2.5	Norway in 8th place together with the United Kingdom
Health economics (2010–2011–2016)			
Total health expenses, as a percentage of GDP ^a (in 2016)	9.3 (10.5)	9.3 (9.0)	15 out of 35 countries have higher GDP than Norway in 2011
Health costs per capita, public + private—USD	5669 6647	3339 4003	Norway is number 1 in Europa, 2011, due to high living costs, and no. 3 in 2016
% of health expenses for treatment in and outside hospitals ^b	56	61	Norway uses less proportion for treatment of patients in hospitals
% of health expenses for treatment in hospitals	31	31	Less than a third goes to the hospitals
Preventive health work as a percentage of GDP	2.5	2.9	11 out of 24 countries pay more than Norway for prevention in 2011

Figures from the OECD Report 2012 and some figures from the OECD Report 2013 and 2017 [31] (compiled by BM Andersen)

Health at a glance 2012: OECD indicators @OECD 2012, as well as some data from 2013 and 2017

^aGDP = gross domestic product—corresponds to gross national product

^bOECD has not included expenses for long-term institutions, medical equipment and joint services

became a top priority for politicians, hospital leaders and health agencies, who misled the Norwegian population.

Industrial language took over with the use of words like “healthcare company”, “product” and “profit” instead of hospital, patient and reduced treatment. Five health regions were formed in 2002 and changed to four in 2007, each with its regional health company (RHF), with the aim of increasing the “profit” while “the patient should be in the focus”. Mergers, demergers, “buying up” hospitals and closure of hospitals and of workplaces became the new words in the “health store”, but the “profit” disappeared in merger breakdowns [33, 35–40]. For example, *Oslo University Hospital (OUS)* merging started in 2009 with the fusion of the four Oslo hospitals into a separated mega concern, Oslo University Hospital [38, 40–48]. From the experiences from the industry, fusions usually break down [40, 44]. Severe problems emerged at OUS in 2011 with the “collapse” of the hospital, closure of the country’s single children’s hospital and distribution of sick children among adult patients in other clinical overburdened wards, to be more effective [38–42]. Two of the four hospitals were further tried to be put down, shaping an ever higher instability, conflict of authority and departmental rivalry, resulting in flight of health experts to other hospitals [38–42]. OUS became larger and less profitable and had fewer employees compared to the number of patients, more debt and less time to their patients than the best hospitals in the United States [44, 43, 46, 49].

Health companies. Within the four large healthcare regions in Norway, with four RHFs, smaller hospitals were merged to subregional healthcare companies (HFs) with many transversal and chaotic leadership levels [25–28, 36, 40]. The RHFs and HFs were responsible for the use of healthcare resources in hospitals, but were not juridically responsible for patients or personnel. On the other side, the hospital manager was juridically responsible for patients and personnel but had no control of the budget.

The infection protection responsibility is changed. From 2005 on, legal authority and responsibility for hygiene and infection control were transferred from individual hospitals to the RHFs. The RHFs should ensure that the regulations on infection control were followed by each individual health company (HR). This resulted in that necessary resources for hygiene, infection protection and control were withheld from the hospitals. Hygiene procedures, like cleaning, textile treatment, patient care, etc. that would ensure infection protection for patients, personnel and visitors, disappeared. The burden of resistant microbes increased in the hospital environment and among the patients, following the patients and staff to the primary care. The patient safety was severely impaired. Even the hospital statutory *Infection Prevention and Control Program* disappeared in many hospitals [40, 50].

Reform of more interaction between specialist and primary healthcare came in 2012 with the requirement of the primary healthcare to receive patients after finishing diagnosis and primary treatment in specialist hospitals to save money [40]. Hospital patients were often in a very bad condition after a few days in the hospital and still too sick to be declared finished from the hospital. Because of shortage of nursing homes and competent personnel, there were several negative effects, including lack of infection control, and the Directorate of Health expressed concern about

the reform [40, 50–53]. Studies from Sweden show a clearly increased risk of death within 30 days postoperatively for hip surgery patients at short postoperative hospital stay (≤ 10 days) [54].

Patient Prioritization Committee followed the fall 2014 with some priority criteria that were adapted to the NPM model. This means that the “user” becomes “valued” against hospital costs before any hospital treatment [55].

1.3 A Future for Healthcare

Today there are many healthcare and administrative levels that the patients and personnel may go “through” by the interaction reform between hospitals and primary health service. This entails a formidable increase in travel and transport costs, additional laboratory tests at the different levels, additional work and time spent in the various levels that will follow up and familiarize themselves with the patient’s disease and treatment, additional expenses due to lack of patient overview and additional expenses due to patient injuries, malpractice and misunderstandings. At least one fifth of the budget for somatic hospitals is likely to result in bureaucracy and waste of resources [40]. The administration of RHF takes annually 2 out of 140 billion NKr of the total specialist budget [30].

About 10% of somatic health resources go to travel expenses between different healthcare levels. Travel expenses increase due to regionalization and merging of hospitals. This leads to an even longer travel time to hospitals than before, resulting in a different offer of emergency medical assistance—with a different chance of survival [40]. A large part of the resources goes to laboratory tests which are often unnecessarily repeated at various levels for many patients.

Hospital patients with a complicated and bad condition often end up in nursing homes with a low level of medical competence. These patients may occupy the beds that should be used for ordinary nursing home patients. In addition, the large bureaucracy located in regional- and small-scale healthcare and cross-border clinics around the country may use a large share of the health resources.

The result is fewer resources to patient care and preventive healthcare and more health administration and bureaucracy.

Good leadership is particularly important in the field of infection protection, illustrated by a study where removal of management at a department reduced staff performance of hand hygiene prior to contact with the patient, from more than 50% to 6% [56].

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Hospital Infections: Surveillance

2

Abstract

Healthcare-associated infections (HAIs) may affect up to 5–20% of hospitalized patients. It is estimated that in Europe, at least 7.5 million patients (3.5 in acute hospitals and 4.2 million in long-term care facilities) acquire HAI each year. More than 147,000 dies directly or indirectly from HAI each year in European hospitals. The most common forms of HAI are urinary tract infections, respiratory tract infections, infections after surgery, bloodstream infections and other infections (skin, intestines, etc.). Outbreaks in healthcare are often caused by spread of *Clostridium difficile* and drug-resistant bacteria. MRSA is isolated from 5% or more of all cases of HAI in Europe. Epidemic viruses like norovirus and influenza may also cause large outbreaks. HAIs usually appear 48 h after admittance up to 30 days after discharge (most common within the first 7 days) and up to 1 year after prosthesis operations. Superficial infections are most often harmless, while the deep infections may cause readmittance and treatment with antibiotics. Surveillance by registering infections is a method to control HAI caused by treatment and stay in a hospital. Results are used as indicators for the quality of hospital care and treatment. It has been a long way to go to raise healthcare-associated infections up from “something that only happens” to a potential severe or deadly injury which in most cases could be avoided by effective and targeted infection control in 20–70% of the cases.

Keywords

Healthcare-associated infections · HAI · HCAI · Prevalence · Incidence · Infection control · Hygiene · Surveillance

2.1 Prevalence and Incidence Surveillance of HAI

Healthcare-associated infections (HAIs) usually appear 48 h after admittance up to 30 days after discharge (most common within the first 7 days) and up to 1 year after prosthesis operations. Hospital infections (nosocomial infections) are measured by

national and international prevalence and incidence studies [1–17]. In high-income countries, the prevalence of HAIs in mixed patient populations may be 7–10%.

Prevalence of infections is usually implemented as point prevalence, a pre-defined day and time (08:00 in the morning), 2–4 times a year. For each department the number of patients with HAI is recorded by the responsible nurse and doctor after certain, often modified CDC definitions [1–4, 15]. Recorded are all microbes involved in the infections. This is done to monitor the burden, type and drug resistance of microbes in the department and the hospital [8–13, 15]. Registered are also all infections that the patient has received outside the healthcare to get an overall view of the infectious load in each hospital department. The use of antibacterial agents in the department, both prophylactic and therapeutic, is registered [8–13, 15]. It is specified how many patients are hospitalized, how many operated and how many with postoperative infections and type of infections. Point prevalence represents a snapshot of the infection situation in each department, is easy to implement, is easy to understand and focuses on important measures for the individual hospital and department. Results are gathered and evaluated by infection control personnel for the actual institution. In Norway, some of the results are posted on the Internet, helsenorge.no, and are available to all [14]. However, the interpretation and evaluation of the results are not included, so that small departments or hospitals with few patients and randomly coinciding events may get too big impact on the rate of infection [16].

Up to year 2000, all types of hospital infections were registered in Norway according to the National Institute of Public Health's modified CDCs guideline [1, 2, 4–13, 15]. Today, Norway, like many other countries, is recording only four types of infection: respiratory tract infections, postoperative wound infections, blood-borne infections and urinary tract infections. International registration methods are, in addition, changed from 2008 onwards [3, 14, 15]. Therefore, prevalence is not comparable over periods or in real time today, since different methodologies are used and the total number of HAIs is not recorded [3, 14, 15].

Incidence of infections is a continuous record where each patient is observed over a defined period [16]. Surgical site infections (SSI) are monitored up to 30 days after surgery/discharge and up to 1 year after prostheses operation [3, 16, 18]. Incidence registering is laborious; goes for long periods of time, often with no feedback to those concerned; and is not reported by some hospitals [19]. Incidence studies are most often used for surgical patients and especially prosthesis operations [19].

Microbes are recorded in local, national and international registers, if defined as important for patients and for the society in general. In Norway, drug-resistant and other problem bacteria and defined viruses are recorded in national registers like MSIS or NORM (human and veterinary microbes and the use of antibiotics) and further sent to the ECDC register for Europe.

Registration of hospital infections was started as systematic studies in the United States around 1975 and was a major breakthrough according to quality and patient safety in healthcare, both in hospitals and nursing homes [1–3, 15–39]. Norway started national prevalence surveys in 1981 [5]. Incidence studies started some

20 years later, but were used as early as 1970 in some hospital centres as “event register/accident registry.”

2.2 Effect of Registration

The intention of registering HAI is to control and monitor patient safety. Actions triggered by findings can lead to the reduction of infections by informing results to current healthcare professionals, patients and family [2, 18–39]. Effects of HAI measurements are described below:

- A 10-year-incidence study in the United States by Cruse and Foord of 63,000 surgical (clean) wounds. Registering SSI led to the reduction from 2.5% postoperative wound infections in 1968 to 0.6% in 1977 [26].
- A national registration of all SSI was conducted from 1999 to 2006 in France [27]. A total of 150,440 operations were followed 30 days postoperatively at 550 surgery departments. During the 6-year period, SSI was reduced from 3.8 to 1.7% with a relative reduction of 50%; $p < 0.0001$ [27]. The reduction in infections was significantly for most types of operations [28].
- MRSA was registered in France in the period 2001–2006 [29]. Prevalence of MRSA-infected patients was reduced by 47% in university hospitals, 37% in central hospitals, 62% in psychiatric hospitals, 11% in local hospital, 24% in military hospitals, 53% in rehabilitation centres and 41% in cancer centres. The total prevalence was reduced from 0.49 to 0.29% [27].
- Results from 14,500 hospitals in the United States, in 2015 [30], demonstrated that between 2008 and 2013, there were:
 - 46% reduction of blood-borne infections.
 - 19% reduction of SSI among ten selected procedures.
 - 6% increase of catheter-associated urinary tract infections.
 - 8% reduction in hospital-started MRSA bacteraemia (2011–2013).
 - 10% reduction in hospital-initiated *C. difficile* diarrhoea (2011 and 2013) [30].
- Pennsylvania State had the lowest infection rate in the United States [31]. The registration was estimated as laborious, required a lot of computer skills and clear definitions but delivered large and robust results [31].
- In a point-prevalence study of 183 hospitals in the United States (2014), had 4% of the patients one or more HAIs [32]. The most common types of infections were pneumonia, SSI and gastrointestinal infections. *C. difficile* diarrhoea was the most common infection, 12% of all infections [32].
- In Norway, regional point-prevalence studies of all types of HAI included 14 hospitals in four counties from 1996 to 2000 [9, 11].
 - 6.5% of 32,250 patients had HAI, with a decreased percentage from 7.7% in 1996 to 5.9% in 1998 in both operated and non-operated patients [11]. There was a decrease of infections in urinary tract, in lower respiratory tract and of SSI, while the rate of bacteraemia remained stable [11].

Table 2.1 Occurrence of hospital infections at Ullevål University Hospital for a period of 17 years, 1991–2007

	Overall	Somatic	Psychiatry	Surgery	Non-surgery
Number of patients examined	57,360	46,194	11,166	12,430	41,865
Number of hospital infections	3934	3725	209	1665	2093
Percentage of hospital infections	6.9%	8.1%	1.9%	13.4%	5.0%

Source: Andersen et al. *J Public Health* 2009; 31: 98–104 Ref [13]

- The smaller hospitals in the region (<200 beds) generally had lower infection rate, fewer infections overall, fewer postoperative infections and lower consumption of antibacterial agents than the regional university hospital [11].
- During a period of 17 years, 1991–2007, the total prevalence of all types of HAI was 6.9% at Ullevål University Hospital, a 1000 beds teaching hospital in Norway [10] (Table 2.1). The same method for prevalence registering was used four times a year: [1, 8, 12, 13, 15]
 - 8.1% of the patients at somatic wards had HAI.
 - 13.4% of 12,430 operated patients had one or more HAIs and 6.2% had SSI. Non-operated had a lower rate, 5% [13].
 - 0.5–1% of the patients was readmitted for HAI.
 - 15–23% of all patients had infections during stay in hospital, nosocomial and non-nosocomial infections.
 - Ca. 25% received antibiotics [13].

2.2.1 Effect of Reorganizing from Public Hospital to Health Enterprise: On Development of HAIs

Ullevål University Hospital became in 2002 a health enterprise, according to the philosophy of the New Public Management (NPM). The hospital went through a major reorganization which resulted in increased workload for personnel doing patient-related work (see Table 2.2) [13].

- Before *reorganization* there was a significant reduction of HAI in somatic patients ($p < 0.001$) and decrease in SSI, both deep and superficial ($p = 0.004$ and 0.006).
- *Afterwards*, HAI increased ($p = 0.002$) in the non-operated group ($p = 0.024$) and operated patients (not significant) [13].
- *Afterwards*, HAI increased in somatic patients ($p = 0.054$) along with increased total workload for staff ($p = 0.024$) [13].
- *Extra costs* due to HAI showed significant reduction before reorganization and significantly increase thereafter; $p < 0.001$ and $p < 0.001$ [13].
- *After the reorganization* the proportion of somatic patients increased by 30% in 2007 compared to 2003. The overall workload increased by 27%, but at the same

Table 2.2 Number of beds, discharges, hospital days, policlinic and day treatments, *per man-labour year*, and change in number of man-labour years before and after reorganization of Ullevål to a health enterprise

Category	Average period 1 1998-2002	Average period 2 2003-2007	Change percent	
Number per full-time man-labour year				
Beds	0.2	0.2	0.0%	
Discharges	8.0	9.0	11.0%	I
Bed days	53.9	51.0	5.4%	R
Policlincal patients	66.8	55.0	17.7%	R
Day treatment patients	3.3	7.9	58.2%	I
Number of positions				
All positions	4944	5039	1.9%	I
Doctors	711	799	11%	I
Nurses	1548	1571	1.5%	I
Administration and office personnel	697	795	12.3%	I
Service and technical personnel	830	635	23.5%	R

I increase, R reduction, from periods 1 to 2

Activity and full-time equivalents at Ullevål University Hospital before and after reorganization to a health enterprise in 2002. After the establishment of health enterprises in 2002 (period 2), there was an increase in the number of discharges and day treatments per man-labour years at the hospital, while there was a reduction of bed days and policlinic patients per man-years. Number of positions at the hospital increased in all job categories after the reorganization, mostly for administration and office, with the exception of service (cleaning and maintenance, etc.) and technical personnel, where there was a significant reduction in the number of man-years (Source: reference [13])

time there was a 25% reduction of service (cleaning, textile work, waste, etc.) and technical personnel (maintenance), important for hygiene and management.

- Fewer people participated in patient-related work, and there were fewer beds, overcrowded in the departments, understaffing and mixing of patient categories [13]. At the same time, the proportion of HAI increased, which led to notification to hospital's management and the health council [13].

2.2.2 Interaction Between Local Hospitals and Nursing Homes: On Development of HAIs

The most active users of hospitals are elderly and residents at nursing homes. This interaction is very important concerning transmission of infections between health-care institutions.

- Point prevalence studies of HAI were done at 65 nursing homes in Oslo, ca. 4500 residents, for a total of 13,762 residents during the period 1997–1999 [23].
- A total of 6.5% had HAI, more than at hospitals in Oslo at the same time [11, 23].

- Surgical treated patients had a high rate of SSI, 14.8%.
- Nursing homes were understaffed; overcrowding was common with few single bedrooms, lack of bathroom and toilet, few isolates and lack of ventilation [23]. Conditions were unchanged during this period, and the rate of infection was not reduced [23].
- Prevalence registering done in 2000 and 2001 showed a significant increase in HAI from 5.6% in 2000 to 7.5% in 2001 ($p < 0.001$) in Oslo [24]. A significant increase was detected with respect to pneumonia ($p < 0.01$) and operated patients in nursing homes ($p < 0.001$), while the proportion SSI was reduced ($p = 0.02$) [24]. There was an increased burden on the nursing homes by newly operated (last 3 months) patients transferred from hospitals to understaffed nursing homes. The early reorganization of hospitals to health enterprises could possibly influence the increase [24].

Registrations may contribute to that other adverse factors are disclosed, as understaffing, overcrowding, too early transfer of recent surgery patients to nursing homes with poor capacity and lower level of competence. Nursing home patients constitute often the largest users of hospital services. It is important to see the context and domino effects of treating the patient in the healthcare system with regard to quality and patient safety.

2.3 The Burden of Healthcare-Associated Infections

Healthcare-associated infections constitute major additional costs for the health service and society as a whole and unnecessary suffering and death among patients worldwide. HAI may be significantly reduced and at the same time being very profitable. Prevalence studies show a large global variation between hospitals and between countries, with a pooled prevalence of 10.1% HAI.

- In the United States, two million healthcare-associated infections are calculated each year (population 300 million), which leads to 99,000–103,000 deaths (5.8%) and direct extra costs of 20–40 billion USD each year [21, 40–43].
- In Europe (population 500 million), HAI may cause 16 million extra days of hospital stay and 37,000 attributable deaths and contribute to additional 110,000 annually [42]. Annual direct cost is estimated to 7 billion Euro [42, 43]. Estimates from 1150 hospitals in 30 European countries resulted in more than 2.5 million HAIs, annually [44]. One in every 20 patients caught an infection during stay in hospital. Pneumonia, SSI and urinary tract infections had the highest numbers of cases per year, while bacteraemia and pneumonia had the highest death rate [44]. Around a third of infections were preventable through better hygiene, detection and improved infection control [44].
- In Norway (population five million), the four types of HAIs registered, urinary tract infection, lower respiratory tract infection, SSI and bacteraemia, may cause infections in 5–10% of admitted somatic patients [4, 25, 45]. These four types

Table 2.3 Relationship between the occurrence of four types of hospital infections and estimated extra stay in hospital because of HAI among 913,000 hospital patients in Norway, 2013–2014

Prevalence spring 2014 [14]	Prevalence [14]	Number of patients	Extra stay in days
Urinary tract infection	1.2%	10,956 (2)	21,912
Lower respiratory tract infection	1.2%	10,956 (15)	164,340
Postoperative wound infection	1.9%	17,347 (7)	121,429
Blood borne infections	0.6%	5478 (15)	82,179
Sum	4.9%	45,650	389,860

Figures from the prevalence spring 2014 [14] (Public Health) and from Statistic Central Bureau [46]
Extra stay in days average per infection type in brackets [25]

amount to approximately 45,600 patients with HAIs each year [1, 25]. With five extra hospital days (900–1000 Euro/day), the four HAIs may cost at least 205 million in direct annual additional hospital expenses [1, 25].

Among the 913,000 patients admitted to somatic hospitals in 2013, 45,650 were infected in the urinary tract, lower respiratory tract, postoperative wound or bloodstream (Table 2.3). This corresponds to almost half of the annual patient treatment for hospitalized patients at a large hospital of 1200 beds. In addition come ca. 25% which constitute other infection types not registered (according to CDC). That would be a total of 60,870 patients. This number does not include all hospital patients with HAI since they in most cases are discharged—after 2–3 days in hospital—to nursing home or home, before the infection occurs.

2.3.1 The Burden of Antibacterial Resistance Globally Is Unknown

This special problem of HAI is increasing and is today a significant threat to patients and the population in general, especially in countries consuming high amounts of antibiotics.

WHO have made some estimates from the United States, Europe and Thailand [43].

- Estimated burden of *antibacterial resistance* in the United States was in 2013 more than 23,000 deaths, more than two million illnesses, and overall social costs up to 20 billion USD direct and up to 35 billion indirect [43].
- Estimated burden of *antibacterial resistance* in Europe is 25,000 deaths per year, 2.5 million extra hospital days, and approximately 1.5 billion Euro per year [43].
- In Thailand (population 70 millions) the burden of *antibacterial resistance* results in >3.2 million extra hospital days, >38,000 deaths and >1.5 billion USD in direct and indirect costs per year [43].

The overall economic impact of the development of antibacterial resistance is high—and with reduced consumer income, employment and savings and increased national investment and spending in healthcare delivery. The result for most developed countries is a reduced gross domestic product (GDP) by 1.4–1.6% [47].

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Microbes, Transmission Routes and Survival Outside the Body

3

Abstract

Microbes like bacteria, virus, parasites and fungi may naturally colonize skin and mucous membranes without any sign of illness, for a longer or shorter period, in all humans, animals, fish, parasites, plants and all other living beings. Some types may be more invasive in human tissue than others. Many microbes are free-living in the environment—in water, soil and air and on equipment—as a part of the normal microbial flora on the Earth. Most of them are not dangerous and live in peaceful symbiosis with other living beings and may also be transferred between living species, from man to animal or man to plants and environment—and vice versa. New and old human pathogenic microbes are increasing all over the world. Some agents, like drug-resistant bacteria and highly pathogenic viruses, are more dangerous than others, and some microbes may cause chronic devastating diseases. Transmission routes depend on the robustness of the microbe in the environment, virulence, infectious dose, anatomical site in the body, etc. Pathogenic microbes are spread by contact, air, water, food, beverages, contaminated equipment and environment and are more seldom vector-borne, by insects or animals. The following chapter is focused on the most frequent pathogenic microbes, their preselected localization in the body, transmission routes and survival in the environment.

Keywords

Microbes · Pathogenic microbes · Virulence · Predilection · Biological material · Anatomical site · Environment · Survival · Transmission · Spread of infection

3.1 Microbes are Mostly Normal, Nonpathogenic Flora

Microbes like bacteria, virus, parasites and fungi may naturally colonize skin and mucous membranes without any sign of illness, for a longer or shorter period, in all humans, animals, parasites, plants and all other living being [1–6]. Some types may

be more invasive in human tissue than others, partly via mucous membranes and lesions in the skin.

Many microbes are free-living in the environment—in water, soil and air and on equipment—as a part of the normal microbial flora on the Earth. Most of them are not dangerous and live in peaceful symbiosis with other living beings and may also be transferred between living species, from man to animal or man to plants and environment—and vice versa [1–6]. Microbes, like bacteria, may outnumber us by a factor of 10^{22} , are heavier than us by a factor of 10^8 , have existed on Earth more than 1000 times longer than us and may undergo 500,000 generations in just one of our generations [7].

The existence of humans and animals is dependent on a rich and active bacterial flora in the gut, participating in the decomposition of food substances to energy and growth. Large amounts of bacteria in the gut (1–2 kg) and on the skin is a normal condition. Humans are releasing microbes into the environment and air wherever they move and—at the same time—are picking up new microbes from the environment.

3.2 Pathogenic Microbes: New and Old

Pathogenic microbes cause illness in most humans if introduced into sterile tissue. “Opportunistic” microbes may cause problems in people with reduced immune defence and/or if large amounts are introduced in sterile tissue. Nonpathogenic microbes nearly never cause illness in humans [1–3]. Human pathogenic microbes often survive for a long time outside the body—in the environment [1–6]. Therefore, they are special threats to patients, personnel and visitors in healthcare institutions where there often is an accumulation of infectious diseases.

New and old human pathogenic microbes are increasing all over the world. Some agents, like drug-resistant bacteria (methicillin-resistant *Staphylococcus aureus*, MRSA, multidrug-resistant tubercle bacilli and others) and highly pathogenic viruses (Ebola, SARS and others), are more dangerous than others. Other viral agents may cause chronic devastating diseases like HIV and hepatitis B and C.

Microbes may have preselected locations and tissues in the host, like influenza virus, pneumococci and tuberculosis mostly in lungs, hepatitis viruses in the liver and blood, *Clostridium difficile* and norovirus in the gut, coagulase negative staphylococci on the skin, etc.

3.3 Transmission Routes: Spread of Infection

The transmission routes of microbes are many and different and depend on the robustness of the microbe in the environment, climate and temperature, virulence, infectious dose, etc. Pathogenic microbes are spread by contact, air, water, food, beverages, contaminated equipment and environment and are more seldom vector-borne, by insects or animals. Drug-resistant microbes and/or resistance genes are

common on the global food market for humans, animals and fish [8–11]. In addition, increased mobility, climatic changes, overcrowding, war and disasters, poor hygiene and poor infection control are increasing the transmission rate. Prudent use of antimicrobial drugs, proper hygiene and good infection control for humans, animals and fish are essential for stopping spread of infections [12–19].

Microbes: pathways and survival outside the body—in environment

Biological material—location/microbes	Transmission routes	Lifetime in the environment ¹
Wound		
<i>Staphylococcus aureus</i>	C/A [2]	3–10 months
Methicillin-resistant <i>S. aureus</i> (MRSA)	C/A	3–10 months
Gram-negative rods (<i>Escherichia coli</i> , <i>Klebsiella</i> , <i>Enterobacter</i> , <i>Serratia</i> , <i>Proteus</i> , <i>Pseudomonas</i> , <i>Acinetobacter</i> , etc.)	C/(A)	2 days–16 months
Multidrug-resistant gram-negative rods – ESBL: <i>E. coli</i> , <i>Enterobacter</i> , <i>Citrobacter</i> , <i>Klebsiella</i> , <i>Serratia</i> , etc. – Others: <i>Pseudomonas</i> , <i>Acinetobacter</i> , <i>Stenotrophomonas maltophilia</i> – New multidrug-resistant with NDM-1 gene; resistant to carbapenem and most other antibiotics	C/A	2 days–16 months
Enterococci, including VRE	C	2 months–4 years
Groups A, B, C, G streptococci	C	1–7 months
Prosthesis, foreign body		
Coagulase-negative staphylococci	C/A	3 months
<i>S. aureus</i> and MRSA	C/A	3–10 months
Gram-negative rods	C	2 days–16 months
Enterococci, including VRE	C	2 months–4 years
Candida	C	Several months
Blood and tissue fluids		
Hepatitis A, B, C, D, E	B (C) [3]	3 days–year
HIV	B (C) [3]	3–14 days
Other retroviruses (HTLV-I, HTLV-II)	B	Days
Parvovirus B19 and others	B	> 1 year
Cytomegalovirus	B/C	Hours to days
Prions	B ⁴	Infinite?
Malaria and other blood parasites	B, insects	Varies
Yellow fever virus	B, mosquito	Varies
Haemorrhagic fever virus	B/C/A, insects	Varies—long?
Respiratory tract infections		
Pneumococci, including penicillin resistant	C/A	Hours–20 d
Gram-negative rod bacteria (<i>E. coli</i> , <i>Klebsiella</i> , <i>Enterobacter</i> , <i>Acinetobacter</i> , <i>Serratia</i> , <i>Pseudomonas</i> , <i>Morganella</i> , etc.)	C/A	2 days–16 months
<i>Haemophilus influenzae</i>	C/A	Hours–12 days
<i>S. aureus</i>	C/A	3–10 months

(continued)

Biological material—location/microbes	Transmission routes	Lifetime in the environment ¹
<i>Chlamydia pneumoniae/Mycoplasma pneumoniae</i>	C/A L	Hours–days
<i>Legionella pneumophila</i> , etc.	A/C/water	Water: infinity
<i>Mycobacterium tuberculosis</i> (tuberculosis)	C/A	1 year
<i>Neisseria meningitidis</i> ; meningococcus	C/A	Hours
Pertussis; <i>Bordetella pertussis</i>	C/A	3–5 days
Influenza viruses A, B, parainfluenza, adeno, rhino, entero, corona	C/A	Hours–20 d
RSV (respiratory syncytial virus)	C/A	Hours–3 d
Metapneumovirus	C/A	Unknown
Coronavirus OC43 (cold virus)	C/A	Unknown
Human bocavirus (<i>Parvoviridae</i>)		
Avian influenza	A/C/B	Days to 6 weeks
SARS, MERS	A/C/B	3–4 weeks
Haemorrhagic fever virus	A/C/B	Varies prolong
Faeces/gastrointestinal tract		
Intestinal pathogenic bacteria (<i>Salmonella</i> , <i>Shigella</i> , <i>Campylobacter</i> , <i>Yersinia</i> , Enteropathogenic <i>E. coli</i> , <i>Helicobacter</i> , <i>Vibrio cholerae</i>)	C/food/water	4–14 days–4.2 years
<i>Clostridium difficile</i> (spores)	C	Years
<i>Listeria monocytogenes</i>	C/food/water	Long, chilled
Bacterial toxins (<i>E. coli</i> , <i>S. aureus</i> , <i>Clostridium perfringens</i> , <i>Salmonella</i> , etc.)	C/food	Hours to days
Rota/adeno/norovirus (Norwalk)	C/food/water	60–90 days
Hepatitis A, hepatitis E	C/food/water	14 days–2 months
SARS, MERS and avian influenza virus	C/A/B	3–6 weeks
Parasites		
<i>Giardia lamblia</i> , <i>Cryptosporidium parvum</i> , <i>Entamoeba histolytica</i> , schistosomiasis, <i>Ascaris</i> , hookworm, trichuriasis, strongyloidiasis, etc.	C/water/food	Weeks–months–year
Urinary tract infections		
<i>E. coli</i>	C	Hours–16 months
Other gram-negative rods (<i>Proteus</i> , <i>Klebsiella</i> , <i>Citrobacter</i> , <i>Enterobacter</i> , <i>Pseudomonas</i> , etc.)	C	Hours to 16 months
Enterococci	C	2mndr–4 years
Resistant bacteria (VRE, ESBL, CRE, MRSA, etc.)	C/A	days–4 years
Others		
<i>Borrelia burgdorferi</i> , <i>Ehrlichia</i> sp. and less frequent bacteria	Ticks/insects, etc.	Varies
Varicella zoster virus	A/C	Hours–days
Herpes simplex virus	C	Hours–2 months
(Measles, rubella, parotitis virus)	A/C	Hours–days
Highly pathogenic microbes		
Multidrug-resistant <i>Mycobacterium tuberculosis</i>	A/C	1 year

Biological material—location/microbes	Transmission routes	Lifetime in the environment ¹
SARS, MERS virus	A/C/B	2–6 weeks ++
Haemorrhagic fever virus	A/C/B	2–3 weeks
(Lassa, Ebola, Sabia, Marburg virus, etc.)	A/C/B	Weeks
Avian influenza	A/C/B	Days–6 weeks ++

From Refs. [1–6]

1. Lifetime in the environment, outside the body. Most gram-negative rod bacteria live almost infinite in water; some also multiply rapidly in water (*Klebsiella*, *Enterobacter*, *Pseudomonas*, *Proteus*, etc.).
2. C = contact transmission, A = airborne transmission (including droplets), B = blood-borne infection, v = variable, k = short life outside the body, ++ can be long life in optimal environment.
3. May be transmitted by mucous membrane contact, especially lesions of the mucosa.
4. Infectious protein molecules; spongiform encephalopathy.

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Antibacterial Agents and Drug Resistance

4

Abstract

To “win the war” against a continuous development of new and old (“emerging and re-emerging”) drug-resistant and pathogenic bacteria is a problem. Super drug-resistant bacteria are now isolated from patients and the environment in most countries in the world. Overuse and abuse of antibacterial agents in treatment and growth promotional activity have led to more resistant bacteria being transferred to animal and fish production, and vice versa, and may be included in the food chain. In addition, increased mobility, climatic changes, overcrowding, war and disasters, poor hygiene and poor infection control are accelerating this chain reaction. Modern infection prevention efforts must be directed towards detection, reduction and removal of unfortunate use of antibacterial agents. Central to this work is proper hygiene and good infection control both for humans and animals. This chapter is focused on practical measures to control overuse and abuse of antibacterial agents and to prevent drug resistance.

Keywords

Antibacterial agents · Antibiotics · Sensitivity · Resistance · Drug resistance
Multidrug-resistant organisms · MDRO · VRE · CRE · MRSA

For the past 30–40 years, only one new antibacterial drug has been produced with a new and extended effect on bacteria (linezolid). Super drug-resistant bacteria are now isolated from patients and the environment in most countries in the world [1–12]. Bacteria outnumber us by a factor of 10^{22} , are heavier than us by a factor of 10^8 , have existed on Earth more than 1000 times longer than us and may undergo 500,000 generations in just one of our generations [13]. It is claimed that the Earth is approaching a post-antibiotic era that will be similar to the pre-antibiotic era—before penicillin and vaccines [14]. Already Alexander Fleming that discovered penicillin warned against the development of resistance in his Nobel Price talks in 1945 [15].

Overuse and abuse of antibacterial agents in treatment and growth promotional activity has led to more resistant bacteria being transferred to animal and fish production, and vice versa, and may be included in the food chain [14, 16–19]. Drug-resistant microbes and/or resistance genes are common on the global food market both for humans, animals and fish [16–19]. In addition, increased mobility, climatic changes, overcrowding, war and disasters, poor hygiene and poor infection control are accelerating this chain reaction. Modern infection prevention efforts must be directed towards detection, reduction and removal of unfortunate use of antibacterial agents. Central to this work is proper hygiene and good infection control both for humans and animals [16, 17].

In Europe, antibiotic resistance is increasing, particularly regarding the multi-drug-resistant gram-negative bacteria such as *Escherichia coli*, *Klebsiella species*, *Acinetobacter baumannii* and *Pseudomonas species* [8, 20, 21]. In South and East Europe, the incidence of multidrug-resistant bacteria increases rapidly with few therapeutic options except for polymyxins, in which there also is a growing resistance against [1, 8, 20] A few European countries have gained control of methicillin-resistant *Staphylococcus aureus*—MRSA. However, in 2013, MRSA shared more than 25% of invasive *S. aureus* in 7 out of 30 countries [8]. Today, 10 out of 30 countries reported MRSA percentages above 25% of invasive staphylococcal strains in European hospitals [20].

In 2007, 382,600 cases of infections with resistant bacteria were detected in the EU and EEA countries, which caused 25,100 additional deaths and 2.5 million extra days in hospital [1]. This cost at least 1.5 billion euros extra each year [1].

4.1 Antimicrobials: Sensitivity and Resistance

The bacterium is *sensitive* if the drug inactivates/kills the bacteria and *resistant* if it does not. *Intermediate* (I), i.e. the bacteria are neither totally resistant nor sensitive to the agent. The effect of antibiotics on bacteria is usually investigated by culturing the bacterium on growth media added different types of antibiotics in tablets. A clear, defined zone around the patch shows that the bacterium is killed. There are many laboratory methods for detection of resistance and of resistance gene(s), such as the *mecA* and *mecC* genes in MRSA that causes methicillin resistance.

Clinically, this is observed (simplified) by a positive response to treatment (temperature drop, improving the general state, etc.) when the bacteria are sensitive or no response when they are resistant.

Resistance can be transmitted between species of bacteria like a small genetic signal. Resistant bacteria are usually more robust than sensitive strains. They survive often for a longer time in the environment, may tolerate desiccation and chemical agents, are forming more biofilm, are often more adhesive to epithelium and may develop into niches, compared to sensitive ones [22]. The resistant property may be intrinsic and constant or a result of mutation, selection or transmission (infectious) of resistance genes from other bacteria or encountered in other ways. Gram-positive and gram-negative bacteria often have different resistance mechanisms.

Gram-positive bacteria have no outer wall (membrane), and antibiotics can enter nearly unimpeded. But they have the ability to close the binding sites for antibiotics or break down the drug with the help of enzymes and can quickly become resistant. Some *S. aureus* strains developed resistance to ciprofloxacin within 3 months after the drug came on the market, and methicillin resistance was described nearly immediately after the drug was available.

Gram-negative bacteria have a strong outer wall with pores that only allow certain molecules—in charge and size—to enter. The pores can be closed/changed, and in addition, the bacteria may have the ability to close binding sites and to expel or destroy antibiotics.

4.2 Reasons for Resistance Development

4.2.1 Overuse of Antimicrobial Agents in Animal Feed and Fish Production

- In the United States, ca. 80% of antibiotic production goes to animal husbandry. Up to 75% of this goes unabsorbed into manure and is spread onto grazing land, together with resistance genes and resistant bacteria like MRSA [19].
- In Europe, Iceland, Norway and Sweden, there was a low consumption (sales) of veterinary-related antimicrobials compared with 19 EU countries in 2010 [1, 8]. Finland and Denmark may consume more in animal husbandry; however, the highest consumption registered was in Hungary, Spain, Belgium, Portugal and the Netherlands.
- In Norway, the total sales of antimicrobials were 57.3 tons in 2015, of which 89.3% (51.2 tons) for human, 10.2% (5.8 tons) for animals and 0.5% (0.3 tons) for fish production [23]. There has been an overall decline in the use of penicillin and cephalosporin. Sales of WHO's "highest priority important antimicrobials for human medicine" in animals, fish industry and humans have declined from more than 6 tons in 2012 to 4 tons in 2015 [24]. These antimicrobials include quinolones, third- and fourth-generation cephalosporins, macrolides and ketolides and glycopeptides.
- Other substances that can select for microbial resistance are pleuromutilin, zinc, copper, etc. in animal feed. In Norway, there has been a doubling of coccidiostatica as monensin and narasin, from 5.9 tons in 2003 to 13.5 tonnes in 2013 [24]. In the fish industry, there is still the use of quinolones and amphenicols—an increase from 2003 to 2013 [24].

4.2.2 Overuse of Antibacterial Agents to Humans

- Percentage of patients receiving at least one antimicrobial agent in European hospitals (ECDC PPS 2011-2012) was for the Nordic countries 30%–45% and more than registered for Germany and France (Fig. 4.1) [25]. Denmark and Finland might have some higher rate: 40–45% of patients.

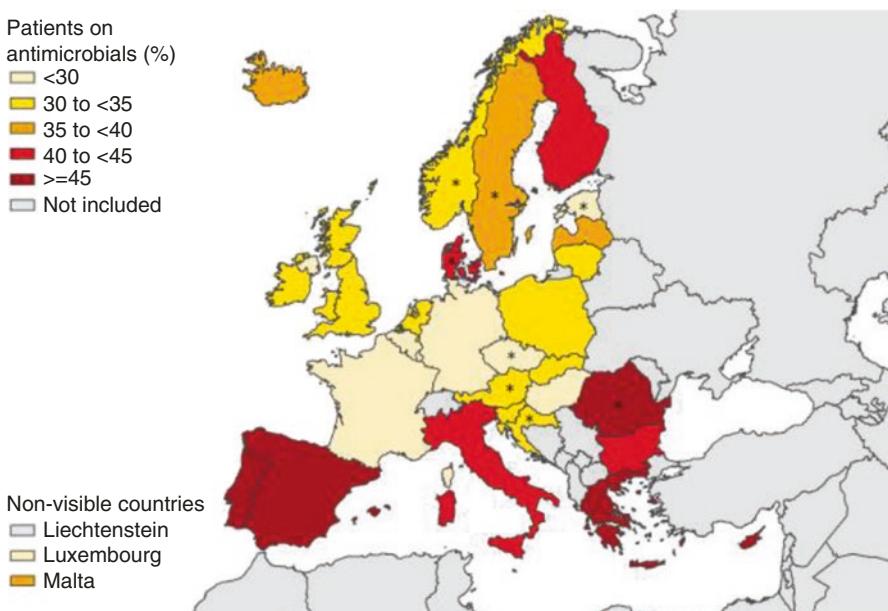


Fig. 4.1 Prevalence of antimicrobial use (percentage of patients receiving at least one antimicrobial agent) in European hospitals, by country, ECDC PPS 2011–2012. Source: ECDC 2013 [25]. “An asterisk indicates that reported PPS data did not provide a proper representation of the situation in a given country. Representativeness of PPS data was poor in Austria, Croatia, the Czech Republic, Estonia, Norway and Romania and very poor in Denmark and Sweden. Consumption of antibacterial for systemic use (ATC group J01) at ATC group level 3 in the community, EU/EEA countries, 2010, expressed as DDD per 1 000 inhabitants and per day” [25]

- In Norway, approximately 30–35% of the hospital patients were given antibacterial therapy [25].
- A high general consumption of—and increased use—resistance-selecting agents increases the development of resistance of MRSA and other potentially resistant microbes [1, 3, 9, 10, 16–19, 25–27].

Overuse of resistance driving antibacterial agents like cephalosporins (2–3 generation), carbapenems (imipenem, meropenem, etc.), tetracyclines, trimethoprim, quinolones, macrolides, linezolid, etc. Typically for overuse of these central agents are:

- Treatment of nonbacterial conditions like virus infections with antibacterial agents [6, 9, 10, 12].
- Too low dose/too short period of treatment/too long period of treatment.
- Lack of infection control and uninhibited spread of resistant microbes in the environment [16, 19, 27].
- Lack of knowledge concerning isolation and other measures to inhibit spread from people colonized or infected with resistant microbes [16, 17, 27].

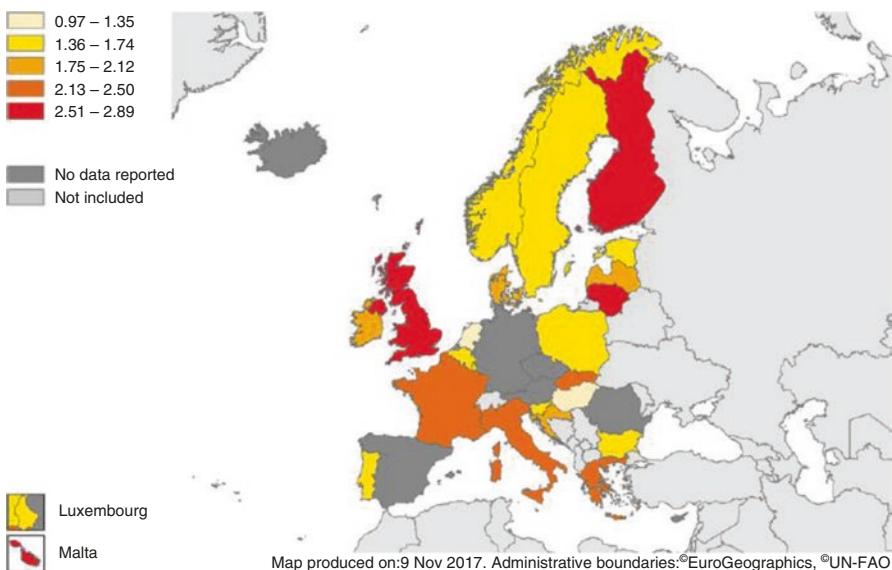


Fig. 4.2 Consumption of antibiotics for systemic use in the hospital sector in EU/EEA countries in 2016, expressed in DDD per 1000 inhabitants per day. Source: ECDC 2017 [20]. Finland: data include consumption in remote primary healthcare centres and nursing homes. Portugal: data related to public hospitals only [30]

- Lack of control with antibacterial and growth-promoting agents, combined with poor hygiene in food processing industry [16–19, 28, 29].

In 2016, the mean consumption of antibiotic use (population weighted) in hospitals was 2.0 DDD per 1000 inhabitants per day, ranging from 1.0 in the Netherlands to 2.9 in Malta (Fig. 4.2) [30].

4.3 Multidrug-Resistant Organisms (MDRO) Are Worldwide Problems

- *Staphylococcus aureus* (methicillin-sensitive MSSA) show increasing resistance to quinolones, clindamycin, Fucidine and other good drugs [1, 16, 27].
- *Methicillin-resistant Staphylococcus aureus* (MRSA). Systematic studies published by WHO in 2014 (WHO. Global Report of Surveillance, 2014) demonstrated that patients with MRSA infections had a significant increase in all-cause mortality, bacterium-attributable mortality, ICU-mortality and post-infection length of stay (LOS) and ICU- LOS, septic shock and discharge to long-term care for MRSA, compared to MSSA [21].
- *Healthcare-associated* (HA-MRSA) are increasing in hospitals and other health institutions—especially nursing homes—throughout Europe. They are often multidrug resistant and the infections may be difficult to treat. Transmission

between healthcare staff and between institutions is common and often uncontrollable, and it is a considerable problem in the food chain, associated with colonized livestock [16–19, 28, 29].

- *Live-stock-associated* (LA-MRSA); special types are spreading between animals and humans, following the food chain and is a considerable problem in the food industry and for infected humans.
- *Community-associated MRSA* (CA-MRSA), which most often is transmitted outside health institutions among healthy people with no contact with healthcare, is a growing problem in the United States and in Europe and an increasing problem in Norway and also spread via the food production [16–19, 28, 29].
- *Vancomycin intermediate-resistant, methicillin-resistant S. aureus* (VISA) has reduced sensitivity to vancomycin and increases globally [16, 31].
- *Vancomycin-resistant, methicillin-resistant S. aureus* (VRSA); there are a few cases in Japan and in the United States [16, 31].
- *Gram-negative bacteria with extended spectrum resistance to beta-lactam antibiotics: ESBL*. Bacteria most often belonging to the *Enterobacteriaceae* like *Escherichia coli*, *Klebsiella*, *Enterobacter*, *Serratia*, *Proteus* sp., etc., resistant to all types of penicillin and cephalosporin and with ability to develop resistance to carbapenems during treatment. They are global problems and increase rapidly. In Europe, hospitals in the South and Central Europe are most affected, but the incidence is also increasing in Scandinavia, including Norway [16, 32–34] (Fig. 4.3). Transmission via the environment in hospitals and elsewhere is considerable [16, 33, 34]. Systematic studies published by WHO in 2014 (WHO. Global Report of Surveillance, 2014) showed that ESBL *E. coli* and *Klebsiella pneumonia* caused significant increases in all-cause mortality, bacterium-attributable mortality and 30-day mortality [21].
- *Other pandrug-resistant gram-negative rods like Pseudomonas, Acinetobacter, Stenotrophomonas*, etc. are mostly environmental bacteria that emerged during poor hygiene and are selected by antibiotics [16, 35–40].
- *Super resistant gram-negative rods*—with resistance to carbapenems and all other antibiotics—genetically encoded, such as New Delhi metallo-beta-lactamase 1 (NDM) [16, 41–43]. They are transmitted by genes and resistant bacteria to other gram-negative rods, even to cholera bacteria in New Delhi.
- *Enterococci, vancomycin resistant; VRE*, often multidrug-resistant, is a growing problem in the United States and Europe. In Norway, there are a few cases each year including smaller outbreaks, but the tendency is increasing [16, 44–46]. The spread of infection is usually associated with low standard of hygiene in hospitals and with overuse and misuse of resistance-selecting antibiotics [16, 44–46].
- *Pneumococci, penicillin- and multidrug-resistant*, have been long-lasting problems in Central and South Europe, the United States and elsewhere. It is an increasing problem in Scandinavia [16]. In Norway, there were in 2016 only 30 cases with invasive penicillin-resistant *Pneumococci*. However, 7.5% have reduced sensitivity (intermediately susceptible) to penicillin [29].
- *Neisseria meningitidis, penicillin resistant*, are known in South Europe and England but not imported to Norway [16].

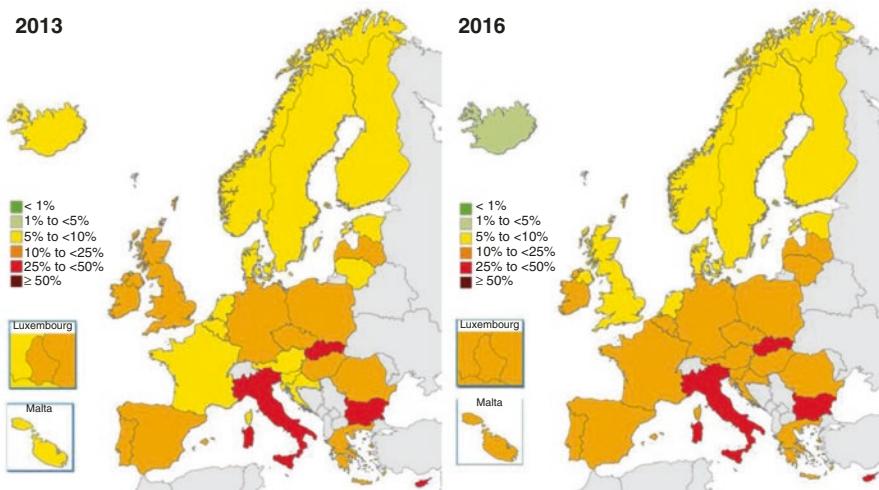


Fig. 4.3 *Escherichia coli*: percentage of invasive isolates with resistance to third-generation cephalosporins, EU/EEA, 2013 (left), 2016 (right). Source: ECDC: Summary of the latest data on antibiotic resistance in the European Union. ESAC-Net surveillance data November 2017 [20]

- *Intestine-pathogenic bacteria* (*Salmonella*, *Shigella*, *Campylobacter*, etc.), *multiresistant*, are mostly present in regions with a high consumption of antibiotic as in the Mediterranean countries and Central and South America. It is an increasing import problem to Norway and other Scandinavian countries [16, 21].
- *Aminoglycoside-resistant Gram-negative* bacteria are mostly detected on the Balkan countries: Greece [16].
- *Macrolide-resistant *Staphylococcus epidermidis** and resistant group A *Streptococci* are increasing in the community. *S. epidermidis* may develop resistance to clarithromycin after a week of treatment with clarithromycin [16, 47].
- *Mycobacterium tuberculosis*, *multidrug-resistant*, increases globally and is especially associated with the development of HIV infection. Multidrug resistance is also increasing in Norway and other Scandinavian countries [16, 48].

More than half of the invasive *E. coli* reported to EU in 2016 were resistant to at least one of the following antibiotic groups under surveillance: aminopenicillins, fluoroquinolones, third-generation cephalosporins, aminoglycosides and carbapenems. The highest resistance percentages were reported from south and east of Europe [20].

4.4 Practical Measures

4.4.1 Surveillance

The national surveillance of consumption of antimicrobial drugs for humans, animals and fish production is good in many countries [1–4, 7, 8, 12, 20, 21, 29,

[48–53]. ECDC monitors the use of antibiotics for humans, animals and fish production and a variety of bacteria that create resistance problems in Europe [8, 20]. CDC monitors resistance globally and in the United States [1–4, 7, 12]. WHO has a global, continuous monitoring of tuberculosis and other resistant problem bacteria [1, 21, 48].

4.4.2 Hygiene and Infection Control

- Good hygiene prevents infections and thereby unnecessary use of antibiotics and the following development of resistance.
- Reasonable and appropriate use of antibiotics reduces the development of resistance [6, 9].
- Isolation of patients with resistant microbes, tracing and disinfecting the environment, prevents spread of microbes in the environment and between persons [16].
- Infection control of patients and personnel exposed to infection in the community or in healthcare, or have been in contact with healthcare abroad, may prevent the spread of resistant microbes like MRSA, ESBL, CRE, VRE and TBC, among others [16].

4.4.3 Choice of Antibiotics

Choose the antibacterial drugs that the bacterium is sensitive to—preferably after resistance studies [1, 16, 25, 29, 30, 49, 50–57]. Use the minimum of antibiotics. Choose narrow-spectrum drugs that act as little as possible on normal intestinal flora. Treatment should start as soon as possible, given in high enough doses and terminated as soon as possible. This prevents resistance development. The resistance pattern of the most common bacteria isolated from patients in a country with low prevalence of resistance, like Norway, is shown in Table 4.1.

4.4.4 Treatment

Antibacterial agents are used to treat bacterial infections, according to clear criteria [20, 21]. One of three patients (33.6%) in Norwegian hospitals is on antibiotics, including 10.5% of patients receiving antibiotic prophylaxis in connection with surgical intervention [20, 51, 52]. Consumption of antifungal and antiviral drugs increases [16, 20, 29, 30].

In a study of hospitals, 2011–2012, in the EU/EEA, the patient bed occupancy per day was over 1.4 million, and more than 81,000 (5.7%) had at least one of four defined hospital infections (urinary tract infections, lower respiratory tract infections, postoperative wound infection, blood-borne infections), and every third patient received antibiotics [25]. The table 4.2 shows some selected results of this

Table 4.1 Nosocomial microbes and sensitivity to the most common antibacterial agents in Norway

Microbe	Antibacterial agent, % sensitivity								
	P	A	M	C1	C2	C3	I	AM	E
<i>S. aureus MS</i>	20	20	100	100	50	100	100	95	95
<i>S. aureus MR</i>	0	0	0	0	0	0	V	100	V
<i>S. epidermidis</i>	0	0	40–90	40–90	V	40–90	50	60	V
Gram-neg. rod									>99
<i>Escherichia coli</i>	0	60–70	0	50	90	95	100	95	0
<i>Klebsiella</i> sp.	5	0	90	95	95	100	95	0	0
<i>Enterobacter</i> sp.	0	0	0	0	0R	100R	100	0	0
<i>Pseudomonas</i> sp.	0	0	0	0	0R	90R	90	0	0
<i>Enterococi</i>	0	100	0	v	R	v	v	0	100
<i>H. influenzae</i> BL	95	95	v	100	100	100	v	100	0
<i>Pneumococcus</i>	100 ^a	100	100	100	100	100	5–10	100	100

^aImport strains can be resistant to all penicillins

P penicillin, A ampicillin, M methicillin (oxacillin), C1, C2, C3 cephalosporin 1, 2, 3 generations, I imipenem, AM aminoglycoside, E erythromycin, F Fusidine, CL clindamycin, KI quinolones (cipro/oflox), V vancomycin, v variable, R resistance development/resistant

From references: [23, 29, 49, 51–57]

Table 4.2 Number of patients with at least one hospital infection and the number of patients receiving at least one antibacterial agent on any day in somatic hospitals, in Europe: ECDC, PPS 2011–2012 [25]

	Patient occupancy per day-N	Patients with hospital infections %	Patients with hospital infections	Patients on antibiotics %	Patients on antibiotics
Denmark	11,861	9.8	1165	43.3	5131
Finland	9167	7.4	676	40.5	3713
France	166,752	4.9	8188	21.4	35,685
Germany	350,137	5	17,647	23.9	83,648
Island	738	10.2	75	39.2	289
Netherlands	24,932	7.4	1835	31.8	7916
Norway	9568	7.8	751	33.6	3213
Sweden	16,164	7.3	1186	39.3	6354
Europe—Total	1,426,526	5.7	81,089	32.7	466,226

Source: PPS or HAI and antimicrobial use in European acute care hospitals 2011–2012. ECDC 2013. Reference [25] (made by the author)

study. Approximately 40% of somatic patients in the Nordic countries, except Norway, received antibiotics. France and Germany had the lowest proportion of hospital infections and lowest consumption of antibiotics in hospitals (Table 4.2).

4.4.4.1 General Guidelines

- Resistance occurs for all types of antimicrobials but most frequent when using broad-spectrum agents [20, 21, 29, 30].
- Antibiotics should be given targeted. Fever may have other reasons than infectious disease.
- Broad-spectrum antibiotics often give no better results than narrow-spectrum agents.
- Select antibiotics that have the least affect to normal flora in the gut and provides least allergy and organ toxicity.
- Choose antibiotics with simple dosing and the cheapest option.
- Evaluate the effect after 1–3 days, especially if the patient is in a clinically bad condition. Consider further measures.
- Switch from intravenously or intramuscular therapy to oral therapy as soon as possible. Exception: meningitis, endocarditis, osteomyelitis and other specific infectious diseases.
- Treatment started in primary healthcare may influence on further treatment in hospitals.

4.4.4.2 Sampling for Specimens

- Patient specimens for detection of the causative microbial agent should be taken before the treatment is started.
- Follow guidance for sampling and, if in doubt, contact the laboratory.
- The requisition should be correctly filled with information about the sample, when taken, wanted examination and clinical indication.

- The samples should be sent as soon as possible to the laboratory and kept otherwise cool (except for blood cultures stored in an incubator at 35–37 °C).
- Important nosocomial bacteria and resistance patterns in countries with few resistance problems, like Norway; see Table 4.1.

4.4.4.3 Recommended Treatment Period

For how long a period a patient should receive antibiotics depends on the condition of the patient, the nature of the infection and the severity. A too short treatment period increases the risk of relapse, while a too long treatment period increases the risk of side effects and development of resistance. The treatment periods should follow local and national guidance which is dependent on microbial resistance pattern.

• Uncomplicated lower urinary tract infection	• Women, 5–7 days; men, 7–14 days
• Recurrent urinary tract infection	• 7–10 days, up to 6 weeks if required
• Upper urinary tract infection	• 10–14 days
• Uncomplicated bacterial infection, such as pneumonia	• 7–10 days
• Mycoplasma/chlamydia pneumonia	• 2 weeks
• Streptococcal angina	• 10 days
• Bacteremia/sepsis	• 7–10 days or longer (vary)
• Acute osteomyelitis	• 6–12 weeks
• Chronic osteomyelitis	• 3–9 months
• Erysipelas	• 10–14 days

Yeast and fungi—systemic infections: contact specialist in infectious diseases.

Viral infections—systemic: contact specialist in infectious diseases.

4.4.4.4 Primary Choices of Antibacterial Drugs in Countries with Low-resistance Problems

Antibiotics are chosen according to the resistance pattern and local/national guidance. Suggestions set out below say something about primary choices in countries with a low prevalence of resistant bacteria [16, 29, 49, 53–57]. Pay particular attention to children and the elderly. Contact specialists in infectious diseases for questions and complicated infections, before the use of broad-spectrum antibiotics or vancomycin, linezolid and other special antimicrobial drugs.

1. Urinary tract infections (UTI)

- (a) Uncomplicated lower urinary tract infections—following the resistance scheme: pivmecillinam, or trimethoprim-sulfamethoxazole, or trimethoprim, or nitrofurantoin. Treatment period 3–10 days. Microbiological cultivation control. If treatment failure: new microbiological investigation and extended treatment period.
- (b) Severe upper urinary tract infection and the need for parenteral management—following the resistance scheme: ampicillin + aminoglycoside or mecillinam intravenously (iv) or co-trimoxazole. Optional: fluoroquinolones (avoided in primary healthcare). Cultivation control.

2. Lower respiratory tract infection (LRTI)
 - (a) Community-onset pneumonia: benzylpenicillin (iv); alternatively when penicillin allergy or lack of effect after 48 h—erythromycin. Macrolides or tetracycline in suspected mycoplasma or chlamydia pneumonia.
 - (b) Hospital-onset pneumonia: benzylpenicillin iv + aminoglycoside. Optional: cefotaxime or ceftriaxone.
3. Postoperative, deep wound infection, surgical site infection (SSI): always cultivation and resistance control
 - (a) Suspected infection with *Staphylococci*: cloxacillin or dicloxacillin. In the case of penicillin allergy: clindamycin. Cultivation and resistance scheme.
 - (b) Suspected or detected other bacterial cause: if necessary to treat, follow the resistance scheme.
4. Wound infection: always cultivation and resistance control
 - (a) Superficial wounds—antibiotics are usually unnecessary. If a systemic treatment should be necessary: cloxacillin or dicloxacillin.
 - (b) Deep wounds: cloxacillin or dicloxacillin + aminoglycoside.
 - (c) If severe penicillin allergy: replace cloxacillin/dicloxacillin with clindamycin.
5. Sepsis/bacteraemia (before/after known microbial agent)
 - (a) Benzylpenicillin + aminoglycoside by weight/kidney function.
 - (b) If severe penicillin allergy: replace penicillin with clindamycin.
6. Osteomyelitis
 - (a) Cloxacillin or dicloxacillin, eventually + aminoglycoside.
 - (b) If severe penicillin allergy: replace cloxacillin/dicloxacillin with clindamycin.

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Tracing and Preventing Infections

5

Abstract

A total of 10–20% of somatic patients experience hospital infections during/after hospitalization. Pneumonia, sepsis, surgical site infections and urinary tract infections are most often associated with patient-related use of medical devices for approximately 65% of cases, while nontechnical equipment may be linked to 35% of cases. It is resource-intensive to detect the cause of infection outbreaks and even more expensive not to take action. Unexplained causes of outbreaks may lead to uncertainty and reduced activity at the hospital. To trace and prevent hospital outbreaks, joint efforts from hospital management, microbiology and infection control are needed. This chapter is focused on practical measures to trace and prevent hospital outbreaks.

Keywords

Outbreaks · Nosocomial infections · Hospital infection · Tracing · Multidrug resistance · Dangerous pathogens · Preventing infections · Infection control Notification

5.1 Purpose

- To prevent spread of infections from patients, the environment or a specific source of contamination (food, water, airborne) to other patients, staff, visitors and environment by good, implemented infection control routines [1–4].
- To control by surveillance incidence of relevant microbes by point prevalence registration, by contact with clinical departments and by daily overview of microbes and resistance patterns, detected in the laboratory.
- To detect and stop the source of infection and transmission routes; risk areas for spread of infection, possibly secondary-infected patients (e.g. cross-infection

between patients in the same room), exposed personnel, visitors, environment, equipment, medicines, etc.

5.2 Comprise

Patients, personnel, visitors, routines, equipment, environment, etc., exposed to infectious patients or other suspected sources of infection.

5.3 Responsibility

The hospital management is responsible for the existence of an *infection control programme* which describes the necessary measures concerning general prevention of infections, biosecurity, survey of pathogenic microbes and infections, tracing of the source and transmission of infections and measures to control or stop the infection [4, 5]. The management is responsible for protection of patients, personnel, visitors and the environment from infections, by always isolating infectious patients. There should be surveillance of prevalence and incidence, daily microbiological reporting and rapid microbiological diagnostics. Infection control and the responsibility for preventing and halting outbreaks are on the hospital management in cooperation with the actual department's management and infection control staff [1, 4–7].

The head of each department is responsible for ensuring that biosecurity procedures and the *infection control programme* are implemented to inform hospital management and infection control personnel concerning suspected outbreak and to participate in tracing work.

The personnel are responsible for following biosecurity procedures and for informing the leader if there is suspected outbreak.

Infection control personnel are responsible for the daily monitoring and control of microbiological agents and unusual occurrence of infections/unusual microbes and for follow-up of contact, information, advice and action.

Others such as occupational health and safety/human sources department/union representatives, etc. are responsible for attending if the workplace/personnel is involved in—or exposed—or subject—regarding the spread of infection [8, 9].

5.4 Practical Measures

Unexplained causes of outbreaks (may take several days to weeks) may lead to uncertainty and reduced activity at the appropriate department(s) [10–13].

General prophylactic measures are often necessary for sustaining activity while tracing progresses [4].

5.4.1 Common Nosocomial Infection

Wound infection, respiratory tract infection, urinary tract infection, diarrhoea, etc., with or without any known microbial cause—onset in the hospital and not known before admission.

- Reviewed with the department management.
 - Microbial agent
 - Number of cases
 - Cross-contamination? Common source of infection?
- Sharpen routines for hand hygiene, and discuss other routines that may have been involved.

Nosocomial cases should be recorded consecutively as undesired events in computer systems to monitor infections over time.

5.4.1.1 Registration

- Name, age, when admitted and from where (other departments, nursing homes, etc.).
- Infection localization and date when discovered.
- Type of infection (pneumonia, wound infection, conjunctivitis, diarrhoea, urinary tract infection, etc.).
- Microbiological findings, possibly.
- The doctor writes a note in the patient's chart about presumed cause and progression.

5.4.2 Unusual, Serious, Extensive Infection with Onset (Infected) in the Hospital

Wound infection, systemic infection, pulmonary infection, renal infection, sepsis, blood-borne infection, etc., onset after admission and not known or in incubation phase upon admission.

Note: Patients with pre-known, isolation-requiring infection are expected to be isolated from the time of admission and should not constitute a risk to others.

Outbreak:

- One case *infected in the hospital* with particularly resistant and/or unusual microbe (MRSA, ESBL, VRE, other MDROs, *C. difficile*, tuberculosis, *Listeria*, *Legionella*, etc.). One case *infected in the hospital* with certain virus (influenza virus, norovirus, etc.). This applies also to personnel and visitors.
- Two or more severe cases infected in the hospital with an identical microbe or with similar clinical symptoms, time-related. This also applies to personnel and visitors.

- Many cases with the same clinical symptoms at the same or different departments, time-related.
- Deaths caused hospital infection; unusual cause or unusual number of patients.

Registration; see above under Sect. 5.1.

5.4.2.1 Information

The department management informs other departments/units/hospitals/nursing homes/home services, etc. that the actual infected patient has been in contact with. This also applies to infections with onset outside the hospital, prior to admission, but only known after admission. The patient's infectious status and risk of transmission are dependent on isolation procedures from the admission. See routines for information. Remember to inform the infection control staff and the director.

5.4.2.2 Tracing/Checking List for Routines

Review the case, as above; see Point I.

- *Break of routines?*—unusual work conditions, failing hygiene when using medical devices, other equipment, accidents, new routines, barrier breaches, etc.
- *Hand hygiene*—are routines for personal hand hygiene followed?
- *Procedures*—review current procedures (patient care, insertion of and care of catheters and needles, wound care, respiratory treatment, etc.) and check if there is discrepancy between practical and written practice of routines. In that case, could it matter? If the routine is changed, when and why?
- *Check*—technical equipment, other equipment, medicines, intravenous equipment; function and temperature of the decontaminator, instrument washing machine, dishwasher, autoclave and hygiene conditions in the decontamination room, kitchen, etc. Use internal control checklists; see separate chapter.
- *Cross infection?*—between two or more patients been on the same room, use the same equipment?
- *Isolation routines*—are contact and air isolation routines understood and followed?
- *Antibiotic consumption*—is there a high consumption of resistance-selecting agents such as clindamycin, third-generation cephalosporins, carbapenem, and ciprofloxacin (associated with ESBL, other resistant gram-negative, unusual rods, *Clostridium difficile*, MRSA)?
- *Contaminated water or ice dispenser?* (*Legionella/Pseudomonas* sp. and other gram-negative rods).
- *Respiratory infections?*—associated with the ventilator or other respiratory equipment/liquids?
- *Sepsis?*—associated with intravascular routines?
- *Urinary tract infection?*—associated with catheter use routines?
- *Imported infection (from abroad)?*—isolation, testing and where the patient has been in the hospital.
- *Exposed to infection, inside or outside the department?*

- *Transferred* from another unit with infection?
- *MRSA?*—MRSA tests of patients, of personnel and of the environment to investigate carrier status in exposed patients and employees.
- *Multiresistant bacteria?*—check the use of antibacterial agents, local and general in the hospital, and if more patients at the unit are infected with the same bacterial strain.
- *Group A streptococcus?*—postoperative wound infections after surgery in two or more consecutive patients. Check for identical bacterial strain and if so, check the operation team for carrier state.
- *Norovirus outbreaks?*—check that isolation procedures are followed, that the actual disinfection process has effect and that personnel and patients are isolated from other patients for at least 2 days after recovery and freedom for symptoms.
- *Clostridium difficile?*—outbreak; check that routines for the cultivation and detection of microbes and toxins and for isolation and disinfection are carried out, and check the use of clindamycin, third generation of cephalosporins and ciprofloxacin that all selects for *C. difficile*.
- *Active pulmonary tuberculosis?*—exposed patients in the same room and personnel; check that all are followed up by tuberculosis control. Search if the source of infection is initiated immediately. Usually by the infection control personnel in hospital together with the primary healthcare and a tuberculosis coordinator.
- *Infected with contaminated blood (hepatitis virus, HIV, etc.)?*—check routines for reporting and reviewing stab wound and other injuries; the first actions with disinfection of the wound, the reporting of injuries, vaccination (hepatitis viruses), spread of blood particles via splashes/drops and other risks in work with contaminated blood.

5.4.2.3 Limit the Spread of Infection

The department leader in collaboration with infection control personnel creates a plan to limit the infection outbreak—spread of infection. In all types of outbreaks, it is important to reinforce routines for hand hygiene, personal hygiene and general work routines (patient care, isolation treatment, serving, information beforehand about patients to be admitted, etc.). Consider the following from the proven or suspected infection:

- Isolation of infected patient—contact or airborne infection?
- Isolation of exposed patients until infection status is clarified—for example, norovirus or MRSA?
- Exposed personnel—the use of personal infection control equipment until infection status is clarified, for example, norovirus or MRSA?
- Exposed personnel—restricted tasks or workplace, in order not to spread the disease. Do not work anywhere else before test answers, for example, outbreak of norovirus or influenza?
- Delimit exposed ward/department to infection status is clarified, for example, norovirus and *C. difficile*?

- Restricted access to the unit? No new personnel into the unit, and no passing through the unit?
- Is information and training of personnel and the patients families needed?
- The extent of environmental disinfection in the unit? Disinfection of technical and other equipment exposed to infectious patients, carriers or the environment and consecutive disinfection of the entire department during major outbreaks.
- Suspected infection via food products (food and beverage)?—see separate chapter.
- Is internal control and risk analysis with regard to infection necessary?
- Does reduction or alternation of antibiotic consumption have an effect on the outbreak? [14, 15].

Depending on the date of infection and the time after the last detected case, special contraceptive measures are terminated in collaboration with infection control personnel. The report is written with feedback to the department and is used for closing deviations and for learning.

5.4.3 Operation Department: Postoperative Infections

Surgical departments have the cleanest rooms in a hospital, with controlled and filtered ventilation with positive air pressure, requirements for clean dressing of personnel and sterile conditions for the equipment. Nevertheless, infections may occur in surgery departments, for example, by introducing unsterile equipment, fluids or unsterile routines into the operating room.

A major outbreak of multidrug-resistant *Enterobacter cloacae* occurred in cardiac surgery patients who inadvertently got this type of bacteria around the heart through contaminated ice water (“sludge”) [10, 12]. The bacteria came from the surgery department’s room for treating, rinsing and collecting plaster waste into a container below the sink. Plaster is a good growth medium mixed with water, and more than 20 different resistant gram-negative bacteria types were detected in this container, including the special *Enterobacter* strain [10]. Despite a series of septicaemia and severe wound infections, all patients survived the infection, and the epidemic stopped after detection of the transmission routes [10–12]. Similar events are later also reported from other hospitals.

In the case of suspected serious infection occurring during operative treatment/other contact with the operating department:

- Enjoin the *lock function* to the surgical department: the use of special clothing, hand hygiene and controlled access. This applies to personnel, patients and relatives entering the department.
- Review the procedures for *preoperative* preparation of the patient.
- Was the patient infected or exposed to infection before surgery?
- Length of stay before surgery?—more than 1–2 days?

- Review the current *operating procedure*—is it in accordance with written procedures? Skin disinfection and coverage of defined operating area, array of surgical appliances, preparing of the patient, handling and covering of sterile instruments and equipment during surgery, the technique of the surgeon (tissue damage, blood loss, etc.), sterile clothing throughout the operation, safety concerning glove use, problems around and duration of the operative procedure and the use of sterile anaesthetic fluids and ventilation equipment.
- Enjoin the use of attire of the staff and of covering of skin, hair and ears and of removing the jewellery. This applies to all, including the anaesthesia personnel. Sharpen surgical hand wash and use sterile gloves. In the case of ultraclean surgery, air contamination is dominant and most bacteria come from the operating staff. Therefore, fewest (possible) participants should be present during the operation.
- Review written washing and cleaning procedures—wash with soap and water between each operation to remove biological material, disinfect after infected operations and follow procedures for major cleaning and disinfection. Main cleaning of all rooms in the operation department should be done twice a year.
- Check the temperature and the cleanliness of washing machines/decontaminator/autoclave/airing cupboard/sterile stock. This is logged in separate books.
- Check the cleaning, sterilization, storage and handling of sterile and clean equipment.
- Are there restrictions for traffic in and out of the operating room during the surgery? The overpressure on the operating room does not work when the door is open. There is suction of corridor air that has higher bacterial numbers.
- Are there restrictions on how many people can be in the operating room?
- Avoid air turbulence. Do not shake clothes/sheets, etc. and minimum speed of movements.
- Responsible waste treatment?—handle waste/use clothing and equipment carefully so that no aerosol is formed. Review routines.
- Unclean equipment into the surgical ward? Do not bring unsterile equipment, fluids for IV use, etc.—which has often been stored unsterile on corridors—into the operating room. Thoroughly wash/disinfect the surface before taking it in. Place this equipment in a place that does not come close to the operating team or sterile equipment.
- Avoid water sources that could lead to gram-negative bacterial growth in the operating room (heat exchangers, water mattresses, etc.). The connection (if manual, non-sterile) is almost always contaminated by gram-negative rods. Such links must be considered infected. Special connections must be done with utmost caution. Heat exchanger with a temperature scale of 5–45 °C can usually not be sterilized or be rinsed with boiling water (*Legionella* thrive in water of temperature 5–65 °C). Check bacterial and fungal growth in such water sources.
- Is the ventilation in order? Check air filter for regular operation rooms and for the ultraclean (laminar airflow rooms—LAF) × 2/year. Measurements performed by the technical department.
- Have the operating rooms overpressure? Does this work?

- Is the temperate air regulated from the outside? Heaters/refrigeration systems located in the operating department generate uncontrolled air circulation and must not be used (growth of fungi and bacteria are spread into the room together with skin cells and dust).
- Is the bacterial count in air (CFU/m³) satisfactory?
- Beard is not recommended at work in a surgery department because of possible increased risk of infection.
- The room for surgical hand washing is not storage for sterile/clean equipment. Wet rooms are not storage spaces.

5.4.4 Intensive Department

Intensive care units are particularly vulnerable to outbreaks of resistant bacteria due to the lack of infection control around the patients (often placed in the same common bays), many entry ports for infection (catheter, surgical wounds, etc.), high consumption of broad spectrum antibacterial agents and densification and large spread of microbes in the environment, with a high risk of cross infection [16–18].

Intensive care units are often a “microbiological jungle” and can be a source of spread of resistant bacteria throughout the hospital as it was experienced at a hospital in Singapore with a total of 103 patients infected with multidrug-resistant *Acinetobacter baumannii* [19]. Risk for the spread of multiresistant bacteria such as *Pseudomonas*, related to some patients and a highly contaminated environment, can be reduced by good biosecurity measures in the unit [20]. Particularly neonatal units are relatively often contaminated by resistant bacteria like *Pseudomonas* [21]. Access to rapid identification of resistant bacteria is important to avoid cross infection in such heavily loaded and complicated departments [22].

In case of suspected serious infection during treatment at/other contact with the intensive care unit:

5.4.4.1 Review Written Procedures for

- Hand hygiene, including information of all visitors on arrival to the department.
- Hand hygiene and the use of gloves.
- Hand disinfection between each patient and before clean procedures?
- Uses the staff jewellery? Wristwatches?
- Are mobile phones, calling systems, etc. disinfected daily or more often if needed?
- Are stethoscopes, BP apparatus and other patient equipment disinfected after each use?
- Ventilator treatment; are cleaning and disinfection of the machines satisfying and following the procedures?
- Intravascular treatment—are procedures followed? Are the routines clear and complete? [23].
- For contact, airborne infection and the use of isolation, are hygienic routines followed?
- Attire and the use of patient-related care gowns; changed for every shift and taken from the storage of clean textiles?

- Space for proper suspension of patient-related care gowns—separated from other patients?
- General cleaning of all fixtures and disinfection following the procedure?
- What about washing the curtains and folding screen between patients?
- Cleaning and storage of medical equipment—satisfactory?
- Cleaning and storage of textiles—not exposed to infection?
- Clean and large enough storage area for sterile equipment?
- Cleaning of beds: MRSA, *Acinetobacter* species and many other microbes may survive for weeks and months in contaminated beds and can be transferred to the next patient [24].
- Storage space for large, non-sterile equipment—clean, and not mixed with uncleared items?
- Treatment of infectious waste, of other wastes and of used textiles according to procedures?

5.4.4.2 Check Routines and Control of

- Washing machine/decontaminator/airing cupboard/sterile stock.
- Air filter, measurements carried out by the technical department.
- Ventilation, optionally target bacterial numbers in air (<150 CFU/m³)—12–14 air changes per hour.
- New equipment/drugs, etc.
- The technical equipment from other departments are washed/disinfected before it arrives on the ward and after use.

5.4.4.3 Avoid

- Abrupt removal of compresses, shaking linen, etc. that can provide increased bacterial load in the air and increased turbulence.
- Unnecessary water sources (flowers, plants, etc.) where gram-negative bacteria are in continuous growth.
- Aerosols in the environment by suction, coughing, and mechanical ventilation.
- Contaminated curtains and the use of curtains.

5.4.4.4 Consider

- The risk of cross infection.
- The patient/nursing ratio.
- The area per patient, including technical equipment.
- Cleaning routines and opportunities to implement good housekeeping to avoid accumulation of dust generated from the general activity, skin cells, particles, dirt and from unpacking single use equipment, etc.

5.4.5 Other Clinical Departments

If a suspected serious infection occurs in connection with treatment/contact with a particular clinical department:

- Enjoin hand hygiene, hand disinfection and wearing of gloves according to procedures.
- Enjoin cough hygiene—it is not allowed to cough in work clothes.
- Review procedures for the care of the patient [25].
- Review procedures for handling infections and infectious waste [8, 9, 26].
- Check washing machines/decontaminator/airing cupboard/sterile stock. Temperature control.
- Enjoin treatment of contact and airborne infections and the use of isolation rooms.
- Review written procedures for general cleaning, disinfection, cleaning and storage of equipment. Technical equipment borrowed from other departments should be washed/disinfected before and after use.
- Avoid sudden removal of compresses, shaking linen, etc. that can provide increased bacterial load in the air and increased turbulence.
- Review procedures for intravascular and mechanical ventilation, if used.
- Review procedures for storage and the use of bandages and other sterile wound material. Bandages and other sterile equipment for wound change should not be stored in patient rooms or on open instrument tables.
- Ensure the quality of new equipment/drugs, etc.
- Assess the risk of cross infection and isolation conditions.
- Check patient/nursing ratio.
- Consider area per patient, including technical equipment.
- Check conditions with respect to corridor patients, shared toilets and showers.
- Moving and transporting patients between departments and medical institutions (transport of patients with infections) promotes spread of infection [27, 28].
- Check conditions with respect to part-time work at several institutions simultaneously—risk of infection.
- Check influenza vaccination for infection susceptible patients in influenza times.
- Personnel should be protected from air and contact transmission with influenza and other contagious agents and should stay at home while having symptoms.

5.5 Background Information

It is resource-intensive to detect the cause of infection outbreaks and even more expensive not to take action. An outbreak, for example, *Clostridium difficile*, prolongs hospitalization and often exceeds 20,000 USD per patient in extra costs [29].

A total of 10–20% of somatic patients experience hospital infections during/after hospitalization. Pneumonia, sepsis, surgical site infections and urinary tract infections are most often associated with patient-related use of medical devices for approximately 65% of cases, while nontechnical equipment is linked to 35% of cases [30].

Major infection outbreaks as in the Dent-o-Sept oral brush case in Norway, in February 2002, are exceptional [2]. At least 140 patients had serious infections of an oral brush contaminated with *Pseudomonas aeruginosa* and other gram-negative

bacteria. The brush was registered as “antiseptic.” Microbiological control of patient-only disposable devices such as oral brushes/pencils did not exist.

Pseudomonas thrive in water and are causing outbreaks from shower, sink and water taps, especially in departments with infection-risk patients with development of sepsis and fatal course of pneumonia [31–33]. The bacteria are associated with the lack of hand hygiene and long or artificial fingernails [34]. During a period of 15 months, there were 46 (10.5%) of 439 children in a neonatal intensive care unit infected with *P. aeruginosa*. Of these, 16 died (35%) [34]. The same bacterial types were detected on the hands of 3 out of 104 personnel and were associated with long nails or artificial nails [34].

Outbreaks of infection at the same time in one or more patients can be documented a few times each year. New, rapid gene technology more often detects the relationship between patients with infections, as shown in an outbreak of *Burkholderia cepacia* infection in 14 ICU patients, caused by contaminated indigo-carmine dye used in enteral nutrition [35].

Contaminated drugs often cause large spread of infection. Less serious drug manufacturers are constantly a cause of serious hospital infections such as in 2011 when 19 patients, of which 9 died, received *Serratia marcescens* in contaminated total parenteral nutrition [36]. At the manufacturer was the bacteria detected in environmental samples at a number of places in a sordid and unhygienic production process [36].

Resistant gram-negative bacteria survive in contaminated “sterile” fluids and equipment. This is also reported for fungi, mycobacteria and other new and unknown environmental bacteria such as *Elizabethkingia meningoseptica* [32, 33, 37, 38]. Factory-made food (powdered infant formula) for neonates in intensive care units have been contaminated by environmental bacteria *Cronobacter* (*Enterobacter sakazakii*)—with serious and fatal course [39].

Severe respiratory infections are reported to be caused by environmental contamination with multidrug-resistant bacteria such as *Acinetobacter baumannii* in an intensive care unit where 2% of environmental samples were positive [40]. A high consumption of antibacterial agents may promote risk of resistant *A. baumannii*—epidemics [17, 41]. In a surgical intensive care unit, 36% of 262 patients had hospital infection, and 37% of these were caused by cross-contamination between the patients [18]. Most gram-negative bacteria thrive in water, and resistance is promoted by the use of antibiotics [32, 33].

Hospital microbes are often robust survivors and live for a long period in the environment. The most antibiotic-resistant bacteria, like *Pseudomonas* and *Acinetobacter*, may survive in dry conditions in a “sleep state” in biofilms on surfaces, equipment, beds, respirators, etc. for many months to years. With a little moisture or transferred to the skin and mucous membranes, the bacteria start to grow again with fast propagation and doubling within 8–16 min. Many bacteria retain their resistance for long periods, even in the environment. Outbreaks are usually caused by such robust microbes that are spread by routine failure and failing hygienic barriers.

Staphylococci and enterococci follow the patients and personnel as a part of the normal flora, and resistance development is very common. Resistant MRSA and VRE are easily spread between patients, often via hands of personnel and via contaminated equipment and surfaces [7, 25, 42–44]. It is measured greater amounts of MRSA in the air than on the surfaces in departments with patients infected with MRSA [45]. Air contamination is an important transmission route for the spread of MRSA. Methicillin-sensitive *S. aureus* (MSSA) may have several resistance factors and can be transmitted to many other patients in departments with a high consumption of resistance-selecting antibiotics. A serious outbreak of gentamicin-resistant *S. aureus* occurred among premature at the neonatal intensive care unit, Ulleval University Hospital [46]. For a long period, there had been a high consumption of gentamicin as a standard treatment when suspected infection in the neonates. *S. aureus* isolated from the patients were regularly not tested for resistance against gentamicin [46]. The department was unaware of the resistance to gentamicin, selected out by gentamicin as routine treatment [46]. Children were infected with this gentamicin-resistant strain, causing sepsis and pulmonary infections, and the strain was also detected in several samples from the environment [46].

Legionella infections are usually the result of the lack of control and maintenance of water systems. Legionella attacks the most vulnerable patients with high mortality rates [2, 47–49].

Listeria causes serious infections in patients with severe immunodeficiency, colon disease, and cancer or in pregnant women. The focus must be directed on the quality of food and beverage, unpasteurized food products and fresh toppings that go against the date of end. Also water may contain listeria, especially living in water amoeba [2].

A serious type of hospital infection (septicaemia, mediastinitis, infection in vascular prosthesis, peritonitis, pneumonia, blood-borne infection, etc.) that occurs almost simultaneously *in two or more patients* may give rise to suspect human error, the disruption of routines or error in medical treatment or medical technical equipment. Patients with the same symptomatology and/or apparently identical microbiology may involve a common source of infection or joint pathway.

Limitation of spread of infection depends on rapid and effective microbiological diagnostics, as in MRSA screening with responses within a few hours [50, 51].

5.5.1 Outbreak of Infections in Hospitals (Nosocomial Transmission) Is Described as Follows [4, 52]

- (a) Suspected *epidemic* outbreak if many persons (>3–4) are consecutively becoming sick with the same or similar illness (gastroenteritis, respiratory tract infections, etc.) in the ward, department or hospital. This includes both patients and staff.
- (b) Suspected outbreaks with microbes obliged to be *isolated* from other patients (see separate chapter):

- *Contact transmission, mostly (Salmonella, Shigella, Campylobacter, Yersinia, other entero-pathogenic bacteria, Clostridium difficile, VRE, ESBL, hepatitis A, rotavirus, etc.)*
 - *Contact and droplet/airborne transmission, mostly (tuberculosis, MRSA, entero-haemorrhagic E. coli (EHEC), respiratory infections with other multidrug-resistant bacteria, influenza, varicella, morbilli, RSV, norovirus, SARS, MERS, haemorrhagic fever viruses, etc.)*
- (c) C. Repeated instances (two or more) of *serious* postoperative or other infections where there is suspected common source of contamination/infection source/infectious agent and/or breaks in infection barriers. Includes cases infected with unusually resistant bacteria.
- (d) D. Suspected serious *blood contamination* (hepatitis, HIV) or other serious infections transferred to the patient or staff.

5.5.2 Important Reasons for the Spread of Nosocomial Infections Are

- Failing hand hygiene and the lack of ability to implement good hand hygiene.
- Lack of infection control programme.
- Missing or misunderstood monitoring of hygiene guidelines.
- Lack of infection control in the handling of medical and medical technical equipment.
- Frequent and high use of antibacterial agents.
- Lack of isolation of patients with contagious infections.
- Infectious disease carriers in the environment.
- Understaffing of health professionals (especially nurses) [6, 7, 42, 53].
- Too many short-term temporary workers, part-time employees and too large rotation of personnel [54].
- Overcrowding; too close between patients and too many patients in each room [6, 7, 42, 43].
- Frequent transfer of patients between departments and institutions (increases risk x 4 for hospital infection) [27, 28, 55].
- Mixing of patient categories (patients with infections in the same room as patients without infections).
- Shared use of medical and other patient associated equipment between patients and wards without adequate cleaning and disinfection after each use.
- A poor structure and functional state of the ward/department; missing or not satisfactory service rooms and bathrooms/toilets for patients; run-down buildings that may complicate cleaning and effective work; two or more patients on the same room, overcrowding, and a capacity that is less than demanded for the population served, leading to corridor patients.
- Hospital network may promote spread of infections. Antibiotic-resistant bacteria and other microbes accompany patients and personal who travel in the hospital networks, including networks of nursing homes, leading to increased spread—

dispersal—of hospital-pathogenic microbes [27, 28, 55]. This is demonstrated for hospital networks in the United Kingdom and is expected to increase by centralization and reorganization of the patient flow [28, 55].

- Inadequate follow-up of cases with infections—from infection control personnel [56].
 - See also specific chapters on surgical site infections, pneumonia, urinary tract infections, intravascular infections, neonatal infection, MRSA, etc.
-

5.6 Notification and Warning on Suspected Infection and Dissemination

5.6.1 What Should be Reported? [57]

- (a) Suspected *epidemic* outbreak in which many (> 3–4) eventually become sick with the same/similar clinical symptoms and course of disease (gastroenteritis, respiratory infections, etc.) on ward, department or in hospital. This includes both patients and staff [58].
- (b) Suspected microbial agents obliged to isolate. More about the specific microbe in Reference 2.
- (c) Repeated instances (two or more) of *serious* postoperative or other infections where one suspect same source of infection/transmission route/infectious agent and/or breaks in infection barriers.
- (d) Suspected serious *blood contamination* (hepatitis, HIV) or other serious infections transferred to the patient or staff [2, 57–60].
- (e) Suspected of deaths caused by hospital infection.

5.6.2 To Whom Should it be Reported?

- Department management, the doctor on duty and responsible physician in primary care.
- Infection control department.
- The hospital medical officer—occupational health (for suspected infection transferred to personnel, for example, tuberculosis).
- The hospital management (by death, resource-intensive measures).
- The National Institutes of Health and the county administrative officer for some obliged notifiable infections, according to the Infection Control Act or defined routines.
- Remember nominative notifiable diseases.

5.6.3 Who Should Report or Warn?

- Responsible physician, attending physician, nurse, medical supervisor, infection control personnel and responsible physician in primary care.

- Department of microbiology (the detection of special agents/resistance patterns/ clinical information).
- The occupational health (for suspected serious infection transmitted to staff).

5.6.4 How to Notify or Warn and How Often?

- Daily when there is outbreak; telephone, telefax (NB not patient name) or written messages.
- Evaluated by the professional responsible for the relevant department together with infection control personnel, according to the extent and severity of the outbreak.

5.6.5 Coercive Measures When Proven Hazardous Infection to Public

In a few cases, leads notification and contact tracing to enforcement action by law; in Norway by the Infection Control Act of 01.01.1995, with compulsory medical examination and compulsory isolation in hospitals; § 5.2 and § 3.5 [61, 62]. It has happened a few times in connection with infectious pulmonary tuberculosis.

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Part II

Infection Control for Health Care Workers



Staff Uniforms and Uniform Policy

6

Abstract

Personnel in contact with patients or equipment and textiles should always use the hospital's work attire. It includes anyone handling food, medicines, textile, waste or cleaning tools. By caring, treating, examining and transporting patients, there will be direct contact between own work clothes and the patient's cloths/ bedding or skin. The same is true when working with used patient equipment such as bedpans, toilet chairs, beds and other aids and working in patient rooms, toilets and bathrooms or when handling bedding and bandages, giving physiotherapy, etc. The work uniform is particularly exposed to organic matter and microbes, for example, in ambulances, in emergency services, in restless and anxious patients and children, during sampling and examination/treatment, etc. In acute wards, the staff is often exposed to splashes from patients, especially blood but also vomit, sputum, pus, faeces and urine. This chapter is focused on practical measures to prevent transmission of infections via contaminated staff uniforms.

Keywords

Staff uniforms · White coats · Gowns · Healthcare worker's uniforms · Attire · Transmission of microbes · Contamination · Infection control · Hygiene

6.1 Purpose

Healthcare worker's uniforms protect them against the spread of infections. The hospital uniform signifies a professional identity that ensures professional patient safety and infection protection.

6.2 Comprise

All employees who are in contact with patients, equipment, textiles, medicines and food (food, water, beverages) or who treat contaminants and waste [1–7].

6.3 Responsibility

The hospital management should ensure conditions and resources where all employees receive adapted uniforms, training and follow-up with regard to personal hygiene and the use of the hospital's uniform. This includes good and clean wardrobe conditions.

Department management should ensure training, information and control of all employees, including temporary workers and extra help, and that they follow the hospital's procedures with regard to the work attire. All staff should have lockers for private clothes and shoes in clean and well-kept wardrobes.

All employees have a personal responsibility to follow hospital policy with regard to the use of work attire and for personal hygiene and infection control.

6.4 Practical Measures

- The hospital work uniform and attire replaces the use of private clothes [1–7].
- The hospital work clothing should only be used in hospital or in service.
- Shift work suit daily or by local codes [8, 9].
- In direct contact with the patient, clean or unclean equipment or textiles in the health care; change work uniform daily or more often if contaminated. This also applies to work with psychiatric patients.
- Hospital shoes, for own use, are used only in the hospital. Change to hospital shoes and place private one in the locker when arriving the hospital.
- Use the hospital's socks, especially if not shoe cover heel and toe.
- It is *not* allowed to use jewellery at all work with patients or equipment (finger rings, bracelets, necklaces, all kinds of earrings and all other jewellery). Piercing is not allowed. Jewellery leads to increased bacterial growth [10, 11].
- It is not allowed to use the wristwatch at point of care or work with equipment as it increases the bacterial load on the hands [12].
- Nails should be short and clean. Artificial nails are not allowed [10, 11].
- Long hair is collected and secured. There can often be large amounts of bacteria in the hair.
- If covering the hair for religious reasons: use the hospital fabrics (hijab). The use of own hijab or headscarf is not allowed. The head restraints are changed daily and connected in such a way that the “snaps” do not hang down the front of the uniform and contaminate.
- Shift work clothes if contaminated with biological material.

- Surgical personnel and anaesthesiologists have a particular responsibility to follow the hospital's uniform routines—see the surgical department.
- Work clothes should be of sturdy yet dense material resistant to washing at 85 °C for at least 10 min and to disinfectants and frequent washing. All washing of outfits and other fabrics must be done in approved laundries for hospital textiles.
- Work attire should *not* be taken home and washed there because of the risk of spreading disease.
- Work attire should be comfortable and not trigger allergies.
- By care of patients, use care coat with long sleeves and cuff. These may be used in a blue or other specific colour and be patient bound.
- Use cover coat or disposable plastic aprons at work where there is danger of soiling of the ordinary work clothes.
- By care of infectious isolated patients, use yellow infection coats with long sleeves, cuffs at the wrist without pockets and with closing behind.
- Infection coats and care coats must be replaced daily or immediately if visible soiling or soaking. *An advantage in work with infectious cases is the use of yellow, disposable coats changed after each use.*
- Clean work clothes to prevent the spread of infection and to reduce bacterial load on the hands [13].

6.5 Background Information

In hospitals, there is an accumulation of infectious agents. Bacteria are often more antibiotic resistant than those detected outside hospitals. Contaminated work clothes pose a high risk of infection in a hospital environment [14–24].

Personnel with direct contact with patients or with clean and unclean equipment and textiles should always use the hospital's work attire. It includes anyone handling food, medicines, textiles, waste or cleaning tools. By caring, treating, examining and transporting patients, there will be direct contact between your own work clothes and the patient's cloths/bedding or skin. The same is true when working with used patient equipment such as bedpans, toilet chairs, beds and other aids and working in patient rooms, toilets and bathrooms or when handling bedding and bandages, giving physiotherapy, etc.

The work uniform is particularly exposed to organic matter and microbes, for example, in ambulances, in emergency services, in restless and anxious patients and children, during sampling and examination/treatment, etc. In acute wards, the staff is often exposed to splashes from patients, especially blood but also vomit, sputum, pus, faeces and urine [25].

In hospitals, the workout will be an alternating exposure for the work uniform to contaminated and clean material, for example, to go from nursing of a patient to storage rooms for sterile equipment or clean textiles. Competence and knowledge in infection control reduce the cross-contamination to other patients and the environment.

Change of attire daily. An additional certainty is that the outfit is changed daily or more often when needed. Bacteria, viruses and fungi live on textiles for up to several days and can pose a significant risk of infection [26–29]. During the SARS outbreak in 2003, a laundry employee in Taiwan was infected and caused a large outbreak through the washed and contaminated laundry sent out to the departments.

The work wear quickly becomes contaminated already after 8 h, partly from own skin and microbes, and partly from patients, personnel and the environment [30, 31]. Up to 60% of uniforms may be colonized with pathogenic microbes [15, 24]. In endemic areas of MRSA, the uniform may be contaminated with MRSA in 30–80% of cases [16, 32]. The bacteria are sitting for long periods on the sleeves and pockets and are risk to patients and other employees, particularly when hands are contaminated by own working clothes [32]. The more contaminated the outfit is, the more microbes are detected on the hands. From there, the road is not long to the mouth and to other parts of the face [13, 33]. The use of stethoscope, tourniquet, telephone, intercom systems, etc. in the coat pocket or around your neck increases the burden of microbes on the uniform, especially if the stethoscope and hands are not disinfected between patients and activities [34].

Good housekeeping in a department contributes to reduced infection pressure on the hands and the work wear [35]. Handwash must be carried out in such a way that the uniform is not contaminated with splashes and bacteria from the washbasin [36].

Do not wash the work wear at home. The washing of work clothes transferred to the user is justified by the fact that “home washing is as good as professional washing with regard to the cleanliness of the laundry” [8, 37]. This is not recommended and not true. Hospital-associated microbes should not be introduced to the home environment [9]. Both the Norwegian and the European occupation health and safety (2000/54/EU) highlight that workers like healthcare professionals and their families should not be subjected to unnecessary infection [7].

The patient's view on uniforms. Patients feel greater security and communicate more easily with personnel and special doctors, formally dressed in the institution's attire [38]. Doctors of “white coats” are perceived as being more hygienic, professional, authoritative and skilled [38]. Medical student's white coats show high bacterial contamination on the sleeves and pockets [20, 39]. Similar observation is done among 100 doctors at a hospital in England where the white coat was changed once a week [19]. Staphylococci (*S. aureus*) were isolated from one of four coats and more frequent from surgeons than from internists [19].

Wardrobes and storeroom for uniforms must have a high standard with regard to cleaning and maintenance to eliminate the risk of cross-contamination. The wardrobe should have a handwash and hand disinfectant. The textile store must be clean and always have the door closed. If the door is open, clean clothes are usually contaminated by air currents from the corridor [23].

Laundries should be approved, accredited and quality assured [1–3, 6]. Laundering of textiles may be a weak link in the treatment of hospital textiles which may contain pathogenic bacteria [40, 41].

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Vaccination and Control of Employees

7

Abstract

Healthcare workers in hospitals should be protected against infections by training and learning hygienic measures, the use of protective equipment when needed and in some instances by vaccination against vaccine-preventable diseases. Most patients with serious infections are treated in hospitals, and the personnel may therefore be more exposed to infections than other people, if not following routines. A basic good personal hygiene and a clean environment are mandatory.

Keywords

Vaccines · Immune sera · Infection control of employee in healthcare

7.1 Purpose

- To protect healthcare workers against vaccine-preventable types of infections in healthcare [1–3].
- To protect the patients against vaccine-preventable types of infections.

7.2 Comprise

All employees who are in contact with patients, equipment, textiles, medicines, food and water and contaminants or waste should be protected against vaccine-preventable infections. All patients exposed to vaccine-preventable infections.

7.3 Responsibility

The hospital management has overall responsibility for ensuring that all staff and patients receive the necessary offer of actual vaccines that can protect them against infectious disease like influenza [1–3].

Department management is responsible for providing an overview of the necessary vaccine offered to employees and patients.

7.4 Practical Measures

At least 25 vaccines and combination of vaccines, in addition to immune sera, are officially described in the Norwegian healthcare system, and similar descriptions are present in other countries in Europe and in the United States. However, only a few vaccines against the most common vaccine-preventable diseases may be of current interest for hospital employee.

7.5 Hepatitis A/B vaccines

Norwegian Ministry of Social Affairs of 19 May 2000: “Persons at risk of infection during education in Norway: Students in medicine, surgery, anaesthetic care, intensive care, midwife care, dentistry, dental care and bioengineering” [1–6].

7.5.1 Hepatitis A Vaccine

Effective vaccine: two doses. May be relevant where staff are relatively frequently exposed to hepatitis A infection or travel/work in endemic countries [1–5]. May also be given in combination with hepatitis B vaccine.

7.5.2 Hepatitis B Vaccine

The occupational health service or designated therein vaccinates and monitors the level of antibodies, revaccination and control. The vaccine is effective and mostly uncomplicated. The combination vaccine against hepatitis A and B is good. Antibody levels are often detected after 10–11 years. Revaccination may be considered if antibody titres <10 IU, by degree of exposure to blood via puncture of the skin or mucous membrane contact. All employees are offered vaccination. For questions, contact the hospital health service or infection control staff.

Target group: Persons whose work involves contact with the human blood and tissue and special patient groups like dialysis patients, intravenous narcotics, hepatitis- or HIV-positive, men who have sex with men, relatives of hepatitis B carriers, etc.

The following personnel groups should be offered hepatitis B vaccine:

- Surgical personnel and personnel from anaesthesia, intensive care, post-operative-, acute ward- and paramedics.
- Personnel working with dialysis, infectious diseases, gastroenterology, lung medicine, haematology, cancer, and personnel at all surgical departments.
- Midwives and nurses working with children.
- Personnel at children medical department, child radiology, child infection and paediatric-intensive units.
- Surgical department: cleaning and assisting.
- All bioengineers in laboratory medicine departments, general radiology and other invasive investigations.
- Cleaning personnel who are particularly exposed to blood/blood contamination.
- Laundry: people working with contaminated textiles.
- Psychiatry: treatment of restless, anxious, unpredictable patients with infections.

7.5.3 Hyperimmune Hepatitis B Immunoglobulin [2, 3]

Post-exposure prophylaxis of persons not vaccinated or with incomplete vaccination and low values; <10 IU/L, if exposed to infections or to newborns of HbsAg-positive mothers or other causes.

7.6 Polio Vaccine

Polio vaccine is a part of the childhood vaccination programme.

Employees at special departments receive vaccination status updated and followed up with vaccination if needed. This applies especially to notification of outbreaks of poliovirus which now only exist in a few places in Asia, the Middle East and Africa.

Live inactivated viruses (drops × 3) or inactivated viruses (syringe × 3) have very good preventive effect, possibly lifelong immunity. One dose revaccination may be sufficient even though it has elapsed 10 years after the last polio vaccine, but women may have low levels of antibodies against the virus.

Target group: Revaccination, especially of employee, that may treat children and adults with infections and when working in healthcare and travelling in areas where polio is endemic [1, 3].

7.7 Influenza Vaccine

Healthcare personnel are offered influenza vaccination each year. It is especially important to protect persons that have chronic heart and lung diseases or other disease that may be complicated by the influenza. It must be ensured that

the vaccine is not added adjuvants, is a one-dose vaccine and does not contain mercury [3].

Season: December to February/March.

Vaccination: from September to January

- All employees are offered the flu vaccine without addition and in single-dose container.
- The number of doses is ordered by the department's management.
- The order is sent to the National Institute of Public Health (NIPH) or other decided address.
- The department's management makes sure to offer the vaccine to its own personnel.
- Vaccination of risk groups among patients at the department is done according to the general recommendations for the country.
- Full effect after 2–3 weeks and immunity may last for 4–12 months. Antibody development in individuals with endogenous or iatrogenic immunosuppression may be insufficient.

Target groups

- Adults and children with serious respiratory diseases, particularly those who have reduced lung capacity (COPD, etc.).
- People with chronic heart/vascular disease, particularly those with severe heart failure, low cardiac output or pulmonary hypertension.
- People with reduced resistibility against infections.
- Adults and children with diabetes mellitus type 1 and type 2.
- People over 65 years.
- Key personnel and health professionals.
- In the United States, influenza vaccination is now recommended for former or current MRSA-infected persons.

Influenza vaccine consists of an annual dose recommended given during September to November. Full effect is achieved after 2 weeks, providing protection in 40–70% of the vaccinated. The effect disappears after 4–6 months. The use of this vaccine is controversial [1, 3, 7–10].

7.8 Rubella Vaccine

Rubella vaccine (against “red dogs,” German measles) is a part of the childhood vaccination program, combined with measles and mumps (MMR). Increasing incidence of rubella is observed in Romania, Poland and other European countries. Outbreaks may involve revaccination [3].

7.9 Varicella Zoster Vaccine

Chickenpox (varicella) is a common child disease, and up to 70–80% of the population may be naturally immune. The vaccine is effective and may be offered to personnel who have not undergone varicella (low immune status in people from Asia) and who are exposed to infection relatively frequently [1, 3].

Varicella zoster immunoglobulin—VZV IgG—is used in special cases of impaired immune system and other special cases [2, 3].

7.10 Mumps Vaccine

Mumps vaccine is a part of the childhood vaccination programme (MMR vaccine). Epidemic outbreaks of mumps (parotitis) are reported in a number of countries in Southern and Eastern Europe. In Norway, there were outbreaks in 2015 [3]. Outbreaks may involve revaccination, even among personnel [3, 11].

7.11 Measles Vaccine

Measles vaccine is a part of the childhood vaccination programme (MMR). Epidemic outbreaks of measles (morbillo) can lead to recurrence of infections in those vaccinated. In Europe it has been outbreaks with more than 20,000 cases in 2013 [3]. Few cases in Norway are most often associated with import.

The vaccine has a limited effect after a number of years [12]. There is a high risk of infection for unvaccinated and non-immune persons who are exposed to measles. Vaccination is considered if exposure has occurred for the last 72 h. Exposed health-care professionals should be tested for antibody levels, possibly booster vaccine.

7.12 Other Viral Vaccines [1–3]

Tick-borne encephalitis virus, Japanese encephalitis virus, Rabies virus, Yellow fever virus, Rotavirus, Human papillomavirus, etc. May be used in travel medicine [1, 2, 5, 13].

7.13 Diphtheria and Tetanus Vaccines: Duo-Vaccines—Optionally Including Pertussis (Tdap)

A part of the childhood vaccination programme. Primary vaccination and one booster dose every 10 years. Revaccination against diphtheria is recommended every 5 year or more frequently in the appearance of diphtheria (*Corynebacterium diphtheriae*). All

potentially infected persons should be well immunized against diphtheria and tetanus. The vaccine provides limited protection, especially for tetanus (*Clostridium tetani*). Women often have low levels of antibody due to lack of revaccination.

Target groups: Travel to special areas—longer periods—booster. Persons who treat patients with import infections (department of infection medicine, child infections, ear-nose-throat-departments, ambulance staff, etc.) and persons who treat waste/infectious waste (tetanus vaccine).

7.13.1 Diphtheria

Primary (triple) and revaccination of diphtheria every 5 years in the presence of diphtheria [1, 3].

7.13.2 Tetanus

Tetanus vaccine in case of injury

- If a clean wound and earlier full basic vaccination >10 years: one dose. If missing basic vaccination, see the information that accompanies the vaccine.
 - A dirty wound and full basic vaccine >5 years: vaccine, one dose. If lack of basic vaccine, give full vaccination and human tetanus immunoglobulin in addition; see guidance.
-

7.14 Pertussis Vaccine

A part of the childhood vaccination programme. The vaccine against pertussis (*Bordetella pertussis*) is currently used as revaccination during outbreak of pertussis and routine revaccination of children in many countries [1, 3, 14, 15]. Since 1996, there have been several major pertussis outbreaks in Norway, about 2000 registered cases in 2013 [3].

7.15 Pneumococcal Vaccines

Pneumococcal disease is increasing, and the bacteria are more resistant to penicillin [3]. Pneumococci (*Streptococcus pneumoniae*) are significant causes of sinusitis and otitis and serious infections such as pneumonia, septicaemia and meningitis. Vaccine is the only prophylactic treatment to pneumococcal disease. It protects about 60–70% against pneumococcal septicaemia, meningitis and pneumonia [1, 3]. By impaired immune system, such as lack of spleen function, malignant diseases or HIV infection, the protection may be lower [16–20].

Target groups:

- People with chronic heart/vascular/pulmonary disease.
- People who have had severe pneumococcal disease.
- People who have had their spleen removed or have impaired splenic function.
- People who have compromised immune systems, among other things, due to HIV, lymphoma and Hodgkin's disease.
- Persons older than 65 years (recommended by the Institute of Public Health).
- Toddlers.

The pneumococcal vaccine consists of one dose. There are no recommendations for revaccination, except for persons without the spleen. In these, it is recommended to take a blood sample for antibody measurement after 3–5 years. The need for revaccination is assessed on the basis of the antibody level [1, 3].

7.16 *Haemophilus Influenzae Type B Vaccine*

A very good vaccine given routinely to toddlers [1, 3]. Good protective effect so far [3].

7.17 Meningococcal Vaccines

Vaccines used against meningococcal disease with *Neisseria meningitidis* serogroups A, C, Y, W135 [1, 3]. There is a varying effect and no good vaccine against serogroup B meningococci. Vaccination around meningococcal cases with simultaneous antibacterial treatment of close contacts is recommended [3].

7.18 BCG Vaccination

BCG (Bacillus of Calmette and Guerin; *Mycobacterium bovis* attenuated over a long period) provides probably good protection against tuberculosis first 4 years after vaccination and likely effect on disease progression later in life [1, 3]. However, it does not prevent superinfections. If the tuberculin test is still negative after repeated revaccinations, the person should preferably not be employed in departments of infections or microbiology or in other work related to particular risk of tuberculosis. This vaccine has been very controversial.

After 2009, there is no BCG routine vaccination of schoolchildren in Norway. Persons exposed to tuberculosis at home or abroad and their close contacts should be assessed for vaccination [3].

7.19 Other Bacterial Vaccines

Vaccines against pathogenic intestinal bacteria (cholera, salmonella, etc.) have varying and often transitory effect.

7.20 Vaccine Combinations to Children

Infanrix-IPV + Hib (diphtheria, tetanus, pertussis, polio, *Haemophilus influenzae* type b), Priorix (measles, mumps, rubella), etc. [1, 2].

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Employees with Infections or Carrier Status

8

Abstract

It is estimated that about 8% of the population in developed countries undergoes various minor and major infections each year. Translated to hospital employees, these are persons aged 20–70 years with varied composition and disease panorama probably like the rest of the general population. They may charge the hospital with the spread of infection to susceptible patients. There may also be an unknown potential of hospital infections transmitted to and from healthcare workers. Therefore, it is important to have good control measures and routines around personnel with infections.

Keywords

Infection · Carrier state · Healthcare personnel · Sick leave · Responsibility · Control

8.1 Purpose

Protect patients, personnel and themselves from infections.

8.2 Comprise

All employees exposed to MRSA or tuberculosis or who have an infection or carrier state that may be spread in the hospital.

8.3 Responsibility

The hospital management should ensure that all employees receive the necessary personal protection against infection by working in the hospital and not be exposed unnecessarily to infectious agents [1]. Employees that have infection or carrier state must be handled in a proper manner to ensure that the infection does not spread to patients, workers or the environment.

Department management should ensure that employees follow policies and procedures for hygiene and infection control, providing them with access to proper personal protection against infection and that they follow systems for notification and action by infection that can spread in the hospital.

All employees must follow hospital policy with regard to personal hygiene and infection control and are obliged to inform infection control personnel/occupational health or thereto designated unit on suspicion that they themselves may have an infection/carrier state that may be a risk of transmission in the hospital.

8.4 Practical Measures

Control system for appointment. Short- or long-term job: temporary workers, including extra shifts, trainees, night shifts, part-time employees, student-teacher, etc. A common control system is established with an overview of who is working at the hospital and where. It is important for emergency preparedness.

Control scheme. All employees, including extra workers, shall complete a written check form with a request if exposed to MRSA last year or have even been infected with MRSA ever. Information about exposure to tuberculosis is also required. It must also be stated whether the person has recently been ill/exposed to norovirus or other gastrointestinal infections. The latter is especially true for staff with short-term work and/or working at the same time at several workplaces—such as at a hospital during the day and a night shift at a nursing home.

Personnel from healthcare abroad. Personnel who have worked, studied, been hospitalised or been a patient abroad should inform about possible MRSA, tuberculosis or other infection/exposure and be tested before visiting/student teaching/working at Norwegian hospitals. For personnel from other countries that alternate between working periodically at hospitals in Norway and in another country, a routine test system can be established as testing once a month or more frequently if there is known exposure.

8.5 Background Information

It is estimated that about 8% of the population in developed countries undergoes various minor and major infections each year.

In Norway (5.5 million inhabitants), more than 130,000 peoples were employed in 102,000 full-time equivalents in Norwegian hospitals in 2013, including the specialist, somatic, psychiatric and abuse [16]. There were more than 68,300 full-time equivalents in general hospitals. These are persons aged 20–70 years with varied composition and disease panorama probably like the rest of the general population.

Translated to hospital employees, this may account for 10,400 employees with one or more infections every year in Norway, which also may charge the hospital with the spread of infection to susceptible patients. In addition, there may be an unknown potential of hospital infections transmitted to and from healthcare workers. Therefore it is important to have good control measures around personnel with infections.

8.6 Actual Infections or Carrier State

8.6.1 Hepatitis A Infection—Jaundice

Acute disease phase: Sick leave. Usually noninfectious after 2–4 weeks but may have viruses in the blood for longer periods [2].

NB! Follow-up of exposed staff/patients; immune serum, vaccination, testing.

8.6.2 Hepatitis E Infection—Jaundice

Acute disease phase: Sick leave. Probably noninfectious after 2–4 weeks but may have viruses in the blood for longer periods [3]. Infections like hepatitis A but may be more severe for pregnant and immunosuppressed.

NB! Follow-up of exposed staff/patients; no vaccine or immune serum.

8.6.3 Hepatitis B, C, D, HIV, HTLV

Acute phase of disease: Sick leave—varying length relative to disease development [4, 5].

Carrier state: Precautions against transmission to others. If necessarily, contact the company doctor or similar function at the hospital. Sore/abrasions on the hands should be covered with plaster + gloves.

Glove use when:

- Direct care/contact with patients.
- Treatment of equipment used for patients.

NB! A carrier or a person in the incubation period or a sick person infected with these agents should not perform invasive procedures [4, 5].

8.6.4 Varicella Zoster (Chickenpox or Shingles) [6]

Acute disease phase: Sick leave to noninfectious.

Avoid contact with/care of patients with varicella/herpes zoster, if had not undergone infection earlier. If exposed and not informed concerning earlier infection, check immune status, possibly vaccination.

NB! Air and contact transmission, highly contagious!

8.6.5 Herpes Simplex

Involvement of hands/face: no direct patient contact or contact with clean/sterile equipment, textiles, food/beverage, etc. [7] Sick leave.

Involvement elsewhere on the body: no contact with immune-compromised, newborns, premature, etc., optionally sick leave.

NB! There is a high risk of transmission in hospitals if acute HSV infection is on the hands.

8.6.6 Influenza-Flu

Acute disease phase: sick leave ca. a week to avoid the spread of infection to patients and staff [8].

NB! A very contagious virus.

8.6.7 Norovirus, Rotavirus and Other Viral Gastroenteritis

Acute disease phase: In acute diarrhoea and/or vomiting that resembles norovirus, employees must be at home at least 2 days *after symptom freedom* in order to avoid the spread of infection and new outbreaks in the hospital [9].

NB! Very contagious virus.

8.6.8 Bacterial Gastroenteritis (including Salmonella/Shigella/Campylobacter, Yersinia, Tarmpatogene E. coli, etc.) [10]

Acute disease phase: leave until noninfectious, 2–3 weeks.

Once the bowel function becomes normal again, take control samples of faeces. Defined noninfectious after three negative faecal samples with at least 2 days apart (five negative samples by *S. typhi/S. paratyphi*). If treated with antibacterial agents, start the collection of samples minimum 1 week posttreatment.

NB! This is important for all hospital staff, personnel working with children and kitchen personnel [10].

8.6.9 Streptococcus Group A: Impetigo, 3 Days Sore Throat, Erysipelas, Scarlet Fever, etc.

Acute disease phase: sick leave for active phase of the disease and as long as there are signs of infection.

Tonsillitis (sore throat), erysipelas, scarlet fever (scarlatina), impetigo, wound infections and as long as there are signs of infection/sore/crust. In all, 10 days of penicillin treatment and control is recommended to reduce the risk for diseases (rheumatic fever, glomerulonephritis). The bacteria live several months (4–8 months) in the environment [11]. Highly infectious.

NB! When detecting two or more SSIs with group A streptococci, recommend testing of involved surgical teams, including coordinating nurse. Take samples from the throat, nose, pharynx, anus and vagina. A team member with detected infection: sick leave and treatment before returning to work [11].

8.6.10 *Staphylococcus aureus*

Acute phase of disease: sick leave in the active phase of the disease and as long as there are signs of infection/sore/crust [12]. Usually not needed to be followed up.

8.6.11 MRSA (Methicillin-Resistant *Staphylococcus aureus*)

Acute disease phase: sick leave during the phase of infection and during control for carrier state [13].

Carrier state of MRSA: sick leave during the phase of decontamination and followed up to negative test results. The person shall not be at work to not expose other employees, patients or equipment for environmental contamination. MRSA survive in dry environment for at least 10 months if not removed.

NB! *Carriers* of MRSA are reported sick (sick leave) until a specified number of negative samples are taken after a certain system, most often after a decontamination phase. See MRSA.

8.6.12 Infected Wounds on the Hands and Face (Not Chicken Pox)

Not direct patient contact/equipment contact and to be evaluated: sick leave.

This should be assessed by the department responsible physician/occupational health.

8.6.13 Impetigo—Often in the Face and Extremities

Acute phase of disease: sick leave until wounds are healed and the crusts fall off, especially in group A streptococci.

The infection is caused by *Staphylococcus aureus* in one of three cases, streptococcus Group A in one of three and mixed infection of these two in one of three [11, 12]. Impetigo is contagious until the last crust is falling off. Antibiotics have very little effect in the skin due to poor penetration. Good hand hygiene and hand disinfectants inhibit the spread of infection. Local treatment of infections with *Staphylococcus aureus* (after resistance pattern) and local + penicillin treatment (10 days) where Group A streptococci are involved [11, 12].

8.6.14 Infected, Widespread Eczema

Acute disease phase: sick leave as long as it is pus secretion.

Widespread hand eczema: assessed by the occupational health, optionally sick leave. Work adapted to prevent eczema outbreak and spread of infection.

NB! Personnel with chronic wounds or dermatitis should not work with patients infected with MRSA, group A streptococcus and preferably not with VRE [14] (vancomycin-resistant enterococcus) or other resistant bacteria (ESBL and other resistant gram-negative bacteria). This is to avoid unfortunate carrier state.

8.6.15 Upper Respiratory Tract Infections (Colds)

Acute disease phase: sick leave as necessary.

Remember risk of transmission to others! Never go into immunosuppressed with acute colds or other respiratory infection.

Use disposable paper towels when coughing, sneezing and having runny nose. Always have a clean supply of paper towel in your pocket! This is discarded after each use with careful hand hygiene afterwards. Cover your mouth when coughing/sneezing, if it is necessary to be in the job. Be assessed by the departments responsible physician.

NB! Not cough or sneeze into the elbow bend! The hospital uniform should never be used as handkerchief!

8.6.16 Tuberculosis

Acute phase of disease: sick leave for proven infection and active disease [15]. See also separate section.

8.6.17 Sick Leave and Follow-up of Health Professionals

This is done by the general practitioner or occupational health or the defined unit at the hospital.

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Pregnant Employee Exposed to Infection

9

Abstract

Pregnant employees are an important workgroup in the hospital. Conditions must be taken to ensure the best possible working situation and that the foetus is not infected during pregnancy. Upon infection, there are two lives instead of one that might have problems. It is a somewhat greater infection pressure in paediatric and infectious diseases departments than in other departments. This may be the situation in most developed countries. Personal hygiene is especially important, both in private life and at work, and pregnant healthcare workers should avoid being infected during work in hospitals.

Keywords

Infection · Carrier state · Pregnant healthcare worker · Sick leave · Responsibility Control

9.1 Purpose

Protect pregnant employees from infections or carrier state.

9.2 Comprise

All pregnant employees exposed to MRSA, tuberculosis or other infections that may be of importance for the pregnant women or her child.

9.3 Responsibility

The hospital management should ensure that all pregnant employees receive the necessary personal protection against infection by working in the hospital and not be exposed unnecessarily to infectious agents [1]. Employees that have infection or carrier state must be handled in a proper manner to ensure that the infection does not spread to patients, workers or the environment.

Department management should ensure that pregnant employees follow policies and procedures for hygiene and infection control, providing them with access to proper personal protection against infection, and that they follow systems for notification and action by infection that can spread in the hospital. It is of importance that pregnant employees are protected from exposition to any kind of infection in the hospital.

All pregnant employees must follow hospital policy with regard to personal hygiene and infection control and are obliged to inform infection control personnel/occupational health or thereto designated unit on suspicion that they themselves may have an infection/carrier state that may be a risk of transmission in the hospital.

9.4 Practical Measures

See the practical measures in Chap. 8. In addition to other actual infections, pregnant employees are especially vulnerable to microbial agents that may affect the foetus [1–5].

9.4.1 Rubella (German Measles) [2]

Check immune status, vaccinated? Avoid contact with persons infected with rubella. Rubella hardly occurs today in Norway, but exists in most countries in the world.

9.4.2 Cytomegalovirus (CMV)

Check immune status at prenatal care. If antibody is negative, avoid contact with known CMV secretor (children with CMV, immunosuppressed with CMV).

Regardless of immune status, use contact regime, and use a face mask/screen/hood when taking care of a patient with CMV pneumonia or other CMV diseases.

9.4.3 Varicella-Zoster (Chickenpox or Shingles)

Avoid contact with/care of patients with varicella/herpes zoster, especially if had not undergone infection earlier. Check immune status, possibly vaccination after birth.

NB! Air and contact transmission, highly contagious!

9.4.4 Parvovirus B19

This is a rash like rubella; fever and often arthralgia—in small joints, especially in women.

NB! Avoid contact with patients with rubella-like rash.

NB! General caution concerning contact with infected patients during pregnancy. Good hand hygiene, personal hygiene and knowing the use of protective equipment are especially important during this period.

9.5 Basic Information

Pregnant employees are an important workgroup in the hospital. Conditions must be taken to ensure the best possible working situation and that the child is not damaged during pregnancy. Upon infection, there are two lives instead of one that might have problems. Pregnant women have a safe work in Norwegian hospitals, with few infection situations that pose a risk during pregnancy. It is a somewhat greater infection pressure in paediatric and infectious diseases departments than in other departments. This may be the situation in most developed countries.

In addition to the above, some infectious agents are common in the community and may have varied risk in pregnancy, like infections with *Listeria*, toxoplasmosis, influenza, group B streptococci, and gastrointestinal infections or genital infections which can cause poor foetal development or premature birth. Personal hygiene is especially important, both in private life and at work.

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Tuberculosis: Prevention

10

Abstract

Staff in healthcare is usually more frequently, than others, exposed to *Mycobacterium tuberculosis* and similar mycobacteria that may cause tuberculosis. Systematic control of exposed individuals, good and quick diagnosis and isolation of infected cases and DOT (directly observed therapy) should be recommended. Recently it was in Sweden a nosocomial outbreak at a hospital where seven people, including three medical staff, were infected with the same TB strain. This was discovered during a period of 10 months after an HIV-positive patient died of pulmonary tuberculosis. In Norway, the following up is not good enough; up to 30% of the patients will disappear from the health system. Infection among health professionals is often not followed up adequately. Good and proper practical measures are very important, because the bacteria are progressively evolving towards total resistance.

Keywords

Mycobacterium tuberculosis · Healthcare worker · Transmission · Control

10.1 Purpose

To protect staff, patients and visitors against infections.

10.2 Comprise

All employees, including extra shifts, trainees, visitors, night shifts, part-time employees, etc.

10.3 Responsibility

The hospital management should ensure procedures for control of patients and personnel with possible tuberculosis and be responsible for that employee and others affiliated with the hospital are not exposed to infection with *Mycobacterium tuberculosis* [1–5]. In case of suspected infection, the exposed staff and patients should be followed up in an appropriate manner to prevent transmission to patients, workers or the environment [1–5]. The hospital is also responsible for the control of the employees before they begin working at the hospital.

Department management shall ensure preventive measures that protect the employee against TB infection, by protective equipment, control of exposed persons, and notice and information, and ensure that employees have upgraded vaccination status in accordance with applicable guidelines. This includes also temporary work, extra help, part-time workers, night shifts, trainees and other visitors.

Occupation health or similar functions should follow up exposed employees in collaboration with the primary healthcare, TB coordinator, lung medical ward and infection control personnel.

Each employee has *personal responsibility*. All personnel are obliged to follow procedures to prevent infection and spread of tuberculosis and to inform if exposed to infection.

10.4 Practical Measures

1. Personnel Possible Exposure to Infection—Import

Employees who have stayed in risk areas for tuberculosis in at least 3 months are obliged to undergo tuberculin testing before accession/re-entry into position in healthcare [3–5]. This obligation also applies if the person has stayed in particularly TB-risk areas, such as hospitals, refugee camps, war zones, etc. in less than 3 months.

Tuberculin test of personnel who have contact with patients is required in the following situations:

- (a) Upon their return after stay at least 3 months in countries with high prevalence of tuberculosis.
- (b) If there is suspicion that a person is or has been at risk of being infected with tuberculosis.

Newly appointed/reappointed to the position/return from service abroad should fill out questionnaires about staying more than 3 months in countries with high prevalence of tuberculosis or in areas with particularly high risk of infection in less than 3 months. There is no limit on the length back in time after staying in high-risk areas.

The National Institute of Health indicates the countries that have a high incidence of tuberculosis, as all countries outside of Western Europe, the United States, Canada, Australia, New Zealand and Japan. This applies to all the permanent or temporary positions, in full- or part-time positions, including persons in

training or work experience in healthcare. Some people have weaker ability to react to tuberculin (anergy), in the early phase after infection with tuberculosis. Negative tuberculin test does not rule out tuberculosis.

2. Tuberculin Tests by Appointment at Hospital

This should be done by anyone (done by the public health clinics). Exceptions are earlier positive tuberculin reaction (BCG vaccine) documented last 5 years or a positive reaction after TB infection.

3. BCG Vaccination if a Negative Tuberculin Test

Tuberculin testing and BCG vaccination vary between countries all over the world. In Norway, employee that does not have a clear vaccination response or mark may be offered vaccination (done by public health clinics).

Especially, the staff at the Department of Lung Medicine, Department of Infectious Diseases, TBC laboratories or other workplaces associated with a particular risk of TB infection should be tuberculin positive.

4. Screen Examination: X-Ray Survey: Annually or less Frequently

- (a) Super infected, earlier BCG vaccinated and who have an increased subclinical tuberculin reaction of 4 mm or more from earlier samples.
- (b) Natural tuberculin positive, without previous BCG vaccination and with an increase subclinical tuberculin reaction of 4 mm or more.
- (c) Both super- and primary infected with subclinical tuberculin reaction are checked annually in *a minimum of 3 years thereafter and further if prolonged infection symptoms of airways*.
- (d) Consider periodically screen checking or other controls for all natural tuberculin positive *and working at/as:*
 - Paediatric wards/daycare/nursery
 - Maternity wards
 - Infection departments/child infection
 - Pulmonary department
 - Haematological department
 - Oncology department
 - Physiotherapists
 - Paramedics
 - Transplant departments
 - Kidney medicine

5. Exposed to Infection

Employees who have stayed in the same room as a patient with pulmonary tuberculosis and not used PPE with respirator (P3 mask) should be registered as exposed and monitored as possible infected. This applies regardless of the stay length of time—with the patient [5].

6. Isolation Units for Airborne Infections

Patients with suspected pulmonary tuberculosis must be immediately isolated in defined airborne infection isolation units with negative pressure and disinfection of air extraction. Very few types of disinfectants kill tubercle bacteria that are very tenacious. The infectious dose is very small, only one bacterium. The tubercle bacteria may survive in the environment for up to 1 year if not exposed

to sunlight or UVC. The patient's family and close contacts should be treated as exposed or infected and should not reside in the hospital's public areas [5].

10.5 Basic Information

Tuberculosis is increasing despite major efforts from the WHO, CDC and ECDC to prevent the disease [6–11]. Bacteria are about to be completely resistant to anti-tuberculosis agents [12]. Also in Norway, tuberculosis has increased almost exponentially, especially pulmonary tuberculosis. This is strange considering the resources used to stop the spread of the disease [5]. BCG vaccine was a routine offer to all school children until it was stopped in 2009. Since then there has been a steadily increase of cases.

The staff is more frequently exposed to infection than others [13–15]. Systematic control of exposed individuals, good and quick diagnosis and isolation of infected cases, and DOT (directly observed therapy) are required. Recently it was in Sweden a nosocomial outbreak at a hospital where seven people, including three medical staff, were infected with the same TB strain [13]. This was discovered during a period of 10 months after an HIV-positive patient died of pulmonary tuberculosis [13]. Nor in Norway is the following up good enough; up to 30% will disappear from the health system, and still patients in Norway are dying from tuberculosis. Infection among health professionals is often not followed up adequately [16]. Good and proper practical measures for patients and personnel are very important, because the bacteria are progressively evolving towards total resistance [12, 17, 18].

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Accidents with Blood or Tissue

11

Abstract

Blood and body fluids and tissues should always be considered as infectious. Most infections can be transmitted through blood and tissue. This applies to viruses, bacteria, protozoa and prions. *The most relevant agents are hepatitis A, B, C and E and HIV.* Depending on endemic burden, other agents, such as hepatitis D, HTLV-I and HTLV-II, yellow fever virus, West Nile fever virus, haemorrhagic fevers, malaria, etc., may be transmitted via blood and tissue. Accidental stick or cutting injuries are most often occurring in the healthcare, seldom via transfusion of infected blood or via direct contact with wounds or mucous membranes. Microbes may also be spread with small blood-containing aerosols, mostly invisible to the eye. This may occur particularly during surgery and dental treatment. Hepatitis B and C and HIV can penetrate eye mucosa.

Keywords

Accidents · Blood and tissue infection · Hepatitis A, B, C, E · HIV · Healthcare worker · Transmission · Control

11.1 Purpose

- To protect patients, personnel and themselves from accidental blood- or tissue-borne infections [1–21].
- To protect environment/equipment/surfaces/textiles against contamination after accidents with blood and tissue.

11.2 Comprise

All staff and patients exposed to stab/cut with tissue- and blood-contaminated instruments/equipment or who are exposed to blood/tissue fluids/tissues from patients or staff in the mouth, the eye mucosa or in open skin wound.

Equipment, textiles, surfaces and environment exposed to contamination with blood or tissue.

11.3 Responsibility

Hospital management should ensure written procedures for protection against blood contamination, and exposed persons are offered adequate treatment and follow-up [1–4, 8–13].

Department management should inform and ensure that preventive measures and measures after accidents are followed by all employees, including temporary workers, extra help, trainees, part-time employees, etc. Personnel should not be unnecessarily exposed to infection [9–13].

Every employee has a personal responsibility to follow the hospital policy with regard to individual prevention of infection and the use of defined infection control equipment.

11.4 Practical Measures

11.4.1 Prevention of Accidents with Blood and Tissue: Prevention of Infection

11.4.1.1 Ways of Accidental Transmission

- From infected patient to healthcare worker via inoculation (stab, cut, stings, etc.) of blood or infectious body fluids or by splashes/spills on the defective skin or mucosa.
- Contaminated blood (splash, splatter, aerosols) via eye mucosa [1, 6, 7].
- From infected healthcare worker to patient in several ways [2, 4].
 - Infection has repeatedly been associated with addicted healthcare workers.
- From patient to patient directly or indirectly through contaminated equipment, infusions, injections, etc.

11.4.1.2 General Protection

- Always wear gloves when in contact with blood and body fluids. Disinfect your hands afterwards.
- Cover your own wounds with plastic bandage, even when using gloves.
- Protect the eyes, nose and mouth with a face mask/face shield/goggles when there is risk of blood splash. The majority of blood splatter is invisible [6, 7].
- Use in addition a coat when risk for blood splatter.

- Do not use multi-dose containers which can result in the spread of blood contamination between patients [1–4, 22].

11.4.1.3 Handling of Sharp Equipment

- By puncture of the skin and mucous membranes, use enough time for the procedure and calm down. Provide assistance and support when patients or children are restless, to protect against stab accidents [9, 10].
- Handle carefully sharp objects such as hypodermic needles, scalpels, glass, etc.
- The protective cover of needles should never be put back in place after use, to avoid stabbing.
- Do not take the syringe apart after use. Discard the syringe with the needle attached directly into the container for syringes.
- “Stick-secure” intravenous needles can cause blood splatter.
- Container for sharp/syringe waste should never be filled up more than 2/3. Needle-stick injuries may happen when trying to push syringes into almost full containers.

11.4.1.4 Surgical Procedures

- Operation team who tends to get cuts, for example, during delivery of equipment, should go through the work procedures and establish safe handover of surgical sterile equipment.
- Blood from the operator can be transferred to the patient for up to every fifth operation [23].
- The use of double gloving—indicator gloves—can protect against blood contamination when the blood amount of penetrating instruments is reduced as the instrument passes through the glove.
- Indicator glove use may ease the detection of stick accident. The gloves are then taken off; the wound is disinfected and put on a plaster, before a new glove is taken on.
- Double gloving is a safety for surgical teams operating under difficult local conditions that may result in needle-stick injuries, such as heart surgery, gynaecology, orthopaedics, etc.
- Double gloves and face shield/goggles should be used by the surgical team during all surgery that has suspected or known blood-borne agents like hepatitis or HIV. Assisting personnel should also wear a coat that covers the skin.
- During splatter of blood, most blood drops are less than 0.6 mm in diameter; almost no one is over 1 mm and thus invisible to the eye [2, 24]. Large operations often cause the greatest blood contamination in the operating room.
- A high use of diathermy creates a large yield of tissue particles in the air.
- The operating room with equipment should always be disinfected after surgery on patients with suspected or certain blood-borne infections like hepatitis and HIV.
- All textiles and uniforms used during surgery on blood-borne infections are changed after the operation.

11.4.1.5 Package of Sharp/Cutting Waste

- The container must be made of solid material and configured such that syringes can be discarded as a complete unit after use.
- The opening must be designed so that it is difficult to remove the contents.
- The container should not be accessible to children or unconscious patients [1–4, 9, 25].
- The container should be operated with one hand and closed well before it is placed in the container for infectious waste.
- Infected waste must be stored in a safe place, and it should be properly secured for retrieval and disposal.

11.4.1.6 Work Clothes, Objects and Surfaces with Spilled Blood

- Clothing with spilled blood must first be placed in yellow plastic bags resealed and then put in bags for infectious textiles.
- Larger objects with blood contamination should be placed in yellow plastic bags and then brought to disinfection or destruction.
- Equipment, surfaces and the environment exposed to contaminated blood should be disinfected.
- All large medical-technical equipment (respiration equipment, etc.) and other large equipment (bed, commode, wheelchair, etc.) exposed to contaminated blood must be disinfected. Use chloramine, household chlorine or PeraSafe, according to recommendation.
- All surfaces, including floors and rooms where there has been spilled blood from patients with blood-borne infections, should be disinfected.

11.4.1.7 Blood Testing, Use of Multiple-Dose Containers and the Like

- **NB!** Monitoring of blood glucose may be associated with risk of blood contamination unless procedures are followed! Blood can be infectious in very small and invisible amounts, for instance, on wads of cotton, hands, measuring pens, etc. Therefore, hygiene and infection control around blood glucose readings are very important.
- Multiple-dose vials and single-dose vials used as multiple-dose vials for intravascular treatment have been related to several outbreaks of contaminated blood [1–4]. Only single-dose vials should be used—and always as a single dose.

11.4.1.8 Vaccination

- All personnel who work with patients and patient-associated equipment, textiles, medical equipment, water and sewage, ventilation and waste should be offered vaccination against hepatitis A and B.
- There is no vaccine against hepatitis C, D and E or HIV and HTLV [1–4].

11.4.2 Exposed for Infection Accidentally [9, 10]

Infection accident/accidental exposure: to be exposed to blood or body fluids containing infectious agents. This may be caused by infected blood

transmitted from an infected donor to other persons via perforation of the intact skin (needle-stick, sting, stab, cut or bite) or via direct contact with mucous membranes (eyes, nose, mouth, etc.) or defective skin (open wounds, eczema, etc.) or blood-containing aerosol, splatter or contaminated equipment, textiles, waste, etc.

Source person: The person from whom the infected blood or body fluid originates.

NB! Quickly initiated disinfection is the most important immediate measure. *The immediate measures are carried out by the person himself [9, 10].*

1. Spillage of blood in an open wound or needle-stick/cut injuries (mucosa—see below):
 - (a) Wash immediately with plenty of soap and water to remove most of the blood.
 - (b) Disinfect the area as soon as possible with one of the following disinfectants for 4–10 min:
 - Alcoholic solution (ethanol 70% or isopropanol).
 - Chlorhexidine in alcohol solution 5 mg/mL.
 - Chlorhexidine in aqueous solution 1 mg/mL.
 - Chloramine 5%.
 - PeraSafe.
 - (c) If prion disease (CJD) is suspected, rinse the wound with 5% chloramine (or sodium hypochlorite) or 1 N NaOH for 5–10 min, and then wash with soap and water.
 - (d) If practical, use a bowl with the disinfectant and immerse the exposed area in the liquid for 4–10 min. Let the wound bleed into the disinfectant and squeeze gently around the puncture site/cut.
 - (e) Put on a plaster afterwards.

NB! Chloramine 5% and PeraSafe are not approved as disinfectants for use on the skin or open wounds and are therefore used only in accidents. They are completely harmless to the skin.

2. Needle-stick/cutting injuries without spontaneous bleeding:
 - (a) Wash immediately with soap and water.
 - (b) Gently squeeze around the puncture site and disinfect the area as soon as possible, as above.
 - (c) Put on a plaster afterwards.
3. Blood splatter into the mouth:
 - (a) Wash repeatedly with copious amounts of water and use hydrogen peroxide 3% for 3–4 min up to 10 min (normal mouthwash with hydrogen peroxide).
 - (b) If prion disease (CJD) is suspected and mucous membranes are exposed to possible contamination, rinse with sterile saline for 5–10 min.

4. Blood splatter in eyes:
 - (a) Rinse thoroughly with sterile saline or water for 3–10 min.
5. Spilled blood in wounds:
 - (a) Wash immediately with plenty of sterile water/saline.
 - (b) Disinfect the wound with aqueous chlorhexidine solution 1 mg/mL, chlorhexidine alcohol solution 5 mg/mL or alcoholic solution 70%. Chloramine 5% should be used only when no other disinfectants are available.

NB! Needle-stick or cut injuries should be immediately reported to the nearest superior who contacts the doctor in charge for further action. It should also be completed an injury report for the exposed staff, according to the hospitals routines.

11.4.3 Further Measures After a Blood or Body Fluid Contaminated Accident [9, 10]

1. The source is HIV positive or suspected positive.

After exposure to HIV, the exposed person should be given specific chemoprophylaxis, preferably within 1–2 h after the injury. Contact the hospital specialist in charge/department for infectious diseases [4, 9, 26].

- First: the local treatment (see above).
- Second: contact the hospital doctor in charge, responsible for treatment of possible HIV infection (outpatient/on call, etc.), for assessment of the prophylactic medication (within 1–2 hours up to 36 h).
- If known or strongly suspected HIV infection, it is appropriate to initiate immediately post-exposure prophylaxis (PEP) with a total of 4 weeks of treatment and by the national standard. It is important to detect resistance profile of the HIV virus (source) to choose the combination of PEP-medicines [4, 26].

2. The source person is hepatitis A positive or suspected positive.

Hepatitis A vaccine is given if not previously vaccinated and with no antibodies against hepatitis A (anti-HAV IgG-negative). This is examined in the blood sample before administering the vaccine. Gamma globulin should eventually be given after exposure. Gamma globulin may not prevent transmission of infection but prevent symptomatic infection or mitigate any illness. Gamma globulin should be given as soon as possible and no later than 2 weeks after possible exposure.

3. Source person is hepatitis B positive or suspected positive.

As soon as possible, within 48 h after infection incident, hepatitis B vaccine and specific immunoglobulin (HBIG) are given if the exposed person is not fully vaccinated. After 48 h, HBIG has no effect, and then only the vaccine is given. Do not await the results of serological tests on the immune status before

the vaccine is given. The vaccine is administered as a rapid dose vaccination, i.e. a dose after 0, 1, 2 and 12 months, if not previously vaccinated.

4. Source person is HCV positive or suspected positive.

There are no specific antibodies or vaccine that can be used for post-exposure prophylaxis.

The immediate treatment of wound/injury is therefore important.

11.4.4 Blood Samples, Reference to Specialist and Accident Report [9, 10]

Responsibility: department manager, occupational health physician/medical director.

11.4.4.1 Blood Tests

Blood samples should be taken from the source and the exposed person for testing of hepatitis A, B and C and HIV, preferably within 24 h and no later than after 72 h.

Requisition should be labelled *infection accident-blood* and should inform about earlier hepatitis A and B vaccination. Even after recently hepatitis B vaccination, the antibody level should be checked. The examination is voluntary.

Responsible leader of the department:

- Refers the exposed person to blood testing.
 - If necessary, contact hospital specialist in charge.
 - If there is a strong suspicion or known infection (hepatitis or HIV/AIDS), refer the exposed person *immediately* to the doctor in charge.
- Examine the infection status of the source (usually a patient) by journal records, other information and blood test results, and contact microbiological department for urgent test results and other information (archive).

NB! It is important to provide information about the infection accident to the laboratory and to the doctor in charge, from both the source of infection and the exposed person.

Positive test results are reported by telephone from the microbiological department to the applicant.

11.4.4.2 Injury Report

All needle-stick, cut, stab and other injuries involving contaminated blood or body fluids should immediately be notified to the nearest supervisor. Furthermore, the occupational health department or other departments with corresponding function should monitor the exposed person. It should be a completed injury report according to the hospital's routines.

11.4.5 Source Person Has Blood-Borne Infection [9, 10]

11.4.5.1 HIV-, HTLV-, and Hepatitis A/B/C/D/E-Exposed Person (And the Source Person is Positive)

The exposed person is immediately referred to the medical doctor responsible for treatment and follow-up.

Exposed person should not undertake invasive procedures in a follow-up period of 3–6 months after infection with HIV; hepatitis A, B, C and E; or other chronic blood-borne infections (HTLV, etc.) [1–4, 9, 10, 15]

11.4.5.2 Unknown Source of Infection

If the source of infection is unknown/unavailable, it may in some cases be appropriate to give hyper-immunoglobulin and hepatitis A and B vaccine. The exposed person is referred to the medical doctor responsible.

11.4.5.3 Monitoring of Blood: Body Fluid Contaminated Injury/Accident

The occupational health department or hospital-defined unit is following up the employee for controls after 6 weeks, 12 weeks and 6 months. It is important that the hospital has a good system for monitoring persons exposed for infections.

The local accident, the situation where the injury occurred, measures taken, the monitoring of the exposed person and the result of the accident should be registered in a final report. Annual surveys should be made and delivered to the hospital management.

- Further follow-up of individuals who have been exposed to possible contamination with blood depends on the results of the serological tests.
- It may be necessary to take blood samples after 6 weeks, 12 weeks and 6 months. Monitoring beyond 6 months is generally considered not necessary.
- During this period, one should not be a blood or tissue donor.
- By known HIV, HTLV or hepatitis A/B/C/E exposure, invasive procedures should not be done during the latency period [1–4, 8–10, 15–18].
- Protection against any sexually transmitted infection from the exposed during the latency period is recommended.
- Carriers of blood-borne infectious agents should not perform invasive procedures.

11.5 Background Information

Blood and blood-containing body fluids and tissues should always be considered as infectious.

Nearly all types of infectious agents can be transmitted through blood. This applies to viruses, bacteria, protozoa and prions. The most relevant are hepatitis A, B, C and E and HIV [1–4]. Depending on endemic situation, other agents such as

hepatitis D, HTLV-I and HTLV-II, yellow fever virus, West Nile fever virus, Zika virus, malaria, etc. may be transmitted via blood and tissue fluids [1–4].

Contaminated blood or tissue agents like hepatitis A, B, C, D and E, viruses, HIV, HTLV, etc. may be transmitted by accidental stick or cutting injuries and during contact with wounds or mucous membranes, when the source has an active infection [1–4]. “Blood contamination” is blood transmitted between persons; by sharp injuries, contaminated equipment, waste and textiles; and seldom by transfusion and contact (mucosa, wounds). Blood is also transmitted via small aerosols, mostly invisible to the eye, which occur particularly during surgery and dental treatment [1–7]. Hepatitis B and C and HIV can penetrate eye mucosa [1, 2, 4, 6, 7].

Infection risk after sharp injuries is 20–40% for hepatitis B, 1–10% for hepatitis C and 0.3–0.5% for HIV [1–4]. Active hepatitis A or E has a higher risk of infection. Increased risk of transmission from the source occurs when there is a large amount of blood transferred (large needle, transfusion) and a high viral load in the source and the needle goes directly into the bloodstream [1].

Global prevalence of blood-borne infection is very high; 10–30% of the world population is estimated to be infected with hepatitis A, more than half of a billion with hepatitis B and almost half a billion with hepatitis C. There is an unknown but large proportion of the population of hepatitis E and almost 100 million people with HIV, which is increasing, and an unknown number of people infected with HTLV and other chronic, blood-borne virus infections.

In Norway, about 1% (46,000–50,000) of the population are infected with one or more blood-borne viruses such as HIV (0.08%), hepatitis B (0.5%) or hepatitis C (0.55%) [1]. Departments of internal medicine and infectious diseases have usually a greater load of patients with blood-borne infections than others [1].

Needle-stick and cutting injuries among healthcare personnel are a global problem. The WHO estimated in 2003 that 9% of the 35 million health professionals are subjected to exposure to contaminated blood, each year. In the United Kingdom, 4% of healthcare workers experience one to six accidental puncture or cutting injuries each year [1]. In Germany, the accident rate is much higher [1].

In Norway, it may be 25,000–50,000 accidents with sharp instruments each year [1]. The accidents are underreported, and especially surgery and invasive procedures are associated with accidents. It is claimed that the surgeon’s blood can be transferred to the patient through a puncture injury during operation up to one in five cases [1, 27]. It is further estimated that 6–50% of the surgeons are exposed to the patient’s blood or body fluid each year, that 2–10% of all operations may involve accidents and that over half of them are because of procedures not followed [1].

In 30 of 120 (25%) hip surgeries, 1–2 perforations of gloves were detected and 10 with perforations of both gloves (8.3%), and only 5 perforations were discovered during surgery [28]. Most perforations occurred on the left index finger and thumb. [28]

Blood glucose monitoring and hepatitis B outbreaks among patients and personnel at nursing homes in the United States are related to lack of infection control [2, 29–31]. The equipment for blood glucose testing, a blood glucose “pencil,” owned by one patient, was used for several other patients, and in addition the nursing home

had an unsafe blood glucose monitoring [29–31]. The attack rate was high among the elderly, 16–92% [31].

Hepatitis C is a problem in most countries. HCV is a challenge since there is no vaccine or specific immune serum against infection. In the United States, it is estimated that elderly people born in 1945–1967 constitute 81% of all diagnosed with hepatitis C virus (HCV) infection [1, 2]. Today, all seniors admitted in American health institutions are screened for HCV [1].

In Norway, the number of HCV-infected persons is not adequately recorded. In 2007 ten cases of HCV were discovered, related to an HCV-infected surgeon [32]. The surgeon was probably infected from patients with HCV.

In Britain and the United States, a significant part of healthcare workers are infected with HCV [1, 2, 33–35]. There are many nosocomial outbreaks [1, 2, 18–21]. A drug-using anaesthetist in Spain infected 217 patients with HCV using the same anaesthetic syringe that the patient then got the rest of [1, 2].

There have been outbreaks of nosocomial blood-borne infection, even with HIV [4, 18, 19, 21, 25]. In 2012, at least 270 HIV-infected children in Kyrgyzstan were reported [36]. More than 110,000 children were exposed to HIV infection hospitalized during the last 12 years. They were infected because of poor hygiene, infected blood transfusions and reuse of syringes and other medical equipment. [36]

People who should be examined concerning HCV infection

- People who have ever injected drugs with syringe.
- People who have snorted cocaine.
- HIV-positive persons.
- Recipients of blood products prior to 1992 in Western Europe, North America, Japan and Australia and recipients of blood products regardless of the time in other than the mentioned countries.
- Immigrants from high-endemic areas.
- Persons who may have been exposed to contaminated needles and syringes.
- Children born of anti-HCV-positive mothers.
- Patients with elevated ALAT.
- People who have been exposed to accidental needle-stick.
- Patients on dialysis.
- People with not professionally performed tattoos.
- Patients who have had sexual intercourse with HCV positive.

Source: Academic supervisor for follow-up and treatment of hepatitis C. March 2014. Norwegian Association for Infectious Diseases, Norwegian Gastroenterological Association, The Norwegian Medical Association [37].

11.6 Occupation-Associated Blood-Borne Infection and Disease

Blood-contaminated sticks/cutting injuries are the main cause of occupational blood-borne infection. All personnel must follow procedures for handling needles and other piercing or cutting objects and procedures for registration, notification

and monitoring of needle-stick injuries and other exposures to blood and other body fluids [9, 10].

The greatest risk of infection is with blood from a known carrier of blood-borne virus agents. Prion diseases are very infrequent (one per one million inhabitants) but can be a problem if there are injuries with sharp instruments (Creutzfeldt-Jakob disease) [38, 39]. After cuts/sticks or other mishaps where blood and tissue from other persons are transmitted, *fast local treatment* is important.

A fast and appropriate measure reduces the risk of infection to a minimum. Some employee, however, may still be infected and become chronic carriers. In 1990 it was calculated that approximately 0.5% of healthcare workers in the United States were infected with hepatitis B and ca. 1–2% with hepatitis C.

A carrier state may pose risks during invasive procedures. An HCV-positive surgeon may have a cumulative risk of 50% for transmitting HCV infection to the patient over a 10-year period of work. The risk of hepatitis B transmission was previously high, but a hepatitis B-vaccinated personnel poses little risk. Treatment of HCV infection may reduce the amount of virus in the blood to undetectable levels, with viral clearance in 14 of 15 cases, over longer periods [40]. Fast instituted treatment is probably effective, with viral clearance in many cases after 24–72 weeks [40].

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Hand Hygiene and Glove Use

12

Abstract

Good hand hygiene promotes successful patient treatment in hospitals by preventing infections. Hospital infections constitute suffering and death with significant additional expenses in healthcare and for the society. Performing proper hand hygiene is safe patient treatment and reduces infections up to 50%. Hand hygiene should be easy to understand and implement for personnel, patients and visitors as a part of the quality of care. Hand wrists should always be included when doing hand hygiene! Gloves are used to protect against transmission of infections from biological material such as blood, tissues and body fluids. Sterile gloves prevent infections in the patient during surgery and other direct contact with tissue, wounds and mucous membranes.

Keywords

Hand hygiene · Hand disinfection · Handwash · Sink · Infection control · Glove use

12.1 Purpose

- To prevent infection from contaminated hands to patients, between patients, between patients and personnel and to equipment, foods, beverages, textiles and surfaces [1–7].
- To protect yourself, patients, visitors, personnel and the environment against infection and colonization of pathogenic microbes.

12.2 Comprise

- All employees, in contact with patients, food, medicines, equipment, textiles and the environment.
- Always after toilet visits, before food breaks, after contact with organic materials, contaminants and trash, and before and after glove use.
- All patients, visitors and others on arrival, during their stay and when they leave the hospital.

12.3 Responsibility

The hospital's management shall ensure that all employees, patients and visitors receive the necessary training and follow-up regarding hand hygiene, in accordance with the hospital's infection control program [5, 7, 8]. This includes responsibility for all new employees and all occupational groups, including extra help and temporary staff. Priority for good hand hygiene measures is a management responsibility [3, 6, 9, 10].

The department's management provides practical training, information and control of hand hygiene for all employees, including temporary staff and extra help, and for the implementation and regular review of the subject. Time for performing hand hygiene and good access to hand hygiene and to hygiene products should be included in the daily activity. Leaders are role models for the implementation and maintenance of good hand hygiene [10, 11]. Handwash and hand hygiene products, dispensers and routines for refilling, cleaning and maintenance must be provided. Patients and visitors should be recommended and offered hand hygiene.

All employees have a personal responsibility to follow the hospital's guidelines regarding personal hand hygiene. Employees should help patients and visitors with access to and implementation of proper hand hygiene.

12.4 Practical Measures

12.4.1 Jewellery

Hands should not wear rings; other jewellery, piercings or bracelets should not be allowed [4–8].

Wristwatch: Employees working with patients, equipment, textiles and food should not use wristwatches that increase the load of bacteria on the hands and wrists and that prevent good hand hygiene.

12.4.2 Nails

The nails should be short and without nail polish. Long or artificial nails should not be used which may result in increased bacterial number on the hands and poor hand hygiene [4, 6].

Bacterial amount: With a large amount of bacteria on the hands, some bacteria can be left in spite of good hand hygiene [4, 6, 12, 13]. Therefore, it is very important to use gloves in certain situations.

12.4.3 Gloves

Always wear gloves before contact with biological material such as secretes, bandages, urine, faeces, etc. when caring for the patient. Wash or disinfect hands before and after glove use because gloves often have holes or can be easily perforated [4, 6, 14].

NB! In the sink there are always gram-negative rods. Therefore, avoid water spray and direct contact with the tap and the sink during the wash procedure and afterwards.

12.4.4 When Should the Hand Hygiene Be Performed?

(*When hands are clean, hand disinfection is preferred to avoid soreness and drying of the skin.*)

- Before contact with patients.
- Before handling sterile/disinfected/clean equipment.
- Before medicament handling.
- Before and after care of patients.
- Before and after cooking/serving food.
- Before handling clean textiles.
- Before and after patient examination.
- Before and after outpatient procedures.
- Before and after endoscopic examinations.
- Before and after gynaecological examinations.
- Before and after handling central and peripheral venous catheters/needles.
- Before and after managing urinary tract catheter.
- Before and after injections and punctures.
- Before and after touch and wound care.
- Between unclean and clean procedures.

12.4.5 Handwashing

When should handwashing be done?

- When hands are visibly dirty [4–7].
- Before and after food break.
- After toilet visits [4–7].
- After stay on an isolate with an infected patient [7].
- After contact with biological material like blood or body fluids.

- After contact with spore-forming bacteria such as *Clostridium difficile* [15–18].
- After contact with norovirus, where handwash may be most effective [19, 20].
- Before and after wearing gloves if contaminated with organic material.
- After handling contaminated instruments, equipment, food service, furniture, fixtures, textiles and waste, for example, by emptying, tidying and cleaning.
- After contact with patients with infections or colonized with resistant/hospital-associated microbes.
- Between a dirty procedure and a clean procedure when treating a patient, equipment, textiles and food.
- After contact with chemicals, cytostatic, etc.
- As an alternative to hand disinfection; see below [4–7].

How?

- Adjust the water jet so that contaminated water does not spray on your uniform or environment.
- Wash the hands and wrists with water, and wash with dispenser soap for at least 30 s—preferably 60 s. Automatic soap dispenser is preferred [4, 6].
- Wash your hands firmly, palms, fingers, thumbs and wrists. Use internationally recommended washing techniques.
- Rinse the soap well under running water.
- Dry your hands well with soft disposable paper from the holder (used as a blotting paper to avoid soreness).
- Close the tap with the disposable paper to avoid recontamination of the hands.
- Air dryers should not be used as they lead to dispersion to the air and the environment of water droplets and microbes (aerosol) [21].

12.4.6 Hand Disinfection

-It is used instead of handwashing when the hands are not visibly contaminated.

NB! When there are suspected infections with *Clostridium difficile* or norovirus, use handwash!

When should hand disinfection be performed?

Immediately before:

- Contact with patients.
- Handling of sterile and disinfected equipment.
- Medication management.
- Cooking/serving food.

Before and after:

- Contact and care of the patient.
- Handling of all types of catheters.
- Injections, punctures, blood sampling.
- Touch and caring for wounds.

- Contact with medical devices and objects in the patient's immediate vicinity.
- Wearing gloves.
- Between different levels of cleanliness.

How? [4, 7]

- Ideally use automatic dispenser.
- Alcoholic solutions, like ethanol 70% or isopropanol 70% (70–85% alcohol content). Glycerol 1–3% is added to prevent skin drying. A chlorhexidine-alcoholic combination may sometimes be used.
- The hands should be visibly clean and dry before applying the disinfectant.
- Use minimum 3 ml disinfectant to moisten all surfaces on the hands and wrists.
- “Wash” your hands firmly, palms, fingers, thumbs and wrists. Use internationally recommended washing techniques.
- Let it absorb to dryness, at least 30 s [4, 6].

12.4.7 Use of Non-sterile, Disposable Gloves

Glove use should be linked to specific tasks defined by the department. Non-sterile gloves may be colonized with microbes and the glove box can be made contaminated. There have been outbreaks of rotavirus and *Pseudomonas* infections linked to contaminated glove boxes. Even malaria has been transmitted via contaminated gloves [22].

NB! Put the date on when opening on the glove box and use a new box for each patient.

- Non-sterile gloves are never used in contact with wounds, mucous membranes or on sterile equipment (CVK, venous port, intravenous needles, sterile bandages, etc.).
- Non-sterile gloves are used in some work situations as an additional safety measure.
- To handle biological materials, it is important to use gloves with a high quality such as latex or nitrile.
- Prolonged use of gloves leads to increased growth of the skin flora under the gloves.
- Latex gloves are denser than vinyl gloves but can cause allergic reactions [23].
- In case of latex allergy, special synthetic gloves (allergy tested) must be used, e.g. nitrile.
- Use gloves with low levels of latex allergens and rubber additives.
- Use gloves with a long cuff.
- Gloves do not fully protect as they may have or have microscopic holes.
- Therefore, the hands are disinfected before and after use of disposable gloves.

The purpose of glove use is to:

- Reduce the transmission of infectious agents by hands.

- Reduce the risk of cross-contamination of the environment and between persons.
- Protect hands against contamination.

Always wear gloves when:

- Possible or known direct contact with wounds and mucous membranes; then use sterile gloves.
- Contact with biological material such as blood, tissues and secretions.
- Wounds or scratches are on your own hands (cover first with waterproof plaster).

Evaluate glove use if:

- Eczema on your own hands (allergy-tested gloves).

How to wear gloves?

- Change gloves between unclean and clean areas of the same patient.
- Change gloves between each patient.
- Always throw gloves after use once.
- Perform hand hygiene before and immediately after wearing gloves.
- Do not wear gloves on the corridor or touch clean equipment, telephone, switches, etc. with gloves that have been in contact with biological material (contaminated).

12.4.8 Use of Sterile Gloves

The use of sterile gloves should be linked to specific tasks defined by the department. Sterile gloves are used during direct or indirect contact with sterile tissues, mucous membranes or sterile equipment that perforates skin or mucous membranes or during contact with mucous membranes. This applies to operative intervention, placement and handling of catheters in the bloodstream or urinary tract, drainages, respiratory and intubation equipment and various types of examinations of mucous membranes and skin.

Sterile gloves:

- Are used in some work situations as an additional safety measure, in addition to hand hygiene, to protect the patient from infection or vice versa.
- Gloves do not fully protect as they may have microscopic holes or perforations [14].
- Prolonged use of tight gloves may lead to increase of the skin flora.
- Latex gloves are denser than vinyl gloves but can cause allergic reactions [23].
- In case of latex allergy, special synthetic gloves (allergy test) must be used.
- The hands are disinfected before and after use of disposable gloves.

12.4.9 How to Remove Gloves?

Gloves are often used when handling infectious material. Therefore, it is important to learn how to remove gloves after use in such a way that you are not infected by the gloves. This method is used for all situations when using gloves, even during work with isolated patients. A careful handling of the gloves may protect against release of particles and microbes during removal.

- Keep your hands down and out from the body while removing the gloves.
- With the gloves on, grasp with your right hand the left hand glove on the outside, below the wrist. Pull the left glove off with the right hand by wringing it gently. The inside of this glove is quite clean.
- Grasp with your left hand (which is free of the glove) the inside (wringed) of the left glove, and use it as a “cloth” on your right gloved hand. Grasp the right glove through the “cloth”.
- Pull the right glove off by wringing it gently.
- Carefully place both gloves in the waste bag and carry out the hand hygiene afterwards.

12.4.10 Skin Care

- Frequent washing of hands can lead to a dry and sore skin.
- Skin care products give the skin softness and elasticity.
- Use skin care products regularly, at work and at home.
- Write date when opening skin care products. Since bacteria may easily grow in such products, it is important with clean hands before contact with the drug.
- Skin care products should only be used by one person.
- Soap, paper towels and skin care products should be free from perfume and allergenic agents [4–7].

12.4.11 Patients and Visitors

Patients and visitors should be informed about the importance of good hand hygiene [6]. Dispensers for hand hygiene should be easily accessed for patients and visitors. The patients should be offered opportunities for good hand hygiene before and after meals and drinks, after toilet visits, before and after examinations and transportation to other departments and after returning to their own room. Single use wipes should be provided for this use for patients who are bedridden. Posters with hand hygiene methods should be placed nearby dispenser and sink.

Patients infected with *C. difficile* or norovirus—and their visitors—must be informed about the use of handwashing instead of hand disinfectants. Handwashing

with soap and water removes more effectively such contaminants. Still, there may remain infectious agents (10%) on your hands. Dispensers for hand hygiene should be placed with information to patients and visitors about good hand hygiene [15].

12.4.12 Control and Training of Hand Hygiene

Hand hygiene checks should be done at least once a month as an internal control at the department. All new employees should undergo hand hygiene training. This also applies to temporary staff, extra helps and short-term visitors, including personnel from other clinical, technical and service departments. Everyone should undergo a 15–30 min repetition of hand hygiene once a year.

The department shall have procedures for internal control of hand hygiene products and for regular filling, maintenance and cleaning of dispensers, paper towels and soap containers.

12.4.13 Paper Holder Dispenser: Hand Drying

To dry hands with common towels never happens in the healthcare industry, today. Paper holders should be designed so that the person who draws a paper does not contaminate the clean paper left in the container. Unfortunately, many paper holders are easy to contaminate or are not cleaned regularly (preferably weekly). This has been demonstrated by several studies and poses a risk of cross contamination [24]. The equipment must be well tested to ensure against spread of infection [25]. Hot air dryers have been popular, also in hospitals [26, 27], but pose a risk of spreading microbes and water droplets to the immediate environment and personnel, and should therefore not be used in healthcare, and preferably not elsewhere [21, 28, 29].

12.4.14 Hand Disinfectant

There are a variety of different hand disinfectants; most contain alcohols with 70% (or higher), and glycerol is added to lubricate the skin [4, 6]. The patient should be given disinfectant wipes with alcohol (wet wipes) for the disinfection of the hands. Liquid disinfectant should not be placed on the patient's bedside table as this may be misunderstood as medicine. Ingestion of such agents has led to diarrhea and pulmonary complications. Dispensers for hand disinfectant—preferably automatic—should be placed on the wall in corridors, at the front door of hospitals and departments, and in the elevator for visitors, as well as in the patient room and other places where the washbasin is also located. Cleaning and maintenance are carried out as internal control.

12.4.15 The Sink

Washbasins should be sturdy and easy to keep clean: over, under and around. Daily cleaning of the sink is carried out in all patient-associated rooms, including rooms for medicines and personnel. The wall around the sink should be easy to wash. The sink must withstand disinfectants and is usually a smooth porcelain wash or similar material. It should have a lever arm—which is easy to handle and does not corrode or get destroyed. In the washbasin there should be plenty of space for two hands and to tap water into a washing dish. The water flow should be easily regulated. There should be a short distance from the tap to the sink to protect against spraying water on uniforms and the environment. Spread of infection has been documented for small washstands with a strong water flow making aerosols [30].

Washbasins should be placed in all patient rooms, examination and treatment rooms, laboratories, meeting rooms, corridors, medicine rooms, kitchens and dining rooms and always in the toilet and shower areas. The sink is placed on the wall not far from the exit door and at least 2 m away from the nearest patient to avoid accidental spray and aerosols [2].

12.5 Background Information

Hand hygiene is handwash with soap and water or hand disinfection with alcohol-based (70–85%) disinfectant with or without chlorhexidine and added glycerol [1–7]. Good hand hygiene promotes successful treatment in hospitals by reducing infections 30–50%. Hospital infections constitute suffering and death with significant additional expenses in healthcare and for the society [1–6, 9, 31–33]. Having time for proper hand hygiene is important, and it should be understandable and implemented to personnel, patients and visitors as a quality process [3, 34–36]. A too quick wash may still have residual bacteria on the hands that can be transmitted to other patients and personnel and to the environment. Contamination of the environment may cause transmission of 30–40% of these environmental bacteria to the hands [37]. Furthermore, from contaminated fingers, the transfer rate to the lips and mouth may be 30–40% [37]. The total number of bacteria on the hands of a healthcare personnel is reported to be from ca. 10^4 – 10^6 colony forming units (CFU)/cm² and may show a large individual variation [1–4].

Normal, resident (permanent) flora on hands is mostly composed of different types of coagulase-negative staphylococci and corynebacteria (diphtheroids), which rarely cause infection. Bacteria found deeper in the skin are mostly anaerobic bacteria and are relatively resistant to removal by hand hygiene.

Superficial or transient flora on the hands come from contact with contaminated environment and infected material, persons and patients, etc. and may be easily removed by a proper hand hygiene [1–4]. The transient flora include many types of bacteria, such as *S aureus*, Gram-negative bacilli, *Clostridium difficile* (CD), enterococci or yeast. Bacteria, viruses and fungi that survive in a dry condition in the

environment for weeks to months are periodically transmitted to hands via contact [38]. The bacteria and yeast may stay on the hands for more than 2 days and are often further transmitted to clothes and equipment and can multiply in new places [39, 40]. Ca. 30% of dehydrated, but still infectious, hepatitis A virus on hands can spread to equipment and to hands of other persons for at least 4 hours, and pressure and friction may increase the transmission rate [41]. About the same is observed for rotavirus [42].

Handwashing removes loose-sitting, pathogenic microbes on the hands, for example, after a toilet visit, after patient care, handling waste, washing floors, etc. But some microbes will always be left, regardless of the washing procedure [4, 12, 13]. The skin will not be “sterile.” Permanent skin flora is not much affected by the wash but is reduced by alcohol. Alcohols have short-term effects and less effect on fungi and viruses than on bacteria. Mechanical removal of soil, dirt and biological materials from hands with soap and water or wet wipes is recommended.

Alcohol-based hand rub (60–95% ethanol or isopropanol) with added glycerol is more skin-friendly than handwash with soap and water that removes fat from the skin for a shorter period of time. When the hands are clean and not soiled, the use of hand disinfectants is recommended. New microbes are nearly immediately colonizing. The most important reason to perform hand hygiene is that unfortunate and pathogenic microbes are kept in check and not transferred to patients, equipment, other personnel or environment. Between fingers and in the palms, the washing effect may fail, also around nails, under the ring, bracelet, etc. [6, 43, 44]. A smooth skin surface is easy to keep clean. Therefore, use hand creams and soaps that do not damage the skin. “Wash-eczema” may lead to carrier state of more resistant microbes [4, 6].

12.5.1 Compliance and Use of Jewellery

Good hand hygiene reduces hospital infections. However, the implementation (compliance) of this important procedure in the hospital activity is often dependent on the workload, time for hand hygiene, role models and leadership [4, 6].

Rings on hands may bring two -to -five million Gram-negative bacilli and other bacteria under and around the ring, and the whole hand becomes more contaminated. Even gold rings may increase the amount of bacteria on the hands [43, 44]. Hand hygiene is improved by information and control, easy access to the washbasin, easy to use (but avoid photo-controlled equipment at low water speed [45]), good equipment for handwash (soap, paper towels and skin care products) and information from infection control personnel [1–7].

12.5.2 The Problem of Contaminated Hands

Contaminated hands are still the most common cause of spread of infection. There is a clear connection between the hand hygiene rate of the staff and the occurrence of hospital infections [38]. Contact with infected material contaminates the hands

within seconds, often with large amounts of bacteria [37, 38]. In case of heavy contamination, bacteria may be left, in spite of good hand hygiene [4, 6, 12, 13]. In cases of soil, dirt and biological materials on the hands (direct contact with pus bandages and the like without gloves) always wash hands with soap and water. Significant amounts of bacteria can be left, especially on fingertips [12, 13]. A very heavy contamination on hands can be removed by handwashing, followed by a bath of chlorhexidine-alcohol combination for 30 s, not recommended as routine [12, 13]. Gloves are used for all handling of organic materials and infectious agents.

For *C. difficile* (CD) and norovirus, hand disinfection has an uncertain effect [6, 15–20]. Handwash with soap and water has only partial effect; 10% of CD spores on the hands can be left after a thorough handwash [15]. This study found that 14 out of 44 CD patients had spores on their hands before hand hygiene. Hand disinfection with alcohol had no effect, while the handwash removed approx. 90% of the spores [15]. In case of a major contamination of CD, probably chlorine may be used as well.

12.5.3 The Problem of Carry-out Proper Hand Hygiene

Jewellery and watches are removed. Hands should be without rings or other jewellery, bracelets and watches for the care and treatment of patients. The use of wrist-watch increases the amount of microbes on the hands [46].

Nails should be short and clean, without nail polish, and artificial nails should not be used. Outbreaks of *Pseudomonas* among newborns have been associated with long and artificial nails [6, 47]. Over a 15-month period, 46 (10.5%) of 439 children in a newborn intensive care unit were infected with *P. aeruginosa*. A total of 16 (35%) died of the infection. The same bacterial types were detected on the hands of 3 out of 104 personnel and were associated with long nails or artificial nails [47].

International hand hygiene technology. Studies show that in the case of a regular, quickly done handwash, the palm with the little finger becomes relatively clean. The rest of the hand, including the back of the hand and of the fingers, the sides and insides of the fingertips of the third and fourth fingers and the thumb, is less well cleaned [4, 6]. Training using a hand hygiene machine is important to see how own hand hygiene works in practice, as well as to use international described hand hygiene methods. Hand hygiene is often studied using systems such as the “World Health Organization’s five moments for hand hygiene” [6, 28].

Wrist hygiene: In addition to the international hand hygiene techniques, *wrists of the hands* should always be included the when performing hand hygiene [7].

12.5.4 Patients and Visitors

Patients may carry large amounts of microbes on the hands, like CD, MRSA, VRE and other resistant bacteria, as well as influenza viruses, norovirus and rotavirus [15, 48, 49]. Hand hygiene should be offered to all patients and visitors to prevent transmission of infections in the hospital.

12.5.5 Hand Hygiene Related to Profession and Management

Implementation of hand hygiene is observed more often among nurses than among doctors and other personnel [4, 6, 49, 50]. At a university hospital, “compliance” of hand hygiene was 84% among nurses, 78% among doctors and 69% among other personnel [51]. In intensive care units, there may often be a low compliance, 60% [52]. Departments with leading nurses with experience, expertise and responsibility often have the highest compliance [52]. However, this may vary between hospitals and departments.

In a department of infectious disease, hand hygiene was observed for nurses and doctors before patient contact and also before, during and after a hand hygiene campaign [10]. Before the campaign, only 45% of nurses and 25% of doctors performed the hand hygiene. After start, hand hygiene increased to 70% for nurses and 55% for doctors. One year after the campaign, compliance had increased to 85% for nurses and 80% for doctors, but after 4 years there was a significant reduction to 60% among nurses, while it remained at about 80% among the doctors [10]. Loss of a strong leadership (the doctor who was in charge of the department and led the hand hygiene project left the department), led to a reduction in compliance, especially for nurses [10].

Observed risk factors for poor hand hygiene: [1, 4, 6]

- Doctors, assistants, physiotherapists and technicians have poorer hand hygiene than nurses.
- Risk is greater for men than women.
- Risk is associated with work in intensive, surgical, acute and anaesthetic units [4, 6, 53]
- Lack of hand hygiene is associated with hectic work at a high risk of cross-contamination.
- There is greater risk during the week than weekends and evening shifts [4, 6, 51]
- Understaffing and overcrowding are risk factors for lack of hand hygiene and spread of infections [4, 6]
- Time to do hand hygiene may disappear when the “effectiveness” is increased at the department.
- Many activities that need many necessary hand hygiene measures per hour may be risky.
- Corridor patients are at risk due to lack of access to hand hygiene.
- Lack of access to hand hygiene.

- Lack of cleaning routines for computers and technical equipment used by many people [54].
- Lack of general cleaning and disinfection [55].
- Dirty and heavily contaminated uniforms, including white coats of doctors, are associated with increased amount of bacteria on hands and poorer hand hygiene [56, 57].
- Lack of role models in the department—managers and administration—and no hospital priority [6, 10].

Some documented successful strategies to improve hand hygiene: [3, 4, 6, 9, 33–35]

- Sinks—better adapted to hand hygiene and easily accessible.
- Feedback to staff, posters, reminders and information.
- Training, demonstration and information about results of environmental tests [58].
- Administrative support and priority [59].
- Hand disinfection with alcohols introduced [3, 6, 9, 36, 60, 61].
- Wall dispensers—automatic—with hand disinfection.
- Wall dispensers placed in the right place for patients, personnel and visitors [62].
- Own pocket dispensers in intensive departments.
- Internal control (announced).
- Information and training from infection control personnel.
- Involvement of patients for improved hand hygiene among personnel—especially physicians (patient empowerment) [63, 64].
- Financial support for improved hand hygiene [59].

The hands of the staff are central in terms of transmission of resistant bacteria [65]. Problems on bacteria such as MRSA have increased exponentially. The infection occurs via direct hand contact or indirect contact with the environment contaminated with airborne infection by MRSA [65–67]. In this situation, healthcare personnel are often described as “source, vector or victim of MRSA” [68]. The use of hand hygiene is therefore a good infection prevention measure for all personnel. The effect of hand washing is also dependent on different methods of hand drying, environmental cleanliness and on the washing process [63–68].

Table 12.1 Antimicrobial effect of hand disinfectants (from CDC Guideline 2002 [4] and others, see references)

Disinfectant	Gram-positive	Gram-negative	Mycobacterium	Fungi	Virus	Quick acting	Persistent	Comment
Alcohols	3+	3+	3+	2+	2+	Yes	No	60–95% optimal concentration
Chlorhexidine (2–4%) gluconate	3+	2+	1+	1+	3+	Intermediary	Yes	Rare allergy
Iodine products	3+	3+	3+	2+	3+	Intermediary		Irritant, not recommended
Iodophores	3+	3+	1+	2+	2+	Intermediary		Skin irritating in part
Phenol derivatives	3+	1+	1+	1+	1+	Intermediary		Can be inactivated by soap
Triclosan	3+	2+	1+	0+	3+	Intermediary		Not completely skin friendly
Quatern ammonium products	1+	2+	0+	0+	1+	Slowly		Development of resistance

Explanation: 3+ = good effect, but a number of exceptions exist; 2+ = good but do not take everything; 1+ = have a certain effect, 0+ = no safe effect

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Protection of Upper Respiratory Tract, Mouth and Eyes

13

Abstract

Pathogenic bacteria and viruses may invade via upper and lower respiratory tract and via eye mucosa. When an infected person coughs or sneezes heavily, small, invisible droplets with the infective agent may reach a good distance from the source. By using the right form of protection at the right time, infection and disease are prevented. The present chapter is focused on the protection against airborne infections.

Keywords

Airborne infections · Aerosol · Droplets · Respiratory protection equipment · N95 respirators · P3 masks · Surgical masks · Face mask · Goggles · Cap

13.1 Purpose

- To protect patients, staff, visitors and the environment against contaminated air and droplets, according to the occupational health and safety legislation [1–5].
- To prevent direct transmission from contaminated hands to nose, mouth and eyes, and use of the uniform as a handkerchief when coughing and sneezing [6, 7].

13.2 Comprise

- Contact with infectious patients, according to the isolation procedures.
- When performing sterile procedures.
- When in close contact with patients who are in an infection-prone situation, for example, during operations and patients with compromised immune system.

- Contact with wounds and tissues and/or in direct contact with sterile equipment used invasively or when present during ongoing invasive procedures.
- Self-protection against splashes/aerosol of biological material (trachea suction, vomiting, cough, diarrhoea, secretions, diathermy, etc.).
- Patient with suspected contagious respiratory infection—during transport, examination, treatment, etc.; use a face mask—also on the patient—to protect others and the environment from contamination.
- When *cleaning and disinfecting* contaminated rooms like isolates and when handling used patient equipment/machinery with organic material (ventilator, CPAP, etc.) and used patient textiles, infectious waste and bio-organic waste.
- During work with *plumbing and construction* with increased risk of soil, splatter, aerosols or dust particle clouds, such as working with instrument channels in the patient rooms and surgical departments, ventilation systems, sinks, sewer, water leakages with fungal growth, etc.
- Caps should always be used when putting on masks to protect hair.

13.3 Responsibility

Hospital management should ensure an infection control programme that informs all employees about the standards of hygiene and infection control at the hospital. Furthermore, to provide resources to the acquisition, stock reserves and logistics of adequate personal protective equipment (PPE), also for emergency situations [5, 8].

Department management is responsible for training, use and control of face masks, respirators and eye protection and that the equipment and written guidelines are available [5].

Each user is responsible for the proper use of PPE at the right time and in accordance with current guidelines.

13.4 Practical Measures

The following are available in all relevant departments/posts:

- Guidelines—written—for the use of a face mask/respirator/eye protection.
- Surgical masks: put a date on the box when it opens. Only *surgical* masks of good quality are used. Other face masks—thin and of poor quality—fastened behind ears should never be used in the healthcare system because of no protective effect.
- Respiratory protection—P3 mask—with and without valve, separately packed. Put the date on the box.
- Surgical face masks with visor.
- Face shield.

- Goggles. Single-use or multi-use goggles that can be disinfected and autoclaved between uses.
- Cap/hood/head or neck protection (phantom hood, operation caps)—always when using masks.
- Access to good hand hygiene—hand disinfectant—at the place where the PPE is used.

13.4.1 Protect Head, Hair and Neck

When airways, mouth and eyes are protected, the hair and head should also be covered simultaneously. Many people have long hair that can come in contact with the patient, bedding or equipment which can lead to transmission of infection to other patients, in addition to themselves becoming a carrier.

NB! Always use cap/hood/head protection when using surgical mask or other PPE.

13.4.2 Face Shield and Goggles

These may be single-use or multi-use. Single-use devices are thrown away immediately after use. Surgical mask with visor may protect against direct spills and splashes. A complete face shield protects against direct splashing.

The multi-use equipment (check with infection control personnel) is soaked in chloramine 5% 1 h (or household chlorine) before laundered in soapy water or washed in the instrument washing machine by more than 85 °C or autoclaved. It is stated on the package if the goggles may be autoclaved.

13.4.3 Surgical Mask

Quality-controlled surgical face mask is disposable and used for:

- Surgery and sterile procedures.
- Protection for infection—susceptible individuals/situations.
- Protection against influenza (seasonal influenza), RSV, parainfluenza virus, *Mycoplasma*, enterovirus, metapneumovirus, adenovirus, coronavirus, human bocavirus and other acute respiratory infections transmitted through respiratory tract [1].
- Patient with respiratory infection—coughing, sneezing—put a surgical mask on the patient during transportation, examination, etc.
- Patient with uncontrolled wound secretion—wound infection.
- MRSA and VRE, including suspected carrier state [1].

- Multiresistant gram-negative bacteria—including suspected cases [1].
- Norovirus—vomiting and diarrhoea—or suspected norovirus or the like [1].
- *Clostridium difficile*—especially when much diarrhoea [1].
- EHEC—entero-haemorrhagic *E. coli*—and occasionally with other enteropathogenic bacteria (*Salmonella*, *Shigella*, *Campylobacter*, *Yersinia*, etc.) when uncontrolled diarrhoea and vomiting, especially in children [1].

13.4.3.1 Putting On and Taking Off

Putting On

- Disinfect your hands.
- Put on the cap—thin operating hood—that collects all hair. Pull it over your ears.
- Disinfect your hands.
- Take the mask from the surgical mask box, and take only one mask. The box must have the date of opening. All boxes that have been exposed to infection should be discarded afterwards.
- Put the face mask over your mouth and nose with a drawstring at the back of the head/top and the other on the neck.
- Adapt the face mask that has metal string over the nose—so that it fits tightly and comfortably around the mouth and nose.
- Replace the face mask between each patient/situation/procedure or after 2–6 h if you are with the same patient or when it is wet on the inside. Avoid changing the mask if this can cause more contamination and risk, for instance, during surgery. Surgical masks are usually not changed during surgery.
- Never go with a face mask under the chin or around your neck! It is usually heavily contaminated by mouth and nose secretion after use and by splatter from the patient.

Taking Off

- Perform hand hygiene.
- First take hold of the string in the neck and loose this while you bend forward. The lower part of the mask then falls away from the face. Then gently loosen the string on the head, and gently put the mask into the waste container.
- Face masks should not come in contact with hair or clothes.
- Dispose in regular waste during normal use or infectious waste if infection.
- Perform hand hygiene afterwards.
- Grip the cap back and carefully pull it off while bending forward, and put it into the waste container.
- Perform hand hygiene afterwards.

13.4.4 Respiratory Protection (P3 Mask, N95 Mask)

Filtering half masks and guidelines for use of respiratory protection should be available at relevant clinical departments.

13.4.4.1 Single-use device!

P3 mask (some with exhalation valve) is used as protection for

- Suspected tuberculosis and always during operations/intervention on suspected tuberculous tissue.
- Induced sputum if suspected having pulmonary tuberculosis.
- Penicillin-resistant *Pneumococci*—symptoms from the respiratory tract.
- Varicella zoster (chickenpox) and morbilli (measles) if not immunized. Pandemic influenza, avian influenza, SARS, MERS-CoV (Middle East respiratory syndrome coronavirus), polio and certain other enteroviruses associated with paralysis, etc.
- Ornithosis (“psittacosis”)
- Haemorrhagic fever or such suspected disease (Ebola, Lassa, Crimean-Congo haemorrhagic fever, etc.)
- Other high-risk diseases: suspected brucellosis, anthrax, tularemia, diphtheria, melioidosis, plague, Q fever and rickettsioses.
- Laser treatment for suspected human papillomavirus and cancer treatment.
- Surgical procedures in patients with severe infectious diseases where there is risk of aerosol formation or release of tissue particles to the air (prion diseases, blood-borne infectious virus, tuberculosis, etc.) [1].

P3 mask is used by the surgical team and during all sterile procedures: in the case of operative treatment of patients with special types of airborne infection such as tuberculosis, etc., see above. If there is an open breathing valve on the P3 mask, surgical mask must be used outside the P3 mask. P3 mask with covered breathing valve can be used instead.

P2 mask or surgical mask is put on the patient with defined or suspected airborne infection (e.g. tuberculosis, varicella, etc.) during transport, and stay outside isolation units.

13.4.4.2 Putting On and Taking Off

Putting On

- Disinfect your hands.
- Put on the cap—thin operating hood—that collects all hair. Pull it over your ears.
- Disinfect your hands.
- Take the P3 mask from the surgical mask box, and take only one mask. Each mask is usually separately wrapped. The box must have the date of opening. All boxes that have been exposed for infection should be discarded afterwards.
- Put the respirator over your mouth and nose with a drawstring at the back of the head/top and the other on the neck. The cap hood underneath makes it easier to put the mask on—it does not slip.
- Adapt the face mask that has metal string over the nose—so that it fits tightly and comfortably around the mouth and nose.
- Test tightness by blowing vigorously or breathing in; leaks are then sensed on the sides of the mask.
- Change the P3 mask after 3–6 h or longer or if it is wet on the inside.
- Avoid change if this may lead to risk of infection.

Taking off

Take it off very carefully, as the P3 mask may be used in a serious contagious situation and may be contaminated on the outside.

- Disinfect your hands.
- Grasp the band/string *posteriorly*, bend forwards and remove the mask gently without coming into contact with the clothing, skin or hair. Do not touch the mask directly.
- Loosen the band in the neck first so that the mask falls forwardly away from the face. Then carefully loosen the band on the head.
- Put the mask gently into infectious waste bin.
- Perform hand hygiene.
- Grip the cap back, bend forwards and carefully pull it off without coming into contact with the skin or clothes and place the mask in infectious waste bin.
- Perform hand hygiene afterwards.

13.4.5 Goggles/Visor

Eye protection is always used when there is a risk of splashing of human biological material to the eyes and for protection against highly infectious diseases. In the event of a risk of severe airborne disease, wear tight protective goggles where you can use regular glasses on the inside. Multi-use goggles may be reused after 1 h of treatment in 5% chloramine bath (or household chlorine 10,000 ppm) with subsequent soapy water and rinsing.

13.4.5.1 Wearing and Removing Goggles

Putting On

- Perform hand hygiene.
- Put on the cap—thin operating hood—that collects all hair. Pull it over your ears.
- In case of severe, dangerous infection, put goggles on outside of a phantom cap that is sitting outside a surgery cap and a P3 mask; see strict isolation.
- Disinfect your hands.
- Goggles are retrieved from the box, usually separately wrapped. The box must have the date of opening. All boxes that have been exposed for infection should be discarded afterwards.
- Put the glasses or shield over the eyes with a rubber band on the occiput. The operation hood under prevents it from slipping.
- Adapt the goggles—so that it fits tightly and comfortably all around the eyes.
- They can be used as long as they are needed.

Taking Off

Take it off very carefully, as the goggles/face shields may be contaminated on the outside.

- Disinfect your hands.
- Grasp the band/string *posteriorly*, bend forwards and remove the goggles/face shield gently without coming into contact with the clothing, skin or hair. Do not touch the devices directly.
- If multi-use: put it carefully into the container with 5% chloramine. If single-use: put it into the infectious waste bin.
- Perform hand hygiene.
- Grip the cap back, bend forwards and carefully pull it off without coming into contact with the skin or clothes, and place it in infectious waste bin.
- Perform hand hygiene afterwards.

Purchase, Provide and Stock

“The employer must ensure that protective equipment made available to the worker, meets requirements of regulations on construction, design and manufacture of personal protective equipment” [5]. This should be in accordance with official regulations for the use of personal protective equipment [5, 9].

13.5 Background Information

Already in Roman times, it was pointed out by doctor Galen that “when many get sick and die at once, we must look for a common cause, the air we breathe”. During the past 10–15 years, emerging and re-emerging microbes and serious global outbreaks have been major challenges to infection control work and to the use of personal protective equipment (PPE). Multidrug-resistant tuberculosis and other multidrug-resistant bacterial organisms—MDROs—are increasing worldwide. Very serious virus epidemics are emerging, such as SARS in 2003, avian flu in 2005, the pandemic influenza in 2009, MERS-CoV outbreak from 2010 and the Ebola outbreak in West Africa in 2014, re-emerging in 2017 [1, 10–22]. Most cases of these serious, life-threatening diseases may be transmitted via air, droplets and re-aerosols, from patients, carriers and the environment.

An adult breathes in at rest 5–8 litres of air per minute, at medium heavy work 30–40 L and at great exertion 70–100 litres of air per minute. In small rooms and with a high air contamination of infectious agents, some contaminants will be drawn into the respiratory tract. It has been demonstrated that when a person coughs or sneezes, drops, droplets and droplet nuclei from the mouth and nose may reach up to 9 m from the source [2].

Surgical masks and respiratory protection (filter masks) are defined as “equipment that can help prevent the spread of microbes from one person to another” [2, 3]. The difference between surgical mask and respiratory protection is that surgical masks primarily protect the patient and sterile area/equipment against mouth and nose secretion from healthcare professionals, while respiratory protection protects healthcare workers and others from airborne infections from nearby sources of infection [3–5, 14, 23].

Fig. 13.1 Spread of large and small drops when sneezing: “Norway has got a new epidemic with elbow-coughing and -sneezing people. This is a bad hygienic behaviour under normal conditions and a society- critical handling during epidemics” (Source: Illustration photo Gorm Kallestad/Scanpix, Andersen BM. Dagbladet 12.11.2009. Article)



However, surgical masks are not approved as protection against airborne infections: [5, 14, 24, 25] “Harmful microorganisms (bacteria, viruses, fungi) or components of microorganisms (e.g. endotoxins) may occur in air, either in dust, smoke or aerosols, or even finer distributed as droplet nuclei where all liquid has dried in. Surgical masks only protects against splash and drop, not against airborne infection. Therefore, to protect against airborne infection, wear respiratory protection. In most situations, a filtering half mask will provide a good protection. Particle filter class P2 protects against most spores of fungi. At risk of exposure to airborne viruses and bacteria, especially tuberculosis, particle filter P3 must be used. In particularly dangerous situations, during prolonged work or if carrying a beard, should special breathing systems be used” [5] (Fig. 13.1).

13.5.1 Protection Against Airborne Infection

Many human pathogenic bacteria and viruses invade via upper and lower respiratory tract [1]. Some viruses may also invade via eye mucosa, such as influenza, hepatitis B and C and HIV.

Carl Schiøtz, a Norwegian professor in hygiene and infection control, wrote in the textbook of hygiene in 1937 (80 years ago) that the most important measures against communicable diseases are the following: (1) isolation of the sources of infection (home or hospital), (2) disinfection of the exposed rooms and equipment, (3) vaccination if vaccine-preventable disease, (4) quarantine, (5) food hygiene and (6) insect eradication [26]. He noticed that airborne infection was considered to be “the most important form of transmission of infections at our latitude” [26].

Schiøtz meant that drops from the respiratory tracts were large and heavy and went 1.5–2 m away, while saliva droplets went in “up to 20 m distance from

high-speaking people and they could stay floating in the air for several hours” [26]. This was important for the spread of “flu, colds, pneumonia, pest-pneumonia, tuberculosis, pertussis, measles, small-pox, chickenpox, scarlet fever, rubella, diphtheria, poliomyelitis, epidemic cerebrospinal meningitis and several other diseases” [26]. He also focused on inhalation of dust containing microbes [26].

The introduction of antibiotics in post-war times and the sharp reduction of lung tuberculosis caused many to forget that it was something that was infected via air. Tuberculosis has been “recognized” as an airborne infection at least in 100 years, although some still believe that short-term exposure to the patient does not lead to infection. This perception has led to multiple outbreaks of multiresistant tuberculosis, including in the United States [27].

13.5.2 The Definition of Airborne Infection Is Still Controversial

Airborne transmission is most often downgraded by the health authorities to *contact and droplet transmission*—traditionally within 1 m from the patient. This applies to healthcare professionals who are going to treat patients with severe, deadly infections where surgical masks are estimated “good enough” [10–16, 23–25, 28–31].

Droplet transmission is a definition that may put healthcare personnel at risk during dangerous situations since it is still a “form of contact transmission” [17]. The CDC definition from 2007 is upgraded since 2004 but is still very vague and controversial; see the following quotations [17]:

Droplet transmission is generated when “*an infected person coughs, sneezes, or talks - or during procedures such as suctioning, endotracheal intubation, cough induction by chest physiotherapy and cardiopulmonary resuscitation.* ---*The maximum distance for droplet transmission is currently unresolved,*---*Historically, the area of defined risk has been a distance of ≤3 feet around the patient*----*investigations during the global SARS outbreaks of 2003 suggest that droplets -- could reach persons located 6 feet or more from their source.* --- *Thus, a distance of ≤3 feet around the patient is best viewed as an example of what is meant by ‘a short distance from a patient’ ---- it may be prudent to don a mask when within 6 to 10 feet of the patient or upon entry into the patient’s room, especially when exposure to emerging or highly virulent pathogens is likely--”* [17].

“Droplet size is another variable under discussion --- defined as being $>5 \mu\text{m}$ in size. *Droplet nuclei, particles arising from desiccation of suspended droplets, have been associated with airborne transmission and defined as $\leq 5 \mu\text{m}$ in size-* ---*particle dynamics have demonstrated that a range of droplet sizes, including those with diameters of $30\mu\text{m}$ or greater, can remain suspended in the air*” [17].

The worst example until now is the recommendation of “contact and droplet transmission within 1 m” with the use of surgical masks (within 1 m from the patient), by WHO, the first phase (3 months) of the SARS epidemic in 2003, where 90% of those who became ill during this first phase were health professionals [28]. The same was done during the avian influenza epidemic in 2005 and mostly throughout the influenza pandemic in 2009 [29]. WHO and CDC recommended both

“contact and droplet transmission” measures during the first 6 months of the Ebola epidemic in 2014 [1, 30]. During some of the most serious global epidemics that have happened in the last 80 years, healthcare personnel were exposed to infection without proper protective equipment and had the highest death rate associated with work-related infection [10–17, 30, 31].

During the SARS outbreak in Toronto, Canada, 169 health personnel were infected with nosocomial SARS, and 3 of these died [14, 31]. Infection control personnel in Toronto insisted that SARS was primarily transmitted through large droplets—within 1 m—and that there was lack of evidence-based documentation for airborne infection! [31] Despite the fact that health professionals requested it, the respiratory protection (N95) was not handed over to the staff, and the outbreak continued for a long time [31]. A State Investigation Commission came to the following bottom line conclusion: *Safety comes first and reasonable measures to reduce the risk of healthcare professionals do not have to wait for scientific evidence* [31].

In the event of outbreaks of less severe airborne infections such as common flu, RSV, *Mycoplasma*, adenovirus, metapneumovirus, etc., it is important to protect healthcare professionals from infection. The purpose is that infected personnel should not be “vectors” of infections in the hospital. In addition, a large outbreak among the staff may cause that patients with life-threatening diseases like heart attack, trauma, etc. do not get the necessary treatment.

Despite all the controversies surrounding airborne transmission, a number of international guidelines for the use of respiratory and face protection equipment have been developed under varying epidemiological conditions and experiences over the past 100 years. Recent surveys and experiences show that Schiøtz and other researchers had correct facts and guidelines according to airborne infections. Secrets from the respiratory tract can go far off 9 m or more, for example, when coughing and sneezing, and pathogenic viruses and bacteria are detected in the air in rooms with infected patients [2, 14, 17, 18, 20, 21, 26, 32–43]. Airborne MRSA and other multiresistant bacteria may be a greater problem than previously thought [17, 18, 20, 42]. Even *Clostridium difficile* spores may become airborne under certain conditions [43]. Today, it is also known that most microbes are strong, surviving organisms outside the body [1, 44]. They can also survive on the outside of the protective equipment and even re-aerosol from these and even penetrate a wet mask [1, 4, 44–48]. Respirators (half masks) are more expensive (about 4 USD) than surgical mask (<0.1 USD). Because of a shortage during large outbreaks, it has been attempted to decontaminate respirators for reuse. However, this is not effective, is not recommended and cannot be done with disposable equipment [49].

13.5.3 Disease Spread To and Through Air

Most infectious agents are spread through contact, blood, drops, droplets, drop nuclei (aerosol), airborne on dust particles and often in several ways simultaneously [12, 13, 17, 23, 33–43, 50–52].

Transmission of microbes from the respiratory tract to the air occurs by breathing, speech, cough, sneezing, laughing, singing or other aerosol-generating procedures. Sneezing usually leads to greater amount of microbes transferred to air than coughing [51]. How long the contaminant stays alive in the air depends on the agent, temperature, humidity, virus dose response, particle size and presence of other material [50–56]. Some larger drops are deposited close to the patient, and smaller drops—droplet nuclei—pass into a floating phase in the air and are falling slowly over time, such as influenza A virus [2, 50–56]. Transmission of microbes via small particles and droplet nuclei from influenza patients is not adequately controlled by the use of surgical mask [50–52]. Airborne transmission always includes contact transmission and often re-aerosols from the environment [18–21, 39, 42–44, 55–61].

Transmission to the air from the skin occurs via the release of millions of skin particles where approximately 10% carry bacteria or virus from the skin or wound.

Re-aerosols from infectious particles whirled up in the air, for instance, during bed-making, dry mopping of contaminated floor surfaces, from contaminated areas in the room during air currents or when the door is opened or closed quickly [62]. Re-aerosols of pathogenic microbes may be important because of a long survival in the environment, for days, months and years [1, 44]. Influenza A virus survives on paper, textiles and equipment for more than 3 weeks and can become airborne [55–61]. Influenza A virus is very contagious via aerosols and small airborne droplets [56].

13.5.4 Reduction of Airborne Transmission

Microbial load in the air depends on cleaning and air exchange [5, 10–14, 63]. Proper cleaning and ventilation with a positive pressure of filtered air reduce the load in the operating units or during protective isolation. Decontamination and cleaning of rooms, textiles and surfaces and a good air exchange with a negative air pressure are important during isolation of patients with infections.

Air exchange It has been demonstrated that after aerosol-generating procedures such as bronchoscopy, airway suction and intubation, five fresh air changes in the room can greatly reduce air contamination, provided that the source of infection is gone [13].

Respiratory protection prevents people from touching their nose or mouth in an infectious situation and coughing on their own uniforms and thereby exposing themselves to others and to infection [6, 7].

Correct use of respiratory protection Most microbes survive for hours to days on the outside of a respiratory protection as shown for bacteriophage, influenza virus and coronavirus [45–47]. This is the reason why respiratory protection should not be reused and why it is not advisable to touch the outside of the mask. During the SARS outbreak in Canada in 2003, the staff reinfected themselves by handling the mask incorrectly and reusing equipment without decontamination [28]. Among 1441 hospital personnel in China, there was a significantly lower incidence of respiratory tract pathogenic microbes among personnel who used respiratory protection with filter N95 ($p = 0.02$) than among personnel using face mask ($p < 0.01$) compared to controls [64].

13.5.5 Surgical Face Mask

Face mask, covering the nose and mouth, has been used since the Spanish flu in 1919. It was actually developed to protect patients from postoperative infections from the airway flora of the operating team and protect the team against blood and tissue splash from the patient. There is no standard definition of surgical masks, adaptation, leak test or quality of filter [5, 13, 14]. Surgical mask is not approved by the occupational health authorities [3–5, 24, 25]. Nevertheless, there are extensive use and purchase of face masks, especially in the national emergency preparedness plans.

The combination of good hand hygiene and the use of surgical mask within 36 h after the onset of influenza in an index case may however reduce spread of the flu in the household [65–67]. Volunteer subjects infected with seasonal flu breathed out nearly nine times more virus in small particles, <5 µm, than in larger one, >5 µm, after the onset of the flu [50]. The use of surgical masks reduced particularly the larger particles and showed a 3.4-fold reduction of virus released to the air [50]. Using surgical face masks can reduce infection and also had some suppressing effect on the spread of infection by SARS [10].

Surgical face mask protects the nose and mouth from splashing and saliva particles but does not protect effectively against bacteria and viruses that are, respectively, from 0.2 to 8 µm (0.0002–0.008 mm) and from 20 to 300 nm (0.02–0.3 µm) in diameter. There is no safe protection against aerosol or droplet nuclei, either through the mask or from the sides of the mask [5, 13, 24, 25, 68]. It is not certain that a mask may stop microparticles of the blood that can be formed by certain procedures, like centrifugation accidents, spray from dental treatment or surgery, etc. [36, 68]. In such cases, also *eye protection* should be used.

Persons close to sterile areas can contaminate the area by direct drops of saliva and aerosols that are spilled by speech, coughing and sneezing [2, 13]. A good face mask captures these droplets from the respiratory tract and prevents deposition thereof. It catches drops both ways to some extent, but when the surgical mask is wet, it can become less effective, with some growth of bacteria. It is usually effective for at least 2–3 h.

Face masks with visors protect to some extent both nasal/oral and eye mucosa against infected blood and tissue particles/droplets.

13.5.6 Respiratory Protection: N95, P3 mask and “dust filters”

Airborne microparticles of aerosol, drop nuclei and blood drop-bearing bacteria and viruses can be formed during activities of or around the patient (coughing, sneezing, speech, excessive bodily activity, bed-making, dust cleaning etc.).

Respiratory protection such as P3 mask or N95 has shown protective effect in highly severe infections such as SARS, tuberculosis and pandemic influenza [5, 9–16, 20–23, 56, 64]. Respirators are not designed for children or people with beards, and therefore does not provide full protection for these [5, 23].

Respiratory protection is filtering half mask, looks almost like surgical mask and is often called filtering face piece (FFP) respirators or dust filter [5]. They are of different quality (FFP1–FFP3) and capture microbes in both ways. The filter is hepafilter/polypropylene filter with static charge to increase the filter power. FFP2 is equivalent to the US N95 masks that are widely used around the world. The European standard is EN149: 2001 which is equivalent to FFP3 and has a somewhat higher level of protection [13].

Procedures involving large load on the environment around a patient with air-borne infection are, for example, bronchoscopy, trachea suction, diathermy aerosol, suction and drilling (orthopaedics, dental treatment, etc.). In such cases, both respirators *and* eye protection should be used.

Filter class	Filtration efficiency	Protects against	Comments, some examples
P1	Low	Solid particles	Use only if the dust is harmless
P2	Medium	Solid particles and liquid particles	Protects against most types of dust from low toxicity substances, for example, drilling in mountains or mines, sweeping pipes, grinding work, isolation work
P3	High		Used when the dust contains or may contain poisonous or highly toxic particles, carcinogens, radioactive particles, bacteria, viruses

Source: Respiratory protection. Directorate of Labour Inspection, 2007 [5]

The P3 mask protects the user and can also be used on patients with specific respiratory infection and then *without* exhalation valve.

Protection factor is calculated by reducing the degree of pollution in the air. If there is a pollution of 1000 mg/m³ air, a respirator with a protection factor of 500 may reduce the pollution to a residue of 2 mg/m³. That includes inhalation of air through or on the sides of the respiratory protection, which will almost always happen [69–72]. “Protection factors for filtering half masks FFP1, FFP2 and FFP3 matches the protection factors for half mask with respectively filter classes P1, P2 and P3. Motor-assisted filtering air purifying respirators (equipment with a turbo unit) have varying protection factor depending on the equipment design” [5]. A wet filtering mask may be permeable for viruses and bacteria.

The Norwegian Directorate of Labour Inspection indicates protection factors for filtering respirators as follows [5]:

Filter	P1	P2	P3	Gas
Half mask	4	12.5	50	50
Full mask	–	16	1000	2000

Lower protection is expected, because it is often leaked due to poor adaptation; factor 10 is for filtering half mask classes 2 and 3, and factor 100 is for full face masks. “Protection factor for both supplied air and air purifying respirators with

half and full face masks also require a good fit, and this cannot be expected if beard, glasses or the like, in squeeze along the edge of the mask” [5].

Requirements for filtering half masks [5, 12, 13, 69–72].

Mask class	Total efficiency	Total leakage	Protection factor
P1	78%	22%	4.5
P2	92%	8%	12.5
P3	98%	2%	50

P3 has the highest protection factor with 50 times cleaner air inside the mask than outside. The mask’s overall efficiency depends on the filter quality of the mask, fitting the face shape (leakage) and leakage through any exhalation [5, 12, 13, 69–72].

Fit test is the control and training using special odour tests that the person perceives within the mask if it is not tight enough [5, 12, 13].

13.5.6.1 Many Different Models

In a study of five models of the N95 mask (3M 1860S cup, 3M 1870 flat fold, Kimberly-Clark PFR95 duckbill, SafeLife T5000 cup added with iodine and GlaxoSmithKline Actiprotect cup, added with lemon acid), all five types had more than 95% efficiency: $-0.8\text{ }\mu\text{m}$ particles of H1N1 influenza virus and corresponding inert particle sizes [69]. Filtration efficiency was largely based on particle size [69]. So-called elastomeric masks appear to be more effective than regular filter masks [70]. Studies show considerable variation with regard to protection, and for some dangerous, microbial agents, 95% protection may be too low [71, 72].

13.5.6.2 Other Types of Respiratory Protection

- *Turbo Equipment (PAPR = -Powered air-purifying respirators) with P3 filter* (protection factor 500–2000) - may have problems concerning the disinfection of battery-operated, recycling systems, and is dependent on a good training [5, 12, 13].
- *Fresh air/pneumatic equipment* (protection factor, 100–100 000) is used for particularly risky situations of special personnel in laboratories and when working in areas with severe epidemics. However, there may be serious infection problems regarding disinfection of reuse systems (filters, mechanical/electrical appliances).

13.5.6.3 Strategic Stockpile

During non-epidemic times and with low-virulent microbes, respiratory protection (N95 or P3 masks) are not used for other than special types of respiratory infections and pulmonary tuberculosis. This may influence on the state of readiness for major outbreaks such as pandemic influenza. Consumption of masks can be very large as during the SARS outbreak in 2003, where a Canada-based hospital with SARS outbreak used up to 18,000 N95 masks each day [13].

The durability of respiratory protection equipment is good—up to 10 years or more in storage. Items made with rubber or rubber parts should be checked, and

there should be some systemic rotation in the warehouse [49]. At OUH, Ullevål, there has been a strategic stockpile system of such equipment with replacement as required [8]. The experience from Norway is that the national health authorities have been unprepared for stockpiling of emergency response requirements for PPE, also during the influenza pandemic of 2009 [29]. The market may soon be empty for respiratory protection masks during serious outbreaks such as SARS and Ebola virus. Using several surgical face masks superposed did not have enough protective effect [73]. During the SARS epidemic, the Chinese healthcare personnel made their own masks of 12 layers of gauze that supposedly would work well.

13.5.7 Goggles/Visor

This is used when there is risk in soil and splatter of biological materials and to protect against highly dangerous infection. If there is a risk of transmission of severe respiratory infection, tight-fitting goggles are used. The goggles can be reused after 1 h of treatment in 5% chloramine, followed by washing with soap and water, and they may also be reprocessed and decontaminated in a washing machine at >85 °C.

13.6 Conclusion

Controversial issues concerning airborne infection and protection against “droplet transmission” should be further studied. Particle studies; ventilation variations; kinetics; the effect of humidity, temperature and filter types; re-aerosols from dust; environment and PPE equipment; and the survival of microbes in the environment should be better studied. This is the case for most important microbial agents: bacteria, viruses and fungi. Respirators should be preferred over surgical masks when there is suspected droplet or airborne transmission. This choice is essentially a misunderstood price and attitude problem.

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Part III

Isolation



Abstract

This chapter is a short survey—in table form—concerning clinical types of infections, the most important microbes in medicine, recommended methods to isolate patients with infections and recommended use of personal protective equipment.

Keywords

Microbial agents · Symptoms · Transmission · Protection · Healthcare personnel Control

14.1 Isolation at Risk of Spread of Infection

Infection type	Isolation type	Personal protective equipment—PPE	
1. All gastroenteritis cases	CA	Gloves	Gown, mask, cap ^{a,b}
<i>Clostridium difficile</i> ^a	C(A)	Gloves	Gown, mask, cap ^{a,b}
<i>Salmonella</i> , <i>Shigella</i> , <i>Yersinia</i> , <i>Campylobacter</i>	C(A)	Gloves	Gown, mask, cap ^{a,b}
<i>Campylobacter</i> , <i>Cholerae</i> , intestinal-pathogenic <i>E. coli</i>	C(A)	Gloves	Gown, mask, cap ^{a,b}
Enterohaemorrhagic <i>E. coli</i> —EHEC	C + A	Gloves	Gown, mask, cap ^{a,b}
Virus gastroenteritis (Noro, Rota, sapo, etc.) ^{a,b}	C + A	Gloves	Gown, mask, cap ^{a,b}
2. Hepatitis A or E	C + B	Gloves	Gown ^b

(continued)

Infection type	Isolation type	Personal protective equipment—PPE	
3. <i>Staphylococcus aureus</i> in wounds or eczema	C	Gloves	Gown ^b
4. <i>Streptococcus</i> group A in the throat, skin or wounds	C	Gloves	Gown ^b
5. Skin and wound infections, moderate secretion	C	Gloves	Gown ^b
6. Gram-negative <i>Bacilli</i> with copious secretion from respiratory tract or wounds	C	Gloves	Gown ^b
7. <i>Corynebacterium jeikeium</i> , <i>Staphylococcus haemolyticus</i> (only during nosocomial epidemics)	C	Gloves	Gown ^b
8. Poliomyelitis	C(A)	Gloves	Gown ^b
9. Untreated scab and lice	C	Gloves	Gown ^b
10. Other diseases which are transmitted through contact (e.g. tuberculosis in the intestines, urinary tract or in wounds or fistula)	C	Gloves	Gown ^b
11. HIV/AIDS uncomplicated and other blood-borne infectious viruses such as HTLV I and II and parvovirus B19	B + C(wound/mucosa)	Gloves	Gown ^b
12. Hepatitis, acute (unknown cause)	C + B	Gloves	Gown ^b
Hepatitis, chronic (unknown cause)	B	Gloves	Gown ^b
Hepatitis A, B, C, D, E, G	B + C	Gloves	Gown ^b
13. Malaria falciparum, <i>Brucella</i> , yellow fever	B	Gloves	Gown ^b
14. Suspected active pulmonary tuberculosis	A + C	Gloves	Gown, ^b resp., cap, shoes ^a
15. Ornithosis, tularemia	A + C	Gloves	Gown ^b , resp., cap, goggles/visor
16. Pneumonia caused by <i>Staphylococcus aureus</i>	A + C	Gloves	Gown, ^b mask, cap
17. RSV, influenza and other airborne viruses	A + C	Gloves	Gown, ^b mask, cap
18. Varicella-zoster, measles, parotitis, rubella, pertussis	A + C	Gloves	Gown, ^b resp., cap
19. Herpes simplex in newborns, in child and maternity wards	A + C	Gloves	Gown, ^b mask, cap
20. Systemic infection with: Meningococci, group A <i>Streptococci</i> , <i>Pneumococci</i> ; first 24 hours after initial effective treatment	A + C	Gloves	Gown, ^b mask, cap
21. Imported patients ^c (suspected MRSA or other resistant microbes until test results are negative) ^c	A + C	Gloves	Gown, ^b mask, cap
22. Methicillin-resistant <i>Staphylococcus aureus</i> —MRSA (recently or in the last year)	A + C	Gloves	Gown, ^b mask, cap

Infection type	Isolation type	Personal protective equipment—PPE	
23. Other multiresistant bacteria (penicillin-resistant pneumococci, multiresistant enterococci, some multiresistant, gram-negative bacteria: <i>Acinetobacter</i> , <i>Burkholderia cepacia</i> , ESBL— <i>E. coli</i> mm). Airborne transmission isolation is determined in relation to the infection type and symptoms ^d	A ^{d+C}	Gloves	Gown, ^b mask, cap
24. Multidrug-resistant tuberculosis, open cavern and expectoration (first 14 days after initial treatment and on resistance—3 months or more)	SI	Gloves	Microbe impermeable gown, ^b resp., cap, shoes ^a
25. Rare severe diseases (diphtheria, rabies, plague, anthrax, viral haemorrhagic fever, SARS, MERS, avian influenza—See also special guidelines)	SI	Gloves	Microbe impermeable gown, ^b resp., cap, hood, goggles, shoes ^a
Any other contagious and very serious diseases that may be transmitted by contact and air (including droplet)			PPE—Emergency box ^e

NB. Contact infection control personnel in case of suspicion or questions

^aRoom-bound shoes are recommended; changed in the sluice, washed in a special shoe-washing machine or use single-use shoe or shoe-leg covers

^bWhen risk of splashing, vomiting, cough, blood splatter and uncontrolled secretion, evaluate the use of cap, mask and visor or goggles, regardless of the type of isolation

^cImported patients from abroad or in other ways may be exposed to resistant microbes

^dAirborne transmission may be dependent on symptoms of the patient and viability of the bacteria in the environment. The choice between use of surgical mask and respirator may depend on microbial agent, transmission rate, severity and symptoms

^ePPE—emergency box; see PPE

14.1.1 Isolation Type (See Also Separate Regimes)

C = contact isolation; isolate or single room.

B = blood-borne and tissue transmission; single room preferred.

A = airborne transmission, including droplets and contact transmission. (A) may be airborne in certain situations with excessive spills, vomiting, uncontrolled secretion, etc. Isolate with sluice and a separate bathroom (entrance from the patients room) with decontaminator machine. Defined and controlled negative air pressure—separate air supply and hepafiltered exhaust. If shortage: a single room with anteroom and a separate bathroom.

SI = strict isolation; air + droplets + contact + blood. Isolate with sluice and a separate bathroom (entrance from the patient's room) with decontaminator or autoclave (throughput). Defined and controlled negative pressure relative to the corridor, separate air supply and hepafiltered exhaust.

14.1.2 PPE:—Most Used—with Different Combinations, According To Isolation Type

- *Gloves*: high-quality gloves with long “cuff” to cover the wrists (often use of double).
- *Gown* with cuff (water preventing coat) *or* microbe impermeable, waterproof gown *or* coverall with hood (barrier against most bacteria and virus and water impermeable for a defined period).
- *Cap*- surgical cap that covers hair and ears; always use cap if wearing mask/respirator.
- *Mask*—surgical; always use together with cap.
- *Visor*—large (against direct splatter); always use together with cap.
- *Respirator—resp. mask*: P3, N95, waterproof, with hepafilter against airborne and droplet transmission.
- *Shoe/leg covers* or room-bound waterproof shoes (that can be decontaminated at 85 °C or autoclaved or single use).
- *Goggles*: large (tight-sitting); placed outside the surgical cap or the hood (can be decontaminated).
- *Hood*—microbe impermeable that covers the surgical cap and the respirator mask on place and covers the neck down to shoulders (P3 level).

P3—level of protection: tight-fitting, waterproof respirator mask with hepafilter, eventually portable respirator and PPE corresponding to the isolation type.

PPE—emergency box: equipment for two to eight persons, stored at certain acute-care areas.

The box is pre-packed and contains respirator mask (P3), cap, hood, gown with cuffs (or coveralls with hoods), large goggles, waterproof shoe covers/overshoes and two pairs of high-quality gloves with long cuffs. Use only after consultation with hospital infection control personnel. Regular control and upgrading of the boxes, see chapters concerning high-risk infectious disease preparedness.

Prion disease is not included—see separate section Chap. [55](#).



General Information

15

Abstract

Many bacteria, viruses, parasites, fungi and prions may cause serious infections and lead to the isolation of those who are infected from those who are susceptible. Isolation may be done in single rooms or in special isolation units. A *modern isolate for patients with infections* comprises (1) a sluice with a good space for dressing and undressing of personal protective equipment (PPE) and for hand hygiene, (2) a large patient room and (3) a bathroom/disinfection room with own decontaminator or autoclave and with separate entrance from the patient's room. Isolates for airborne and droplet-transmitted infections have in addition a defined negative air pressure and hepafiltered exhaust. In all isolates, doors must be closed in such a way that contaminants do not escape the isolate. A *modern isolate for patients with impaired immune defence* is similar to the infection isolates, with following exceptions: usually no need for decontaminator, hepafiltered clean air into the room and with a defined *positive* air pressure. A positive pressure isolate should never be used for patients with infections, and a negative pressure isolate should never be used for patients with impaired immune defence, except if the patient also has an infection that needs isolation.

Keywords

Microbial agents · Isolation capacity in the hospital · Information to the patient, family and visitors · Symptoms · Transmission · Protection · PPE · Healthcare personnel · Control

15.1 Purpose

To prevent transmission from an infectious patient to other patients, personnel, visitors and the environment and to protect patients with impaired immune defence against infection [1–8].

15.2 Comprise

- All patients having contagious disease that can easily be transferred directly or indirectly via contact, blood and body fluids, air/droplets or via equipment, textiles and surfaces.
 - All patients with significant reduced infection defence or otherwise infection vulnerable and who should be protected against infection.
-

15.3 Responsibility

Hospital management should ensure necessary capacity and type of isolating units: contact- and air-droplet isolates and protective isolates. Updated isolation routines, adequate protective equipment—including PPE—routines for disinfection of rooms and surfaces and disinfectants and hand hygiene facilities should be available.

Department management should implement isolation procedures, train the use of PPE, control the use of routines and provide sufficient stock and capacity of PPE and means for disinfection and hand hygiene.

The staff should follow current guidelines for treatment of patients with infections and for patients that should be extra protected against infections.

15.4 Practical Measures

The need for isolates varies with type of hospital activity, epidemic and endemic conditions and the condition of the hospital [9–24]. Single rooms with separate bathroom and anteroom prevent the spread of infection more than single rooms and multiple bedrooms with shared toilet and bathrooms. Modern isolates, well designed, ensure other patients and personnel against infection, streamline hospital activity and simplify work [21, 22, 25–27].

15.4.1 Isolates: National and Local Overview

Updated status should be available as to the type (infections or protective) and quality of isolates and single rooms—by national and county health authorities. An overview of the number and types of infection isolates in a radius of at least 10 mils around densely populated areas should be available, and collaboration should be established between the hospitals. Isolates should be checked at least once a year. Contact isolate should have a sluice system (priority) and an own disinfection room with decontaminator. An air-droplet isolate should, in addition, have a defined negative air pressure in the rooms and separate ventilation. Protective isolates should have hepafiltered, positive air pressure. It is also important to have overview over single rooms with separate bathrooms—which can be used for contact isolation.

Hospital buildings or other healthcare facilities that can be quickly converted into cohort isolates for defined types of outbreaks like the pandemic influenza should be appointed to the emergency.

15.4.2 Infections that Should Be Isolated

Different measures may be done relatively to preparedness whether there is a normal epidemiological situation or if it is smaller or larger outbreaks in the community that also affects the hospitals.

Normal epidemiological condition: in a developed country, like Norway, 20–25% of hospitalized patients have one or more infections, including hospital-associated infections (HAI); 20–30% receive antibacterial agents, and approximately 20% need a minimum-size single room with separate bathroom, due to infection [21, 22, 28–30]. At least 10% of the hospital infections are transmitted via air-droplets.

Local outbreaks, often seasonal, may double isolate needs: this happens nearly every year concerning norovirus, rotavirus, influenza, metapneumovirus and RSV (toddlers and the elderly) and is an increasing problem concerning resistant bacteria from home and abroad (CD, MRSA, VRE, ESBL, etc.).

Large outbreaks, more difficult to control, such as the norovirus, may be organized by cohort isolation of patients with the same type of infection [21, 22].

Closing departments and hospitals happens occasionally during greater nosocomial outbreaks of norovirus or influenza when many are sick at the same time, both patients and personnel. The intake of new patients is often discontinued during norovirus outbreaks; the ward may be emptied and disinfected thoroughly before opening it again [21, 22]. A study of 194 nosocomial outbreaks in medical departments that ended up closing the ward showed that it took a long time before the unit was reopened, median 14 days [16].

Influenza pandemics and other serious pandemics: in the case of pandemic, up to 0.3% of the population will require hospitalization, and approximately 13% need outpatient treatment [1, 31]. Capacity and readiness for escalation should be calculated and included in preparedness plans for countries and counties [30–34]

15.4.3 Isolate: Types and Numbers

Contact isolation: 25–30% of the bed capacity of surgical, paediatric, postoperative department and intensive care unit, preferably with some negative pressure and separate ventilation. In the case of special wards for patients with infections, 50–75% of the capacity should be contact isolates and the rest airborne infection isolates. At all other clinical wards, the minimum is one contact isolate per ward.

Airborne infection isolation units: at least 10% of the bed capacity for adults and 10–15% of children in hospitals should be isolates well equipped with negative pressure, separate ventilation and private bath/disinfection room with decontaminator. There should be minimum one isolate per 30 beds. Contagious and severe

infections like tuberculosis, pandemic influenza, SARS, MERS, Ebola, Lassa and other haemorrhagic viral infections should not have shared ventilation with other patient rooms, service rooms, etc. [12, 21, 22, 30–34].

Single rooms can be used as for contact isolation if separate bathroom. All rooms with the same air pressure as the rest of the ward may result in risk of airborne transmission. Single rooms may only be used as an emergency solution for common infectious diseases. There are many who need single bedrooms in hospitals, not only for infectious diseases.

Lack of isolation beds may cause inefficient hospital activity and involves risk of spread of infections [21, 22–24, 28, 29, 35–37].

Protective isolation protects the patient from infection. This patient group is highly immunosuppressed, vulnerable and/or transplanted. The isolate is on positive, hepafiltered air pressure compared to the corridor and neighbouring rooms. It has its own, separate bathroom [21, 22]. The number of isolates may be in accordance with the hospital activity concerning this type of patients.

NB! A positive pressure isolate should never be used for patients with infections, and a negative pressure isolate should never be converted and used for patients with impaired immune defence. This is due to the high risk of cross infection from microbes in filters and ventilation ducts.

15.4.4 Isolates Needed During Smaller Infection Outbreaks

Patients: The usual need of isolates for the population is covered if—in addition—use of isolates at other hospitals in the area, flexible. Most outbreaks are related to a few patients, one to five [30].

Close contacts/exposed to infection/disease carriers: a short isolation period may be actual if the index case has diphtheria (adults, elderly), plague, Ebola and possibly anthrax and in some cases where infection-prone person or carrier cannot take care of himself/follow preventive measures.

15.4.5 Information and Education

Information and training are important [19]. Everyone must implement appropriate routines in connection with the isolation. Do not forget the information to other departments (including requisitions)!

15.4.6 Isolation Procedures

Contact isolation: suspected or detected transmittable human pathogenic microbes by contact with body fluids, skin and mucous membranes, textiles, clothing, furniture and contaminated equipment (telephone, computer, keyboard, blood pressure set, tourniquet, stethoscope, temperature measure, etc.)

- Use: gloves and gown.
- Surgical cap, surgical mask and eye protection/visor at risk of splashing of blood/liquid and aerosols.
- *Yellow sign* on the door.

Blood contamination isolation: suspected or detected transmittable microbes like hepatitis viruses, HIV and other pathogens. All biological materials can be infectious, which blood and blood products are the dominant carriers of the pathogen.

- Use: gloves and gown/protective clothing on direct contact with blood/body fluids.
- Surgical cap, surgical mask and eye protection/visor at risk of splashing of blood/liquid and aerosols.
- The patient may be placed on ordinary patient rooms, if not unrestricted or uncontrolled secretion/excretion of tissue fluids.

Airborne isolation: suspected human pathogenic microbes transmitted through air, dust particles, aerosols, droplets and droplet nuclei. There is always simultaneous contact contamination. Air and contact isolation with satisfactory negative pressure, a proper sluice system and a separate bathroom/decontamination room

- Use: gloves and gown.
- Surgical cap.
- Surgical mask or respirator mask when needed (follow routines).
- Eye protection goggles/visor if risk of splashing of blood/liquid and aerosols.
- *Pink sign* on the door.

Strict isolation: suspected highly infectious, virulent and pathogenic microbes, highly resistant bacterial strains and agents that are not accepted in any form of distribution in the environment. Examples are suspected unusual infectious agents like completely resistant *Mycobacterium tuberculosis* in the lungs, viral haemorrhagic fevers, pandemic severe influenza, SARS, MERS, etc.

The isolation unit has a defined, negative air pressure (in Pascal), separate ventilation with disinfection of air extraction, a properly interlock function and also direct access from the outside. The waste water is decontaminated (autoclave). The patient room has sluice systems and bathroom with throughput decontaminator/autoclave with direct entrance from the patient room.

- *Red sign* on the door

Protective isolation: used by extensive burns, leukopenia, severely compromised immune systems or other needs for special protection against infections.

- *Blue sign* on the door

15.4.7 Information for Patient and Visitors

Isolation may be necessary for patients with infections to prevent others from getting the same infection. This does not mean that the patient is particularly in a bad condition but that some bacteria or viruses can spread, for example, by coughing, secrets, blood, faeces or urine. In order to prevent spread of infection, the ward needs participation of relatives and other visitors.

The patient must be informed of the following:

1. The patient's room cannot be left without consultation with a nurse or doctor.
Use the ring bell.
2. The bedpan and urine bottle must be used if the patient room does not have a separate toilet.
3. Avoid touching wounds, bandages or tubes.
4. Pus or blood/secret on the bandage, in bed linens, or loosened dressing; notify the nurse.
5. Good hand hygiene is important. Always wash your hands after toilet visits; after using the bedpan or urine bottle; after any touch of wounds, bandages or tubes; before eating; before leaving the room; and when you return to the room.
6. Use clothes that can be washed at higher temperatures ($>65^{\circ}\text{C}$); preferably use the hospital textiles.

Visitors must be informed about this

1. Contact the nurse for the necessary precautions before entering the patient room.
2. Follow routines for personal use of infection control equipment—you will be notified by a responsible nurse.
3. It may be necessary to reduce the number of visitors. Nurses will report this. Small children should not enter the room without special agreement with the responsible nurse.
4. Disinfect your hands before entering the isolate.
5. Do not sit on the bedside. Use a chair by the bed.
6. Do not eat or drink in the patient's room.
7. Do not use the ward's kitchen or refrigerator or serve on the corridor, etc.
8. There is no access to the ward's service room (disinfection room, textile room, storeroom, etc.).
9. Leave the department immediately after visit—avoid living rooms, etc.
10. Thoroughly wash your hands before leaving the isolate (sink in the sluice), even if you only need a short errand outside.
11. Close all doors after you in a calm and careful manner as you walk in and out of the isolate.

15.4.8 Measures to Make the Isolation Stay Easier

- Dedicated contacts among nurses that the patient accept/like. There should be more contacts so that someone is always present. Interpreting may be used if language problems.
- Visit the patient unasked. It is better with frequent, short visits than one long.
- Good information and update with regard to the patient's illness is important [38].
- Use a flexible visit time. Check that visitors understand, accept and follow the protective routines and other advices from healthcare professionals.
- Private food to the patient is not allowed, possibly delivered directly to the department by appointment in special situations.
- Good aids are TV, video, radio, telephone, data and papers that are appropriate for the patient.
- Isolates should not have curtains, but washable posters, etc. can be used on the wall.
- Large windows and a good daylight are important.
- The room should be clean, neat and well maintained.
- Isolation involves no more depression or fear than what the patient has upon admission [39].
- Isolation does not involve a poorer patient care experienced by the patient, quite the contrary [40–43].
- Close all doors behind you in a calm and cautious manner when going in and out of the isolate in order not to create unfortunate air currents [44].

15.4.9 Personal Protection Equipment (PPE) for Isolation: See Point 6

Contact isolation: Gloves and disposable infection gown with cuffs (Fig. 15.1).

When certain agents are suspected (norovirus, CD, MRSA, etc.), or gastroenteritis, respiratory tract symptoms etc., use in addition surgical mask, cap, and eventually visor, room-bound shoes/shoe covers. In the sluice, clean off the shoes on a “cloth” with chloramine 5% outside the door to get rid of the agents if not using shoe covers. Replace at each shift. Used especially during CD isolation.

Blood contamination isolation: gloves and disposable infection gown with cuffs by direct contact with blood/body fluid—and double gloving when sharp procedures.

Airborne isolation: surgical mask or respirator, cap, gloves and disposable infection gown with cuffs.

Strict isolation: respiratory protection, surgical cap and hood and disposable fluid-resistant gown with long arms and cuff or overall with hood, boots or shoe covers, double gloving.

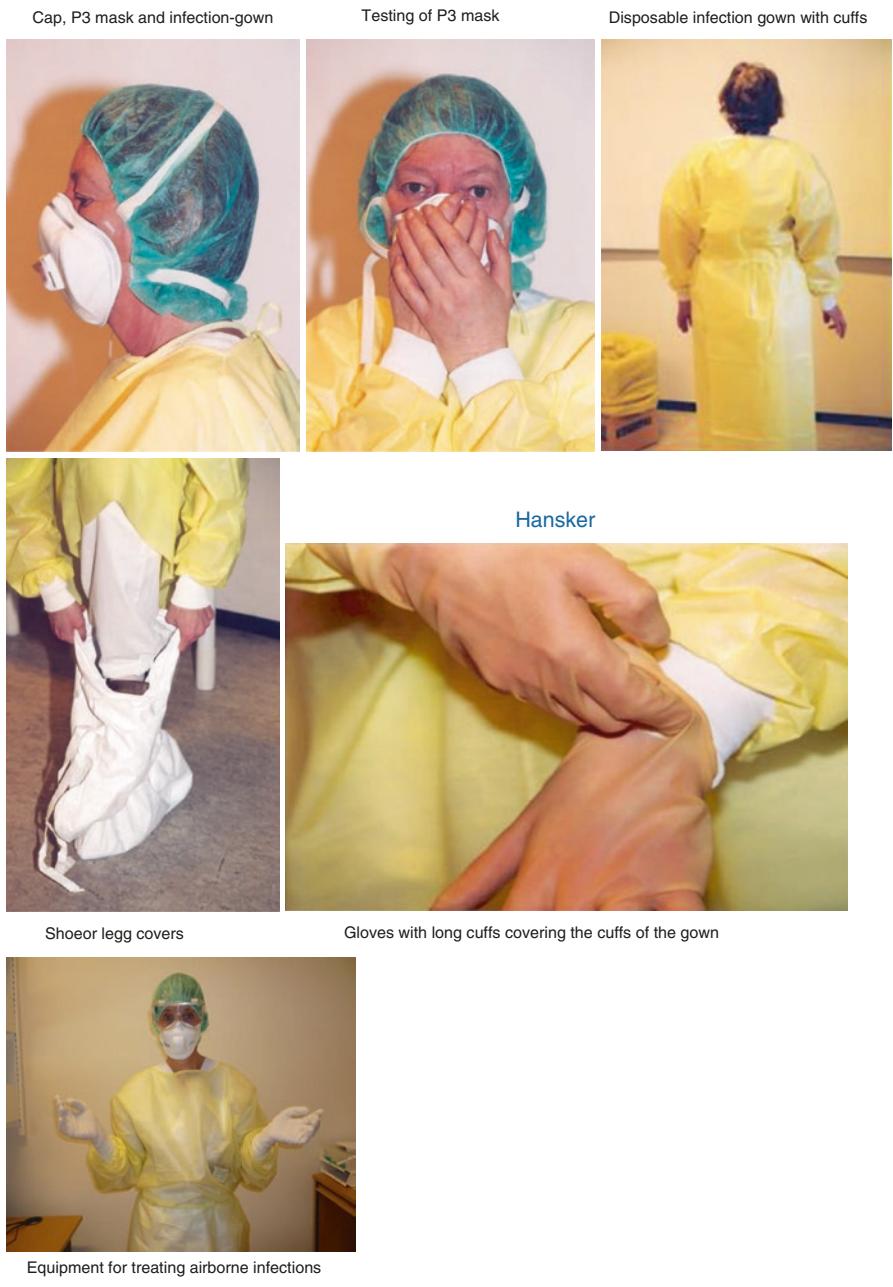


Fig. 15.1 Personal protective equipment-donning. Source: BMA, OUS-Ulleval

Protective isolation: good hand hygiene, clean gown, surgical mask, surgical cap, room-bound shoes.

15.4.10 Where to Take On and Off the PPE: Donning and Doffing?

A *clean, not used PPE* can be taken on in the sluice or on the corridor outside the sluice.

A *used, contaminated PPE* is taken off in the patient sluice, nearby the door of the patient room and is placed directly in an infection waste container. If there is no sluice present, the PPE is removed inside the patient room—at the exit door.

NB! Never take off used PPE in the hallway or corridor—except if a separate sluice is made here.

15.4.11 In This Order Take On (Donning) the PPE Before Entering the Isolate [22]

- *Surgical cap* shall always be used when the surgical mask or respirator mask is used (by airborne infection, strict isolation and when protective isolation). The surgical cap makes the mask easier to fasten on the head and removes hair from the face and neck. Covering ears and all the hair may protect against exposure to microbes when the patient coughs or sneezes.
- *Surgical masks* (gastroenteritis virus, MRSA, respiratory infections/droplets and protective isolation; see isolation procedures). The mask is attached to the back of the head—one strap—and in the neck, the other strap. Make sure that the mask is properly fitted over the nose. Do not use a mask that attaches to the ears.
- *Respiratory protection mask* instead of a surgical mask (severe airborne infections, tuberculosis and strict isolation—see isolation procedures) was attached to the back of the head—one strap/tie—and in the neck, the other strap/tie. Check that respiratory protection is properly fitted over the nose and around the mouth; check the leak test.
- Gown (for contact, blood contamination, airborne infection, strict isolation), waterproof, long and with good cuffs, tightly around the neck, preferably single use gown that is placed in the infection waste bag after use. **NB** The gown is tied on the back—not tied on the front.
- Gloves with long cuffs—for contact, contaminated blood, airborne infection, strict isolation) solid and comfortable. Double gloves at high risk of transmission and blood-borne infection.
- Shoe cover—room-bound shoes, boots, overdrafts, etc. (norovirus, *C. difficile*, vomiting, diarrhoea, high pollution in the room, strict isolation).

15.4.12 In This Order, Take Off (Doffing) the PPE After Being on Infection Isolates [21, 22]

- Shoe protection, overdrafts, etc. if used, disinfect gloves (outside) before carefully taking off shoes/cover and place them in infection waste bag or waste container for shoes that can be autoclaved/disinfected. Put a doffed foot on a clean area in the sluice or directly in your own shoes.
- Hand hygiene—disinfect the outside of the glove.
- Gloves; grab the left glove at the wrist (not higher up) and gently turn inside out when doffing.
 - The inside of this glove is usually clean and can be used as a “cloth” placed on the right hand to grab through to remove the other glove.
 - Learn the technique. For left-handed do the opposite.
 - Can also be used to take off double gloves in one operation.
 - (In special situations like strict isolation or if contaminated hands: perform hand hygiene. Then take on new, clean gloves up to the wrists before doffing the gown).
- Hand hygiene.
- Gown; open the closure back.
 - Hand hygiene.
 - Grab the cuffs (clean because the gloves have covered them) and pull successively the cuffs over the wrists.
 - Do the rest of the doffing from inside the gown; arms off and carefully roll the entire coat away from both sides to the middle and then roll downwards—as “packing in” the contaminants of the gown—learn the technique. Place the used gown carefully in the waste container.
- Hand hygiene.
- Goggles: if used, take careful behind the head and bend forward, so the goggles do not come into contact with skin, hair or textiles—put in container for decontamination if using reusable goggles.
- Hand hygiene.
- Surgical mask/respirator mask; do not touch the front of the mask directly—be careful behind the head and neck. Bend forward and gently tilt so that the front of the mask does not come into contact with skin, hair or textiles. Loosen the band in the neck first and then on the head (the mask should not fall on the chest). Carefully place it in the waste bag.
- Hand hygiene.
- Cap or hood; grab the cap carefully back on the head and gently remove it. Bend forward to avoid contact with skin, hair or textiles. The cap is placed in the waste bag.
- Hand hygiene.

NB! In the case of airborne isolation and strict isolation, it is *never appropriate* to remove the PPE before going out from the patient's room, in the sluice, *and* the door to the patient's room should be closed. This applies only to an established

sluice function. If this function is missing, approved alternatives may be available, for example, a separate and enclosed corridor defined for this use. Contact infection control personnel.

- Take care with the movements during doffing to not release contaminants from the PPE into the environment.
- Take care when opening and closing doors to avoid unfortunate airflows [44].
- Multi-use of gowns where the same gown can be used for several persons entering the patient's room is not recommended because of problems with cross-contamination. If still in use, it must be properly hang up after use; with the outside of the gown *turned out*—in the patient room (at the door)—and the outside of the gown *turned in*—in the sluice. Gowns that are hang up incorrectly or are dirty or wet should be carefully put into the bag for contaminated textiles. Hand hygiene is done before taking on a new gown. The multi-use gown is changed for each shift or more often when contaminated. Never enter the corridor with a gown used for protection.

Isolation regimens should not be a hindrance for—but included in—diagnostics and treatment.

15.5 Background Information

See Chap. 21.

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Abstract

Contact isolation is used in healthcare institutions if risk of transmission of human pathogenic microbial agents by direct or indirect contact with cases or carriers with certain infections, or with contaminated environment, equipment, textiles and waste. Contact isolation requires a trained staff, good knowledge of infections and infection protection, and frequent visits and contact with the patient on the isolate to reduce the feeling of isolation.

Keywords

Contact isolation · Microbes · Symptoms · Protection · PPE · Healthcare personnel · Control

16.1 Purpose

To prevent transmission from an infectious patient to other patients, personnel, visitors and the environment and to protect patients with impaired immune defence against infection [1–8].

16.2 Comprise

- All patients having contagious disease that can easily be transferred directly or indirectly via contact, blood and body fluids, air/droplets or via equipment, textiles and surfaces.
- All patients with significant reduced infection defence or otherwise infection vulnerable and who should be protected against infection.

16.3 Responsibility

Hospital management should ensure necessary capacity and type of isolating units: contact- and air-droplet isolates and protective isolates. Updated isolation routines, adequate protective equipment—including PPE—routines for disinfection of rooms and surfaces and disinfectants and hand hygiene facilities should be available.

Department management should implement isolation procedures, train the use of PPE, control the use of routines and provide sufficient stock and capacity of PPE and means for disinfection and hand hygiene.

The staff should follow current guidelines for treatment of patients with infections and for patients that should be extra protected against infections.

16.4 Practical Measures

Contact isolation is used in healthcare institutions to protect other patients and personnel from patients suspected to have an infection that may be transmitted by direct or indirect contact [1–22]. Outbreaks of infections in healthcare institutions are often caused by understaffing, overcrowding and mixing of patients with or without infections, lack of isolates, misunderstanding or not following hygienic routines, or no routines at all [23, 24].

The source of infection is most often a patient. Healthcare personnel are often vectors of the infecting strain, by direct or indirect contact with cases or carriers, or via contaminated environment, equipment, textiles and waste.

Contact isolation requires a well-designed isolation room, trained staff, good knowledge of infections and infection protection and frequent visits and contact with the patient on the isolate to reduce the feeling of isolation [25–27].

Hospital-associated infections (HAIs) occur in 7–15% or more, of hospitalized patients, and the infection starts usually two or more days after admission to the hospital. Under normal epidemiological conditions, HAI constitute the major part of patients that are treated in contact isolation [23, 24, 27–29].

Actual infections/carrier state that should be contact isolated: [1, 11, 17–24, 26–36]

- Patient with diarrhoea. Note. If the patient is vomiting or there is a great pollution in the room, include a regimen for *airborne transmission* (see airborne transmission Chap. 18).
- Suspected or detected infections/carriers with *Salmonella*, *Shigella*, *Yersinia*, *Campylobacter*, *Cholera*, enteric-pathogenic *Escherichia coli*, *Clostridium difficile*, etc.
- Other infectious gastroenteritis. *Exception:* Norovirus should be both contact and air isolated.
- Acute hepatitis A and E and not defined acute hepatitis (in addition to blood-borne contamination).
- Less severe skin and wound infections with staphylococci or streptococci where the secretion may be controlled with bandage or closed drainage.

- Resistant gram-negative bacilli in skin wounds or urine, sparse secretion and calm patient who understand hygiene and infection control.
- Untreated scabies and lice.
- Other diseases transmissible by contact.

16.4.1 Contact Isolate Unit [1, 8, 9, 19–22, 25–27]

The patient's room/unit is labelled with Isolation-C on the door. A satisfactory contact isolate has a sluice (anteroom) with sink (hand basin), a large enough area for a secure donning and doffing of PPE (5–6 m²), a large patient room and a separate decontamination room with shower, sink and toilet. Air changes are 6–12 per hour. If there is no defined unit for contact isolation, the following may be used:

- Single room with anteroom and separate bathroom.
- Single room without own bathroom—use bedpan/urine bottle.
- Single room with a separate toilet/bathroom outside the room, labelled for use only for the patient.
- Cohort isolation: patients with the same type of infection treated in the same room.

Regardless of the solution, there should be a sink for handwashing in the patient room, enough areal for effective patient care, patient-related equipment, waste bag, PPE and good procedures for handling contaminated equipment, textiles, etc.

In hospitals with usually short admission periods, it is highly desirable that cases/carriers with infections are isolated throughout the stay [21, 22]. Rarely, exceptions must be made for this. A cooperative patient with a good personal hygiene and with any secretion (pus, blood, etc.) under control could leave the room with the consent of the responsible physician/nurse/infection control personnel *only if*:

- The patient understands and follows precautions.
- It is controlled secretion of infectious material in bandages which are clean outside.
- *Do not have* diarrhoea, enteric-pathogenic bacteria (*Salmonella*, *Shigella*, *Yersinia*, enterohaemorrhagic *E. coli* (EHEC), *Campylobacter*, cholera, etc.) and is *not* incontinent.
- *Do not have* norovirus infection or suspected.
- *Is not* carrier or case with resistant bacteria like VRE, MRSA, ESBL or other multidrug-resistant organisms (MDRO) or *Clostridium difficile* (CD).
- *Have not* had respiratory tract symptoms.
- Conducts good hand hygiene

If all of the above points are met, the patient may leave the hospital (walk, etc.), but not in the common living room or dining room, or use the common toilets.

Donning PPE before entering the patient room: [17–22]

- Gloves with long cuff that covers the wrist.
- Gown—disposable—is preferred; long sleeves and cuffs. The disposable gown is only used once. Multi-use gown is not recommended, but if used, it should be hanged in the patient room (beside the door) with the outside out or—if there is sluice/anteroom—should the inside of the gown hang out. The multi-use gown is changed after each shift or more often when needed and should only be used for a single patient. Waterproof, disposable gowns or disposable plastic aprons are also used if there is spillage/liquid.
- Surgical mask and cap should be used in addition if risk of splatter of infectious material by trachea sucking, bagging, coughing, vomiting, sampling, etc.
- Face shield or visor is usually not necessary, but consider use by much splashing, spills and the like.
- Cap—usually not necessary.
- Room-bound shoe or shoe covers—use if widespread transmission of infectious materials in the room (vomiting) and always by CD. Room-bound shoes may be decontaminated after use.
- Work in very close contact with the patient; like personal care, helping with the toilet/bathroom, or there is a lot of contamination in the room, the use of a cap and surgical mask is recommended in addition to gloves and gown.

16.4.2 Doffing in the Sluice or at the Exit Door if the Room Has No Sluice/Anteroom [17–22]

Remove personal protection equipment (PPE) in such a way that you do not contaminate yourself or the environment. Doffing is done in a defined area in the sluice on the unclean side. In this order, take off the PPE that you have used:

1. Room-bound shoes or shoe covers—if used, room-bound shoes are tilted off and put foot straight into your own shoes. **NB!** If shoe covers are used, remove them with gloves on.
2. Gloves – learn the method to take off without recontamination.
3. Hand disinfection.
4. The gown doffing method—open closure on the back (top first), pull the cuffs forward, and gently roll the gown off. Learn to take off the gown. Multi-use gowns should be hung in the patient room at the exit door with the outside out or—in the case of sluice/anteroom, the inside should be out. Change at least for every shift. Disposable gowns are infectious waste; multi-use gown are infectious textiles.
5. Hand disinfection.
6. Surgical mask—if used, take it off and loosen tape first in the neck and then on the head, and bend the body forward to avoid contact with skin, hair, etc.
7. Hand disinfection.

8. Face shield/visor—if used, loosen from behind as a mask.
9. Hand disinfection.
10. Cap—if used, remove from the back as a mask.
11. Disinfect or wash hands.

16.4.3 Textiles Used in Contact Isolation [21, 22]

All textiles from contact isolates are treated as infected textiles and put in a yellow bag defined for infectious textiles. Soiled or wet textiles are packed in plastic bags before they are placed in a yellow bag. All material/textiles that fall on the floor in the isolate are treated as contaminated.

Disposable equipment: [21, 22]

- Disposable equipment and other waste are packed in dense yellow plastic bag before transport to waste disposal.
- Waste is collected in yellow bags and treated as infectious waste. The outer side of the bags must be clean during transport.

Reusable equipment: [21, 22, 37]

- Minimize equipment inside the isolation ward/room.
- Excess equipment should be removed from the isolation unit before the patient arrives. Only necessary equipment and textiles for the treatment of the current patient are stored in the cabinet of the isolation unit.
- Telephone, computer desk, TV, etc. are covered with plastic that are changed and disinfected after each use. Examination equipment such as stethoscope, blood pressure monitor, blood glucose measurement, etc. are kept in the room until the patient is finished treated and disinfected after each use and disinfected before being used for other patients.
- Wipe off medical and other point-of-care equipment once per shift with soap and water and then with alcohol.
- A used reusable equipment is packed before transportation to the disinfection room where it is heat disinfected in a decontaminator or washing machine or by boiling (above 85 °C).
- Equipment that cannot be disinfected by heat should be disinfected with sodium percarbonate 40–60% (peracetic acid) or chloramine 5% or sodium hypochlorite 5.24% in a 1:10 dilution (household bleach) for 1 h before washing with soap and water.
- Thermometers are cleaned with soap and water and then disinfected in a suitable chemical disinfectant, for example, peracetic acid or 75–85% alcohol.
- Other equipment, which cannot be placed in disinfectant, for example, blood pressure apparatus and stethoscope, must be wiped over with a cloth soaked in suitable disinfectant, such as peracetic acid, chloramine 5% or 75–85% alcohol. Examine which disinfectant the equipment can tolerate.

- Used equipment that is to be taken out of the room may be heat disinfected in isolation unit's decontaminator or wrapped in yellow plastic bag and heat disinfected in the disinfection room of the ward. Disinfection is implemented immediately by the person who brings the equipment to the disinfection room.
- Journal trolleys* are not taken into isolates. Avoid taking the patient journal into the room because of risk of contamination.

NB! Only necessary equipment should be brought into the isolate. Equipment falling on the floor is treated as contaminated.

Crockery/cutlery: [17–22]

- Decontaminated in the isolation unit decontaminator or wrapped in tight plastic bags and decontaminated in the disinfection room—before it is sent to regular washing.
- Make sure the unclean and the clean equipment is kept well separated from each other.
- Optionally, use disposable cutlery that is disposed as infectious waste.
- Wash or disinfect hands after contact with used equipment.

16.4.4 Waste [19–22]

Treat all waste as contaminated waste (see contaminated waste). Waste bag's outer surface must be clean before transport. If contaminated outside, a clean plastic bag should be placed outside, double packed. Use clean gloves; avoid contact with own uniform and wash hands afterwards.

16.4.5 Syringes/Needles [21, 22]

All sharp objects like scalpels, lancets, razor blades and needles that have been in contact with the patient are placed directly in the yellow box defined for hazardous waste. The syringe is thrown without putting on the protective sleeve or disconnection. The boxes are discarded when they are approximately $\frac{3}{4}$ full. See fill level check mark. They are packed in yellow waste bags when removed from the isolate.

16.4.6 Medical Examination/Treatment in Other Departments [21, 22]

Provide good advance information on infection risk to relevant departments. The requisition is marked in uppercase letters: CONTACT ISOLATION.

Before transportation to other departments, the patient should be washed; put on new, clean cloth; and put on a clean bed. This is especially important if surgical treatment.

X-ray examination: Upon notification of contact isolation to the X-ray department, a fully contact regime is made for the patient during the examination. The room for X-ray is emptied for unnecessary objects. Contact points for the patient in the room is disinfected and washed afterwards. If there have been a lot of spills and leaks, considered full disinfection of the room.

Surgical treatment should occur at the end of the daily operation program, preferably on an operating room particularly suitable for the purpose, with no positive air pressure, without LAF (laminar air filtration) system and with a subsequent decontamination of the room.

Remember good information to all who are treating/taking care of the patient—even when this occurs in isolation unit—such as physiotherapy, sampling, cleaning and so on.

16.4.7 Laboratory Tests

Follow guidelines for contact isolation. Prepare the label to the glass with information, take the sample, wipe the glass with alcohol outside, and fasten the label immediately afterwards. The sampling and preparation for transport of infectious material should take place in the patient room or in the sluice. The vial and packing outside must be completely clean before sending to the laboratory. Disinfect the workplace afterwards. Note the remiss with capitals for contact isolation.

16.4.8 Transport of Patients Outside the Isolate: [21, 22]

- The patient, cloths, bed linen, bandages and any bed/stretcher should be clean during transport. Drainages from wounds must be clean, covered and without leakage. If the patient is coughing, a surgical mask should be used on the patient.
- Staff that are transporting or receiving the patient must be informed about contact regime in advance to prepare appropriate measures.
- Protective equipment should be used in accordance with information from the ward responsible for the patient.
- Bed/stretcher should be disinfected after use in ambulances, after ambulance service routines.
- Staff transporting the patient does not need special PPE protection if not in contact with infected materials, the patient, bedding, equipment, etc. and if no special problems are related to the patient. Hand hygiene before and after the transport.

16.4.9 Books

Patients can borrow books on the patient library. The library must be informed that the books are loaned to a patient on contact isolation. It is notified to the library if the books are treated as infectious waste, something that should be considered in most cases.

16.4.10 Visitors [22]

- Visitors contact the ward office for information about actual protective measures and hand hygiene.
- Visitors are using a clean gown and are instructed in hand hygiene before entering the isolate.
- They may sometimes carry the same microbe that infects the patient and should therefore not stay in the ward's common area like the dining room and TV or living room; contact responsible nurse.
- It is not allowed to eat/drink on the patient's room.
- There is no access to the ward's kitchen, washing rooms, storage and the like.
- There is usually no involvement in the care of or in close contact with the patient. If there is a need to participate in the care of the patient, the visitor is using the same PPE and procedures as the staff.
- Children should not enter the room to an infectious patient.
- Visitors should not sit on the edge of the bed but use a chair by the bed.
- Hand hygiene before leaving the room and when leaving the hospital.
- See also other information for visitors.

16.4.11 Daily Cleaning [21, 22, 38–41]

- The cleaner utilizes *always* surgical mask, cap, disposable infection gown and gloves.
- The room should be cleaned daily by washing with water and ordinary detergent.
- Mop stand should *not* be removed from the room during the isolation period. Only clean bucket and new mops should be brought into the room when cleaning. Washing trolley should stand on corridor.
- Used mops, cloths and buckets are disinfected in decontaminator (85 °C or more) after each use. This may be done in the decontaminator of the isolate or packed in and washed as contaminated in the disinfection room. Other washing equipment may be manually disinfected (sodium hypochlorite, peracetic acid or chloramine 5%) after each use and not removed from the isolation unit before the isolation is completed. *Do not handle the used mops/equipment without gloves/protective gown!*
- All spills, diarrhoea, vomiting, pus, blood, etc. must be removed immediately, and the area should be disinfected with peracetic acid, chloramine or other means, before it is washed with soap and water.
- Locations that can easily be contaminated, such as beds, tables, sinks, door handles, ring and light buttons and toilets, must be disinfected daily and for *Clostridium difficile* one to two times a day.
- The room should be aired well after each day's cleaning, but the door to the corridor should be closed all the time.

16.4.12 Termination of Isolation [21, 22, 38–42]

- After completion of the isolation period, all disposable equipment like creams, soaps, bandages, etc. which have remained in the room during isolation is treated as infectious waste. All textiles in the room are treated as infectious and sent for laundry.
- Beddings are carefully packaged (to avoid re-aerosols) and sent as infectious textiles.
- Bed equipment and mattresses which cannot be washed or disinfected in the room are packed, labelled and sent to the disinfection.
- Rooms, fixtures, bed, bathroom and all used equipment are disinfected with per-acetic acid, chloramine 5%, household bleach or other means.
- All handles, buttons, switches, call cord, waterproof mattresses, bed, nightstand, toilet, computer, telephone, TV and other contaminated fixtures and equipment are disinfected.
- Floors should be disinfected, and walls are stain disinfected where necessary and particularly in areas where the bed stand against the wall, around the sink and in the bathroom. It is important to have good cleaning on all surfaces up towards the ceiling as lighting fixtures and other equipment, to avoid deposits of dust and microbes.
- The responsible nurse must inform the cleaning staff about the disinfection area and the disinfectant to be used. After the disinfection, the room and equipment is washed with soap and water.
- Textiles, reusable equipment and disposed of as infectious; follow described above recommendations. Unused disposables are discarded. The room is aired 1 hour after cleaning.
- Hydrogen peroxide 5% dry gas may be appropriate in addition to regular disinfection, especially in rooms with a lot of medical equipment and if problems with regular disinfection [35, 42]. Follow written procedures. Three subsequent disinfection cycles must be performed under control of effect and spore test. It does not work against tubercle bacilli but is otherwise approved against bacteria, viruses and fungi [43].

16.4.13 Main Cleaning: All the Isolation Units [21, 22]

Consider the main cleaning of isolates 2–4 times per year, depending on usage and accumulation of microbes and dust. Check filter effect and air ducts. Contact infection control personnel to be sure that the cleaning/disinfection is being conducted in a proper manner.

NB! Good hand hygiene is important! It prevents the spread of infection!

Isolation regimens should not be a hindrance for—but included in—diagnostics and treatment.

16.5 Background Information

See Chap. [21](#).

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Abstract

All biological materials can be infectious, of which blood and blood products are the dominant carriers of certain microbial agents. Blood-borne pathogens most often associated with transmission of infections are hepatitis viruses (A, B, C, D, E), HIV, HTLV. Other viruses; prions, bacteria, fungi and parasites may more seldom cause blood-borne transmittable infections. Person-person transmission of contaminated blood or tissue may occur directly via contact with wounds and mucous membranes, or indirectly via sharp instruments. The source may be a patient or a carrier. The infection is also transmitted via contaminated environment, equipment, textiles, and waste. The patient may be placed on ordinary patient rooms, preferably single rooms, if not unrestricted or uncontrolled secretion/excretion of tissue fluids.

Keywords

Blood-borne pathogens · Contact isolation · Protection · PPE · Healthcare personnel · Control

17.1 Purpose

To prevent transmission from an infectious patient to other patients, personnel, visitors and the environment and to protect patients with impaired immune defence against infection [1–8].

17.2 Comprise

- All patients having contagious disease that can easily be transferred directly or indirectly via contact, blood and body fluids, air/droplets or via equipment, textiles and surfaces.

- All patients with significant reduced infection defence or otherwise infection vulnerable and who should be protected against infection.

17.3 Responsibility

Hospital management should ensure necessary capacity and type of isolating units: contact- and air-droplet isolates and protective isolates. Updated isolation routines, adequate protective equipment—including PPE—routines for disinfection of rooms and surfaces and disinfectants and hand hygiene facilities should be available.

Department management should implement isolation procedures, train the use of PPE, control the use of routines and provide sufficient stock and capacity of PPE and means for disinfection and hand hygiene.

The staff should follow current guidelines for treatment of patients with infections and for patients that should be extra protected against infections.

17.4 Practical Measures

Infection risk is greatest in contact with blood and tissue fluids, particularly for cuts (and seldom blood transfusion) and if exposed to infectious agents to mucous membranes. The patient should preferably have single rooms. Personnel may be exposed to infectious blood and tissue and should therefore follow the hospital guidelines considering protection against blood-borne infection [1, 2, 9–13].

17.4.1 Infections that may be Blood-Borne Pathogens [1, 9, 11–17]

- HIV/AIDS patients who *are not* simultaneously having diarrhoea, respiratory tract infection, or wound infection
- Acute hepatitis of unknown cause (see also contact isolation)
- Hepatitis A, B, C, D, and E in the acute phase or carrier state (see contact isolation for hep. A and E)
- HTLV-I and HTLV-II carrier state.
- Chronic hepatitis of probable infectious aetiology
- Suspicion of intravenous drug abuse
- Parvovirus B19, acute CMV, EB virus, and the like

17.4.2 In Special Geographic Regions, Epidemic Situations [14–17]

- Zoonotic virus, like *Flaviviridae* (yellow fever virus, West Nile fever virus (WNV), Zika virus)
- Viral haemorrhagic fevers (Ebola, Lassa, CCHF, etc.) (see strict isolation)

- Special zoonotic bacteria, like *Brucella*, *Coxiella*, *Francisella*, *Burkholderia pseudomallei*, etc.
- *Malaria falciparum* and other suspected blood parasites
- Creutzfeldt-Jakob and other prion diseases

17.4.3 Hospital Bed [9, 11]

- Single room for the patient, preferably one with private bathroom.
- Single rooms for small children or restless patients who does not cooperate. In situations of frequent and extensive blood contact, single rooms should be preferred.
- Patients with intact skin/mucous membranes can stay together with other patients on the room if they are taking precautions when invasive procedures and when the general hygienic conditions of this room are satisfactory. This applies to patients with hepatitis B, C, and D, HIV, and HTLV.
- *Hepatitis A- and hepatitis E-infected patients may transmit infection via blood and contact and should be treated as blood and contact isolation!*
- Single rooms can be labelled ISOLATION-B.
- Use gloves and gown/protective clothing on direct contact with blood/body fluids.
- Surgical cap, surgical mask, and eye protection/visor at risk of splashing of blood/liquid and aerosols.
- The patient may be placed on ordinary patient rooms, if not unrestricted or uncontrolled secretion/excretion of tissue fluids.

17.4.4 Putting on PPE Before Entering the Patient Room [9, 11]

Use surgical face mask, cap, eye protection, double gloves, and infection gown at the risk of blood spatter, for example, by injection or by sampling.

- *Gloves*—only in procedures where they may come into contact with blood or body fluids. Use double gloves when risky engagement with spilled blood or very troubled patient.
- *Infection gown*—disposable with long sleeves and cuffs. Used only at the risk of direct contact with blood or body fluids or where there is the potential contamination of own uniform. Use waterproof gown or plastic apron outside a gown if risk of spills. If multi-use of a textile protective gown, it should be hung on the patient room with the *outside* out at the entrance.
- Surgical mask, cap, and face shield—used in situations where there may be splashes of blood or body fluids. Hepatitis and HIV viruses can invade the eye mucous membranes.
- Room-bound shoes—usually not necessary.

17.4.5 Undressing in the Sluice or at Exit Door

Remove the PPE in such a way that you do not contaminate yourself or the environment.

See contact isolation.

17.4.6 Textiles

Textiles are wrapped in yellow plastic bags, treated as infectious and put in a new bag/sack which is cleaned outside before transport.

17.4.7 Reusable Equipment

Heat disinfected in decontaminator or in washing machine (>85 °C). Heat-sensitive components (example thermometers) are disinfected chemically in chloramine 5% or other disinfectants in 1 hour before cleaning. See contact isolation.

17.4.8 Crockery/Cutlery

The dishes/cutlery is decontaminated before it is sent to normal dishwashing and heat disinfected before returning to regular machine by central kitchen. See contact isolation.

17.4.9 Waste

Contaminated waste and used disposable materials are treated as infectious waste and put in new clean bag that will be cleaned outside during transport. Other waste is treated as household waste.

17.4.10 Syringes/Needles

All sharp objects, scalpels, lancets, razors and needles that have been in contact with the patient, are placed directly in yellow collection box/can as hazardous waste. Needle is disposed without the application of the protective sleeve or disconnection. The boxes are discarded when they are 3/4 full. It is important that the box is not easily accessible to children, patients or visitors.

17.4.11 Laboratory Tests

Sampling and preparation before further shipment of blood or body fluids should take place in the patient's bedroom. By sampling of patients in multi-bed rooms, the

patient should be protected from the other patients. Using a special “vacutainer” system, use a separate holder for disconnection of the needle. The holder is treated as infectious and disinfected after each use. The vial should be completely cleaned on the outside before shipment to the laboratory. Note on the remiss: blood contamination. See also contact isolation.

17.4.12 Medical Examination/Treatment in Other Departments/Mors

Provide good advance information on infection risk to relevant departments. The requisition is marked in uppercase letters: BLOOD CONTAMINATION. Planned surgery should be done at the end of the daily operation program with subsequent room and equipment disinfection. The operation is carried out with double gloves, face shield/visor, and liquid-tight surgical gowns. Caution with blood splatters and spills of blood/tissue fluids and use of diathermy and other equipment that creates droplet nuclei/aerosols.

17.4.13 Transport of the Patient

Patient, clothing, and bed/stretcher should be clean during transport. Staff transporting and receiving the patient must be informed in advance about blood contamination. See contact isolation.

17.4.14 Books

Patients can borrow books on the patient library. The library must be informed that books are loaned to patients with infections. It should be notified to the library when books are discarded.

17.4.15 Visitor

No need for protective clothing if they do not care for the patient. See contact isolation.

17.4.16 Daily Cleaning

The cleaner utilizes *always* surgical mask, cap, disposable infection gown, and gloves.

Use soap and water and clean equipment, separate for the room. Special cleaning and disinfection may be necessary in certain cases—daily. In case of spills of blood or body fluids, the nursing staff should immediately remove the

spill with gloved hands. The area is then disinfected with chloramine 5% or peracetic acid before cleaning.

After use, heat-disinfect the mops, cloths, and buckets in decontaminator (>85 °C), before washing. Preferably use disposable mops and disposable wipes. Do not handle the used mops/equipment without gloves and gown!

17.4.17 Termination of Isolation: See Contact Isolation

NB! Good hand hygiene is important! It prevents the spread of infection!

Isolation regimens should not be a hindrance for—but included in—diagnostics and treatment.

ACCIDENTS with contaminated blood: see Chap. 11—blood and tissue accidents.

17.5 Background Information

See Chap. 21.

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Airborne/Droplet Infection Isolation

18

Abstract

Airborne/droplet infection is caused by infected agents in the air around a person. Microbial pathogenic agents that are mainly transmitted airborne are aerosols, re-aerosols, microbe-carrying particles, huge amounts of bacteria-carrying airborne skin cells, dust, droplets and droplet nuclei. At the same time, there is always a contact transmission from contaminated environment, equipment, textiles and waste. *Droplet nuclei* are small evaporated droplet residues (<5 µm) produced by coughing, sneezing, shouting, singing and speaking very distinct—especially the consonants. Droplet nuclei remain for many hours in the air and may be carried by normal air currents in long distances outside the room. Therefore, “droplet isolation and droplet precaution” is included in the airborne isolation regime. *The source of infection* is usually a patient but may also be a healthy carrier. The patient should be placed in isolate dedicated for airborne infections.

Keywords

Airborne pathogens · Droplet nuclei · Air and contact isolation · Protection · PPE
Healthcare personnel · Control

18.1 Purpose

To prevent transmission from an infectious patient to other patients, personnel, visitors and the environment and to protect patients with impaired immune defence against infection [1–8].

18.2 Comprise

- All patients having contagious disease that can easily be transferred directly or indirectly via contact, blood and body fluids, air/droplets or via equipment, textiles and surfaces.
 - All patients with significant reduced infection defence or otherwise infection vulnerable and who should be protected against infection.
-

18.3 Responsibility

Hospital management should ensure necessary capacity and type of isolating units: contact- and air-droplet isolates and protective isolates. Updated isolation routines, adequate protective equipment—including PPE—routines for disinfection of rooms and surfaces and disinfectants and hand hygiene facilities should be available.

Department management should implement isolation procedures, train the use of PPE, control the use of routines and provide sufficient stock and capacity of PPE and means for disinfection and hand hygiene.

The staff should follow current guidelines for treatment of patients with infections and for patients that should be extra protected against infections.

18.4 Practical Measures

There are many guidelines that are discussing airborne infections and definitions and methods to stop the spread by air [1, 2, 9–16]. Air outside houses normally contain a variable load of bacteria, dust and particles, and the number of bacteria may be 40–100 CFU (colony-forming units) per m³ (1000 L) air. Inside rooms where healthy people are present, the number may increase to 300 CFU or more, dependent of number of people and area. In operation rooms, it is recommended not more than 100 CFU/m³ air to reduce risk of postoperative wound infection.

All humans are continuously releasing bacteria and skin cells to the air and environment while moving around and are continuously picking up new microbes from the environment and air. In hospitals, there are many patients with infections (20–30% of the patients—hospital associated or not) that may spread pathogenic microbes to the air in the patient room or other places [17–20]. About 10–20% of infections in hospitals and other healthcare institutions are airborne [9, 11, 12]. The transmission may be either directly from a sick patient coughing or sneezing or indirectly via re-aerosols from bedding, cleaning and other activities in the room of a patient with infection [1, 2, 9–16, 21].

The design of isolates for airborne infections is very important to control the spread in the department [22–24]. However, without good knowledge, good routines and the use of personal protective equipment (PPE), no well-designed isolate can stop the spread [2, 9–16, 21–27].

18.4.1 Infections [3, 11, 12]

- Virus gastroenteritis with vomiting, splashing, aerosol, droplets (noro-, rota-, sapo- and bocaviruses, etc.)
- Respiratory tract viruses (respiratory syncytial virus (RSV), metapneumovirus, bocavirus, parainfluenza viruses, coronavirus, influenza virus, etc.)
- Pandemic influenza
- Whooping cough, measles, rubella and mumps
- Chickenpox or shingles (varicella-zoster virus)
- Herpes simplex in newborns in paediatric and maternity wards
- Systemic infection with meningococci first 24 h after start of treatment (meningitis, septicaemia). Also evaluated the same way by systemic, severe infection with *Haemophilus influenzae*, pneumococci and group A streptococci (sepsis, meningitis, necrotizing fasciitis)
- Pneumonia caused by *Staphylococcus aureus*
- Suspected or known infectious pulmonary tuberculosis
- Ornithosis, tularaemia
- Large, uncontrolled secretion of pus from the wound
- Multidrug-resistant bacteria and MDRO (multidrug-resistant organisms)
- MRSA, methicillin-resistant *S. aureus*, or vancomycin-resistant MRSA (VRSA). Earlier been infected by MRSA—ever, to disprove infection by negative tests. Exposed to MRSA last 12 months without supervision and monitoring, to disprove infection by negative tests
- Import patient, after contact with healthcare abroad last 12 months
- VRE, vancomycin-resistant enterococci, or multidrug-resistant enterococci (resistance to ampicillin and gentamicin)
- Penicillin-resistant pneumococci (PRP) or multidrug-resistant pneumococci
- Other bacteria that can infect humans via air (multidrug-resistant microbes like *Acinetobacter baumannii*, *Burkholderia cepacia* and multidrug-resistant *Pseudomonas aeruginosa* in the respiratory tract or burns)

18.4.2 Airborne Infection Isolation Unit [3, 11, 12]

- Airborne infection isolate with a defined negative air pressure (-16 to 25 Pa).
- Alternative is contact isolate with sluice.
- Single room with separate bathroom—entrance from the patient's room—or, if not a bathroom, use of bedpan or urine bottle. This can only be used for a short term until the patient is transferred to an airborne infection isolate and depends on the type of infectious agent.
- *Isolate for airborne infections* should have a sluice (anteroom), patient room and bathroom with toilet/washstand/shower and a throughput decontaminator/autoclave.
- *Ventilation and pressure.* Controlled negative pressure ventilation (-16 to 25 Pa) with the lowest negative pressure in the sluice (-10 to 16 Pa), increasing to the

patient room and further increasing to the highest negative pressure (-20 to 25 Pa) in the bathroom/disinfection room where the room air is exhausted. It is recommended 6–12 air changes per hour. Incoming fresh air comes from the ceiling or high up on the wall of the patient room. Outgoing used air is extracted ca. 15 cm from the floor (diagonal) or via openings in the lower part of the door to the bathroom/disinfection room. Outgoing, used air is extracted ca 15 cm from the floor (diagonal) or via openings in the lower part of the door to the bathroom/ disinfection room. From the bathroom/disinfection room, the used air goes via a full decontamination with UVC, through varying filter types, including hepa-filters, before entering separate exhaust channels over the roof—far away from incoming air pipes.

- *Interlock of doors* so that only one open at a time. One of the doors in the sluice must always be closed.
- *The sluice* must be large enough that a bed can stand there with both doors closed. It must be spacious enough for dressing and undressing of PPE without self-contamination or contamination of the equipment in the sluice. The room must have a sink for handwashing. Throughput cupboards between bathroom and sluice can create ventilation problems and should be completely sealed, and the cabinet doors must be interlocked. Throughput decontaminator or autoclave from the bath to the sluice is an advantage for the disinfection of infection-prone equipment.
- *The patient room* must be large so that visitors do not come too close to the bed—about 2 m distance from the bed on the sides and, at the foot end, at least 20 m². During intensive treatment (respirator, dialysis, monitoring, etc.) and presence of two intensive nurses, there is a need for at least 35 m² space per patient. The room should have a sink for handwashing and a robust inventory that withstand disinfection with chemicals.
- *Decontamination room and bathroom* have entrance directly from the patient room, with door that turns into the patient room. The room contains a toilet, shower, throughput decontaminator or autoclave and cabinets for necessary equipment to the patient.
- *Direct access from outside*. It is an advantage of direct access to the outside of the building via a separate sluice for direct patient in and out.

Well-equipped airborne infection isolates may be used for all types of isolation requirements concerning infectious diseases, including high-risk infections that require strict isolation.

An alternative for a shorter period may be a contact isolate or a single-patient room with sluice (anteroom with handwash) and a separate bathroom with decontaminator.

18.4.3 The Entrance of the Isolate Is Marked

When used for patients with airborne infections, a poster with a pink colour (for instance) with information is set up on the entrance to inform the staff about the

state of the isolate and the use of PPE. Contact hospital infection personnel when needed.

Donning PPE before entering the patient room in this order [11, 12]:

1. *Gown* is used by everyone—disposable is preferred—with long sleeves and cuffs. The disposable gown is only used once. Multi-use gown is not recommended, but if used, it should be hanged in the patient room (beside the door) with the outside out or—if there is sluice/anteroom—should be inside of the gown hung out. The multi-use gown is changed after each shift or more often when needed and should only be used for a single patient. Waterproof, disposable gowns or disposable plastic aprons are also used if there is spillage/liquid.
2. *Cap/hood* is used by everyone. It keeps the hair in place and covers the ears. Surgical mask or respirator mask is fastened outside the cap (and then, it is better fastened).
3. *Surgical or respirator masks* are used by all, fastened on the back of the head and the neck. It should be well fitted over the nose and mouth.
4. *Respirator mask* with P3 quality protection is used for:
 - Pulmonary tuberculosis, all forms and on suspicion.
 - Varicella-zoster, morbilli (measles), pertussis in non-immune person.
 - Serious, highly pathogenic, airborne infections—see strict isolation.
 - Pandemic influenza.
 - Responsible physician decides the use of face masks or respirators.
 - Beard prevents sufficient effect of respirators and other face masks.
 - Leak test should be done.
5. *Face shield/visor/protective eyewear*—used in case of splashes, droplets and aerosols with infectious material.
6. *Room-bound shoes*—by widespread transmission of infection in the room. Room-bound shoes may be heat disinfected in decontaminator after use—or use disposable shoe covers.
7. Gloves—used by all; long cuff that covers the wrist. The use of double gloves may do the work in isolation easier.

Doffing in the sluice or at the exit door if the room has no sluice/anteroom: [11, 12]

Remove PPE in such a way that you do not contaminate yourself or the environment. Doffing is done in a defined area in the sluice on the unclean side. In this order, take off the PPE that you have used:

1. Hand disinfection with gloves on.
2. Room-bound shoes or shoe covers—if used. Room-bound shoes are tilted off and put foot straight into your own shoes. **NB!** If shoe covers are used, remove them with gloves on.
3. Hand disinfection with gloves on.
4. Gloves: learn the method to take off without recontamination. One is turned inside out when taken off and used as a cloth to remove the second glove.

5. Hand disinfection.
6. Gown: learn the gown doffing method; open closure on the back (top first), pull the cuffs forward over the hands and gently roll the gown off without touching the outer side of the gown. Gently place the disposable gown in the waste container. Multi-use gowns should be hung in the sluice/anteroom with the inside out. In the case of no sluice, it should be hanged in the patient room at the exit door with the outside out. Change at least for every shift. Disposable gowns are infectious waste; multi-use gowns are infectious textiles.
7. Hand disinfection.
8. Surgical or respirator mask: take back and loosen tape first in the neck and then on the head, and bend the body forward to avoid contact with skin, hair, etc., when taking off the mask.
9. Hand disinfection.
10. Face shield/visor: if used, loosen from behind as a mask.
11. Hand disinfection.
12. Cap/hood: remove from the back as a mask.
13. Disinfect or wash hands.

For textiles, disposable equipment, reusable equipment, crockery/cutlery, waste and sharp objects, see contact isolation.

18.4.4 X-ray or Other Large Equipment in the Isolate [11, 12]

All equipment must be disinfected after use. Cover the X-ray cassette with a clean pillow case (or other clean cover) before it is taken into the patient. After X-ray, transfer the cassette to a new, clean pillow case (wipe off with alcohol before the transfer) in distance from the patient, in a cautious way. In the sluice, uncover the cassette carefully and disinfect it completely with 70% alcohol. Then bring it out in a new pillow case. It is notified about the infection.

Journal trolleys or papers are not taken into isolates. Paper from the isolate that is needed may be put in clean plastic folders before leaving the room for copy (in plastic folder) before the paper is discarded as infectious material. The copy may be submitted to the journal.

Medical Examination/Treatment in Other Departments/Death of the Patient

Provide good advance information on infection risk to relevant departments. Mors is taken care of in the isolate. The requisition is marked in uppercase letters: AIR ISOLATION.

Before transportation to other departments, the patient should be washed and put on new, clean cloth, in a clean bed and with face mask.

X-ray examination: Evaluate X-ray examination in the isolate—see above. If examination is done outside the isolation unit, a fully airborne regime is made for the patient.

Surgical treatment should occur at the end of the daily operation programme, preferably on an operating room particularly suitable for the purpose, with no positive air pressure (preferably negative pressure), without LAF (laminar air filtration) system and with a subsequent decontamination of the room as airborne contamination.

Remember good information to all who are treating/taking care of the patient—even when this occurs in isolation unit—such as physiotherapy, sampling, cleaning and so on.

18.4.5 Laboratory Tests

Follow guidelines for contact isolation. Note the remiss with capitals for airborne infection isolation.

Transport of patients outside the isolate is avoided if possible [11, 12]:

- Only essential transport is permitted and performed by experienced personnel. The ward's personnel must always accompany the patient. Staff transporting and receiving the patient must receive information about airborne infection regime, *in advance*, and information concerning adequate precautions during transport, including clothing and the use of cap, surgical mask/respirator, gown and gloves.
- The patient should have clean clothes and clean bed and should wear a surgical/respirator mask when outside the isolation ward. Avoid transport through other wards. Transport a dead patient in clean bed and clean cover or in body bag.
- When the patient is going home by ambulance before he is free from infection, the ambulance personnel must be informed so that adequate measures are implemented. The ambulance should not have unnecessary equipment. Bed/stretcher and the cabin should be disinfected after use in ambulances.
- Hand hygiene before and after the transport.

18.4.6 Books

Follow guidelines for contact isolation.

18.4.7 Visitors

- Contact the ward office for information about actual protective measures and hand hygiene.
- Visitors are using the same guidelines for attire as the staff.
- See also other information for visitors.

18.4.8 Daily Cleaning [11, 12]

Use water, ordinary detergent and clean equipment. Special cleaning and disinfection may be appropriate in certain cases—daily. If there are spills of blood or body fluids, the nursing staff should immediately remove the spills with gloved hands and afterwards disinfect the area with chloramine 5% or household bleach, or peracetic acid, before cleaning.

After use, disinfect mops, cloths and buckets in decontaminator. Consider disposable equipment such as mops and cloths.

Do not handle the used mops/equipment without gloves/infection gown/masks!

Termination of isolation: [11, 12]

- After completion of the isolation period, all disposable equipment (including unused) like creams, soaps, bandages, etc. which have remained in the room during isolation is treated as infectious waste. All textiles in the room are treated as infectious and sent for laundry.
- Beddings are carefully packaged (to avoid re-aerosols) and sent as infectious textiles.
- Bed equipment and mattresses which cannot be washed or disinfected in the room are packed, labelled, and sent to disinfection.
- Rooms, fixtures, bed, bathroom and all reusable equipment are disinfected with peracetic acid, chloramine 5% and household bleach or by other means.
- All handles, buttons, switches, call cord, waterproof mattresses, bed, nightstand, toilet, computer, telephone, TV and other contaminated fixtures and equipment are disinfected.
- Floors, walls (1.80 m up), lighting fixtures in the ceiling and other equipment should be disinfected. It is important to have good cleaning on all surfaces to avoid deposits of dust-bearing microbes.
- The responsible nurse, biochemist or radiographer must inform the cleaning staff about the disinfection area and the disinfectant to be used. After the disinfection, the room and all equipment are washed with soap and water.
- The room is aired 1 h after cleaning.
- Hydrogen peroxide 5% dry gas may be appropriate in addition to regular disinfection, especially in rooms with a lot of medical equipment and if problems with regular disinfection. Follow written procedures. Three subsequent disinfection cycles must be performed under control of effect on spore test. It does not work against tubercle bacilli but is otherwise approved against bacteria, viruses and fungi.

18.4.9 Main Cleaning: Turn Out All the Isolation Units

Consider the main cleaning of isolates 2–4 times per year, depending on usage and accumulation of microbes and dust. Check the filter effect, air ducts and negative pressure. Contact infection control personnel to be sure that the disinfection is done in a proper manner.

NB! Good hand hygiene is important! It prevents the spread of infection!
Isolation regimens should not be a hindrance for—but included in—diagnostics and treatment.

18.5 Background Information

See Chap. 21.

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Abstract

Strict isolation: suspected highly infectious and transmissible virulent and pathogenic microbes, highly resistant bacterial strains and agents that are not accepted in any form of distribution in the society or in the environment. Examples are completely resistant *Mycobacterium tuberculosis*, viral haemorrhagic fevers like Ebola and Lassa, pandemic severe influenza and coronavirus like SARS, MERS, etc. In most countries, strict isolation is a rarely used isolation regime but should be a part of the national preparedness plan. For instance, in Norway, strict isolation has not been used for the last 50–60 years, except for one case of imported Ebola infection in 2014. Patients in need of strict isolation should be placed in a separate isolation ward or building.

Infection spread by contact, droplet and airborne infection, aerosols, re-aerosols, airborne microbe-carrying particles, skin cells, dust, droplets and droplet nuclei. At the same time, it is always contact transmission (contaminated environment, equipment, textiles and waste).

The source of infection is usually a patient but may also be a symptomless carrier or a zoonotic disease.

Keywords

Highly infectious · Dangerous microbes · Airborne pathogens · Droplet nuclei · Air and contact transmission · Strict isolation · Personal protective equipment · PPE · Healthcare personnel · control

19.1 Purpose

To prevent transmission from an infectious patient to other patients, personnel, visitors and the environment and to protect patients with impaired immune defence against infection [1–8].

19.2 Comprise

- All patients having contagious disease that can easily be transferred directly or indirectly via contact, blood and body fluids, air/droplets or via equipment, textiles and surfaces.
 - All patients with significant reduced infection defence or otherwise infection vulnerable and who should be protected against infection.
-

19.3 Responsibility

Hospital management should ensure necessary capacity and type of isolating units: contact- and air-droplet isolates and protective isolates. Updated isolation routines, adequate protective equipment—including PPE—routines for disinfection of rooms and surfaces and disinfectants and hand hygiene facilities should be available.

Department management should implement isolation procedures, train the use of PPE, control the use of routines and provide sufficient stock and capacity of PPE and means for disinfection and hand hygiene.

The staff should follow current guidelines for treatment of patients with infections and for patients that should be extra protected against infections.

19.4 Practical Measures

19.4.1 Strict Isolation: Red Sign on the Entrance [9]

The isolation unit is usually located in a separate isolation ward or building and has defined as negative air pressure systems (in Pascal), separate ventilation with disinfection of air extraction, a properly interlock function and also direct access from the outside. The waste water is decontaminated (autoclave). The patient room has sluice systems and bathroom with through-put decontaminator or autoclave with direct entrance from the patient room.

19.4.2 Specialized and Trained Personnel

Personnel involved in treating high-risk infections should be specialized in isolation work and be healthy, not immunosuppressed, and if possible should be vaccinated, if vaccine is available. The staff should be bound to the ward/unit while isolation treatment takes place. Fewest possible should participate in the isolation work. The staff should come and go directly to the high-risk unit and should not stay, work or visit other wards during the isolation period.

19.4.3 Surveillance and Control

The infection ward should have restricted admission with registering (name, address, date, time, etc.) and follow-up of all staff and visitors that attended the department.

19.4.4 Actual Infections or Carrier State [1, 7, 9–20]

- Pulmonary tuberculosis with total resistant *Mycobacterium tuberculosis*, lung-cavern and expectoration.
- Diphtheria, plague and anthrax.
- Viral haemorrhagic fevers: Ebola, Lassa, Sabia, Junin, Lujo, Crimean-Congo (CCHF), etc. [9]
- Dangerous coronaviruses like systemic acute respiratory syndrome (SARS) and Middle East respiratory syndrome coronavirus (MERS-CoV).
- Other high-risk viruses: Nipah virus, bird viruses (avian influenza A) (H5N1, H7N9 etc.), rabies and other high-risk agents.
- Optionally by other infectious and serious diseases which can infect both via contact and air/droplet.
- Uncontrollable outbreaks of unknown infectious agents, with severe course and relatively high mortality. These patients should always be isolated in defined airborne infection isolation units with satisfactory negative pressure (-15 to -25 Pa) in relation to adjoining rooms, wards and outdoor air pressure.

19.5 Background Information

See Chap. 21.

19.6 Strict Isolation Unit

Isolation units for airborne infections should be safe enough for high-risk cases, if used properly [1, 9, 16–34].

There should be no offices, laboratories, other patient wards or other regular human activities under, over or around this isolation unit. The unit should be located in a separate ward, preferably in a separate building with direct access via an external sluice and internal access through a negative air pressure sluice with sufficient area for donning and doffing and for a safe treatment of infectious equipment and waste.

- Each isolate should be 35 – 40 m 2 , including sluice (6 m 2), decontamination room/bathroom (5–6 m 2) and patient room (20–25 m 2). There should be a minimum of 2-m free zone around the patient's bed on both long sides and at the foot end.
- There must be *direct access* from the patient room to the decontamination room/bathroom.
- Interlocked doors must be included in the sluice system. Opening of the doors should be in direction from negative pressure to the positive pressure room to avoid air leaks. If the negative pressure increases in the room, the door will close even tighter.
- No through-put cabinet from the disinfection room/bathroom, because it can create imbalances in the air pressure.

- *Through-put autoclave/decontaminator* from disinfection room to the sluice may be recommended if secured and controlled against air leakage.
- *Graduated negative air pressure* is quality ensured by measurements, pressure manometer and control of ventilation.
- *Exhaust from the isolation unit* must be disinfected in a satisfactory manner so that it does not expose personnel, patients or passers-by to infection. Exhaust is usually sent out from the disinfection room, via a separate disinfection unit where the used air is treated with UV-irradiated hepafilters, and sent out over the roof (see below).
- *Waste water, sewage and other waste* should be disinfected/autoclaved before it is discharged outside the isolation area. If the isolate is not a unit for collecting and treating infectious waste/liquid, the faeces, urine and other body fluids are treated locally with 5% chloramine in 1 h before being discharged to the public sewage system.

19.6.1 Negative Air Pressure and No Air Contamination

[1, 9, 16–34]

There should be written guidelines for air pressure and air flow. Negative pressure should be defined in relation to adjacent rooms and to outside pressure. Pressure conditions are checked outside of the patient unit, *before* entering the unit. There should be an increasing negative pressure from the sluice through the patient room to the disinfection room. The following negative pressure in Pascal is recommended in the unit:

o	Sluice:	-6 to -10 Pa
o	Patient:	-10 to -20 Pa
o	Bathroom/disinfection:	-25 to -45 Pa

The negative air pressure must withstand fluctuations in the pressure outside the building, for example, during high winds with increased pressure against the building. It should not be related to pressure fluctuations within buildings. The unit must be tight to prevent air leakage and pressure variations.

19.6.2 Ventilation

- *No air leaks.* All ventilation ducts must be completely sealed without any air leaks (e.g., all-welded steel pipe) and with a separate (over roof) air input and outlet for each isolation unit. Disinfection systems for air extraction/exhaust should be placed as close as possible to each isolation unit so that contaminated air does not go far in the piping on the way out. Exhaust air must be sterile after the disinfection process. Externally placed pipes for air inlet and outlets from isolates must be protected from strong winds that can create unfavourable pressure conditions. The air inlet/outlet to other parts of the hospital must also be

protected against contamination from the isolates. Therefore, separate isolate buildings are the best solutions.

- *Air change.* Minimum of six changes of fresh air per hour in the patient room. This involves the replacement of all air in approximately 70 min. Avoid short circuit of the air currents.
- *Clean inlet air*—HEPA-filtered and backlash secured—is introduced from the ceiling or top of the wall of the patient room in such a way that the least possible turbulence occurs during normal use.
- *Exhaust air is contaminated* and should be disinfected and HEPA-filtered closest possible to the isolation unit. All air from the isolation unit goes out via the separate exhaust system; from the patient's room through grates on lower end of the door to the disinfection room. The exhaust air is disinfected close to—or in the isolate to avoid contaminated air in the piping. Exhaust air is never drawn directly out from the patient room or from the sluice because of risk of unfavourable air currents and increased infection burden on personnel. Exhaust air must be sterile after treatment and sent out via pipe over roof.
- *Gassing of ventilation pipes* with disinfecting gases (formaldehyde, chlorine dioxide, hydrogen peroxide, etc.) must be implemented in a regular manner. Assuming the ventilation duct is completely closed and separately for each unit, various types of gas could be used. If leakages are suspected, it may be difficult to use formaldehyde gas (allergy) and chlorine dioxide gas if other part of the building is to be used. The type of gas used must be chosen according to documented effect of the infectious agent, for instance, Ebola infection. Chlorine gas and hydrogen peroxide dry gas are among the safest gases used today. There is currently no gas which disinfects tubercle bacilli.
- *Continuous electricity supply* must be ensured in the isolation unit and the ventilation and negative pressure system.

19.6.3 Robust Fixtures, Walls and Floors

All fixtures and equipment must be disinfected with strong disinfectants, including disinfecting gases, and must be cleaned easily and satisfactorily. Note! Disinfectant gas can affect instruments and equipment. There should not be wood, tile or other building materials that are easily chipped or cracked, with storage niches for infectious agents.

There should be handwashing and suspension of automatic dispensers of disinfectants and paper towels in the sluice, patient room and disinfection room, to avoid unnecessary contamination of doorknobs, etc.

19.6.4 Water Drains and Sewers

Thermal disinfection/autoclaving of waste water from the unit should be done the closest possible to the unit to prevent other wards/departments be charged with

infectious agents. The container, tank and piping must be absolutely tight and robust for heat/cold/corrosive agents and for ground movements. The drainage system must be shutdown, if needed. Air systems connected to the drain/sewer/water must be connected to isolation unit's exhaust system for full inactivation of infectious materials and must be completely sealed.

In isolation units with collection of infectious waste water in tank for further disinfection/autoclaving, it is particularly important to ensure safe and risk-free isolation conditions. This means that infected air, liquid and waste should not be spread to nearby areas, even under accidents in the decontamination process. All supply pipes to collection tanks must be sealed, controllable and withstand disinfectants. The sluicing function to such special areas for collecting and decontamination must be ensured in accordance with regulations for the airborne infection isolation units. In case of technical accidents in the collection and treatment rooms, the air should be disinfected with gases before technical personnel enters.

Technical staff, handling medical equipment, including collection tanks and autoclaves, shall be specially trained in infection control and must be able to use a sluice function with the use of PPE, when entering these disinfection areas.

19.6.5 Sluices In and Out

The sluices should be roomy with plenty of space for larger equipment, handwashing/hand disinfectant, through-put disinfection machine/autoclave, etc.

There should be a *separate out sluice* for doffing (undressing), bags for contaminated waste/equipment and opportunities to disinfect/autoclave used PPE—or parts of it—and other equipment. Room for a separate shower in the out sluice system should be considered and a room for disinfection of equipment to be reused (e.g. goggles, shoes, etc. that can be disinfected in chloramine 5% in 1 h or autoclaved).

The sluice system should be adapted for separate gas disinfection via sealed and tight pipes and interlocked system that can be implemented systematically daily or as needed, without affecting the patient in the isolation room.

Inter-locking. One of the doors in the sluice/anteroom must always be kept closed. Preferably use controlled closures for all doors.

19.6.6 Quarantine Unit and Cohort for More Patients [1, 9, 16–22]

- A *quarantine unit* should include some large patient rooms where it is a place for intensive treatment, acute surgery, dialysis and other invasive treatments, X-ray, microscopy of infectious materials, some important biochemical analyses, etc.
- *Cohort treatment* is important during larger outbreaks, i.e. two patients or more in one isolate room if they have the same infection and where reinfection does not occur.
- *Service unit associated with quarantine unit*. A separate *clean* service unit should be accessed via a separate sluice with interlocking doors for staff supervising the quarantine unit: the ward office, area 16 m², toilet/shower 5 m², storeroom

6–10 m², storage for large equipment 15–20 m², textile room 6–10 m², waste disposal room 10–12 m², etc.

19.6.7 In and Out Sluicing of Waste, Equipment and People [1, 9, 16–22]

- *Waste, reusable equipment, etc. from the patient or disinfection room* should be autoclaved in the through-put autoclave (or disinfection machine) from the disinfection room or patient room to a clean sluice where it can be taken out and treated as noninfectious. All equipment from patient unit must be autoclaved or disinfected in an appropriate manner. Equipment can be decontaminated at high temperature (>90° C) in an instrument washing/decontamination machine or submerged in a bath of chloramine 5% 1 h (or peracetic acid or household bleach 10%), depending on the agent in question. s.
- *In-sluicing and donning (dressing)* is done in a clean sluice before entering the unit, with clean, new clothes and clean, new PPE every time. Reuse of disposal PPE is not recommended.
- *Out sluicing* needs plenty of space for washbasin and suitable hand disinfectant, for doffing (undressing) and for the use of at least three waste bags (disposal, textiles and reusable equipment). PPE must be removed carefully, following guidelines, and placed in a waste bag which is then placed directly in through-put autoclave. Reusable equipment (goggles, shoes, etc.) that can be decontaminated/autoclaved are placed in separate containers for reuse. Then shower with, for instance, chlorhexidine (Hibiscrub) disinfectant in disposable packages, optionally soap in disposable packages. The shower head is set low and with weak force to avoid aerosols against the face. After the shower is finished, the entire cabinet interior, including the floor, is treated with hot water (>75 °C). Self-disinfecting shower unit (after use) is advantageous (gas or disinfectant liquid). Used towels are put in the textile bag. New, clean clothes are taken on in a clean wardrobe. Only the hospital's clothing and shoes are used.

19.6.8 Donning (Dressing) PPE Before Entering the Isolation Unit [1, 9, 16–20]

- *Gown*—disposable, with tight-fitting cuffs and discarded after each use. It should have long sleeves, be tight around the neck, long and liquid tight. The opening should be on the back; it should be tied back, never on front. Option: disposable coveralls with hood or full and tight costume.
- *Cap/hood—surgical*—covering all the hair and ears. Keeps the hair in place and covers the ears. Respiratory protection is set on the outside of the cap.
- *Respiratory mask, P3-level*, check leakage with leak test (to be learned). In special cases, a turbo equipment (PAPR, powered air-purifying respirators) or fresh

air/compressed air system is used. Remember that battery and reusable parts should be disinfected between each use.

- “Phantom hood” (surgical large disposable hood) is placed gently over the head and covers the neck and cheeks.
- *Face protection.* Tight-fitting goggles if high risk. Face shield with danger of splatter of infectious material.
- *Gloves* with long “cuff”, double gloves to make work in isolation easier. Latex gloves are denser than vinyl gloves.
- *Shoe covers/room-bound shoes* that may be autoclaved after use or boots that are submerged in chloramine bath or other disinfectant after each use.
- *Special leg covering* up to the knee at high risk, serious infection.

19.6.9 Doffing (Undressing) of PPE when Leaving the Isolate for out Sluicing: [1, 9, 16–20]

Follow the hospital’s procedure that must be learned, trained and supervised.

Check if waste bags and equipment for undressing are available in the sluice out. All work in the sluice out, like assistance with undressing, takes place only with full dressed PPE. As a rule, there are two people when undressing; a person who can advise and provide assistance, double pack infection bags and take care of equipment to be autoclaved. The assistant uses full, clean PPE. Gloves and hand disinfectant must be used before any handling of the equipment. All undressing must occur very carefully and quiet to minimal re-aerosols of microbes from the PPE.

Remove the individual infection equipment in such a way that you do not contaminate yourself or the environment. Carried out in this order:

1. Hand disinfection while the gloves are on.
2. Room-bound shoes/boots are tilted off and put foot straight into clean shoes.
Reusable shoes or boots are put in a separate container for autoclaving or disinfection. Shoe covers—if used—are carefully removed one after another and placed gently in the waste bag. Rinse the shoes on chloramine inserted diaper lying on the floor.
3. Hand disinfection while the gloves are on.
4. Gloves—double gloves are removed simultaneously—learn the method. Grab the left glove at the wrist (not higher up) and gently turn inside out when doffing. The inside of this glove is usually clean and can be used as a “cloth” placed on the right hand to grab through to remove (roll off) the other glove. Learn the technique. For left-handed do the opposite. Place gently in the waste bag.
5. Hand disinfection.
6. Put on clean gloves for further undressing—not over the cuff.
7. Gown—learn the method, open closure on the back (neck first). Pull the cuffs over gloves and roll the gown gently along from the side and from above downwards without touching the outer side. Place gently in the waste bag.

8. Hand disinfection while the gloves are on.
9. Goggles: take back and bend the body forwards to avoid contact with the skin, hair and cloths while taking off the goggles carefully. Place in container for autoclaving of reuse.
10. Face shield/visor—loosen from behind as mask and take off bending forward.
11. Gloves—learn the method to take off without recontamination (see above). Placed gently in the waste bag.
12. Hand disinfection.
13. “Phantom hood”; take back on the lower part of the hood that has been covered by the gown, and with both hands tear it up along the seam behind while bending the body forwards to avoid contact with the skin, hair and cloths; take off the hood slowly, and put it in the waste bag.
14. Hand disinfection.
15. Respiratory protection mask—grasp the elastic back on the head; bend the body forwards to avoid contact with the skin, hair and cloths; take off carefully, and place the mask in the waste bag.
16. Hand disinfection.
17. The surgical cap/hood—which was under masks and phantom hood; take off from behind, bend the body forwards to avoid contact with the skin, hair and cloths and place the cap in the waste bag.
18. Hand disinfection.
19. Showers and dressing of new clothes as described above.

19.6.10 Textiles

Autoclaved or heat disinfected (85–90 °C for 10 min) or submerged in disinfectants (chloramine 5%, household bleach 10% or peracetic acid) before normal processing.

Option: All textiles are treated as infected and put in a container for used textiles. Contaminated/wet fabrics are packed in plastic before placing in waterproof textile bag. The outside of the bag is decontaminated and washed with 5% chloramine before double packed with a new clean bag in the sluice. The outside will then be clean during transport for further treatment. The type of the infectious agent and local possibility determine further treatment of textiles (heat washing, chemicals, autoclaving, burning).

19.6.11 Reusable Equipment

Excess equipment should be removed before the patient arrives. Used equipment should be autoclaved in a through-put autoclave before the normal treatment.

Option: Disinfected in the isolation unit’s disinfection room. Equipment that can withstand heat is heat disinfected in decontaminator or instrument washing machine. Heat-sensitive components like thermometers are disinfected in 5% chloramine or other disinfectants for 1 h.

19.6.12 Crockery/Cutlery

Used equipment should be autoclaved in a through-put autoclave before normal treatment.

Option: Decontaminated in the isolation unit's disinfection room (85–90 °C) or double packed and brought to the decontamination room in the ward for decontamination—and then processed as usual. Disposable equipment is treated as infectious waste.

19.6.13 Waste

Infectious waste is autoclaved in through-put autoclave, before processing as ordinary waste.

Option: All waste is double packed and treated as special infectious waste. The outside of the bag is decontaminated and washed with 5% chloramine before double packed with a new clean bag in the sluice. The outside will then be clean during transport for further transport and treatment. Infectious waste is brought directly to incineration without intermediate storage.

19.6.14 Syringes/Needles

Follow general guidelines. The boxes may be autoclaved in through-put autoclave, before processing as ordinary waste.

Option: Boxes are double packed and treated as special infectious waste. The box must not be filled more than about $\frac{3}{4}$ full. See labelling for filling level. The outside of the bag is decontaminated and washed with 5% chloramine before double packed with a new clean bag in the sluice. The outside will then be clean during transport for further special transport and destruction. Infectious waste is brought directly to incineration without intermediate storage.

19.6.15 Examination/Treatment/Death

In most cases it is not recommended to bring the patient out of isolation during the period of active infection. Special solutions should be made for these. If transport out of the isolate is necessary, everything must be planned carefully in advance. Death bodies are wrapped in body bag, double packed in the sluice and sent directly to the pathologist or burial. Remember information in advance!

19.6.16 Laboratory Tests

Follow general guidelines and contact serving microbiological laboratory or the National Institute of Public Health before transport of sampled biological materials from the patient! Sampling/preparation for transfer of infectious sample material should be provided in the patient room or its disinfection room. Sample vials and outside of the package must be clean before transport. Blood samples from patients with blood-carrying infection are packaged in special cases (sleeves) before transport. The outer package is put on in the sluice. NB! A good cleaning and disinfection of the workplace!

Note on the outer bag suspected high-risk agent with red ink! Special transportation!

Contact receiver in advance, and ask how to bring the samples to the laboratory.
SEND NO SAMPLES AS POST IN PNEUMATIC TUBE!

19.6.17 Transport of the Patient

Only essential transport is allowed, depending on infectious agents. Patient, cloth and stretcher/bed should be clean during transport. Bandages must be clean, and drains, etc. must be covered and free of leaks. Staff transporting and receiving the patient must be informed about the infection *in advance* and guided on individual infection prevention and the use of PPE. Patients with respiratory infection should wear surgical mask or respiratory mask (P1–P3 level) outside the isolate.

The transport should not go through wards or crowded areas and avoid the use of a lift. Internal transport in hospitals is not recommended in certain highly infectious and severe illnesses.

19.6.18 Books and Newspapers

In agreement with the patient library, the patient can borrow books that can be discarded. The books are kept in isolation. All books are treated as infectious waste by termination of the isolation.

19.6.19 Visitor

Restricted admittance and use the same guidelines and PPE (donning and doffing) as for the staff. Handwashing is required when the sluice is left. Limit visits to a minimum, especially with highly infectious diseases such as SARS.

19.6.20 Daily Cleaning

The cleaning and disinfection is performed by trained personnel with required attire and use of PPE. Regular detergent, water and clean equipment are used if no other routine is ordered. Bucket and squeegee are disinfected in the decontaminator of the isolation unit; shaft is disinfected chemically in 5% chloramine (or household bleach) in 1 h and kept in the unit during the entire treatment. Use only disposable mops and cloths placed in yellow plastic bag in yellow infectious waste bag and autoclaved in the isolation unit. Discard as infectious waste after appointment.

Option if not autoclave/decontaminator in the isolation unit: Infectious waste bag is treated exterior with 5% chloramine and double packed in new yellow thick plastic bag in the sluice. Special infectious waste is brought directly for burning/autoclaving. In case of spills, the nursing staff should immediately remove the spill and disinfect the area with 5% chloramine 1 h (covered by plastic) before cleaning.

19.6.21 Termination of Isolation: Disinfection

Before regular disinfection of the isolation unit after terminated isolation, it is recommended to treat the unit with hydrogen peroxide dry gas, three cycles, using a spore control. Only trained personnel are participating in the work with disinfection, and they use mandatory infection control equipment. The nurse, in cooperation with infection control personnel, is responsible for informing the staff about what should be disinfected and how.

Bedding, curtains, drapes, etc. should be autoclaved, if possible, before sending it to laundry or to incineration. Floors, walls, ceilings, all horizontal surfaces, ceiling suspension, lighting in ceilings, etc., handles, dial string (changed), levers, buttons, switches, bed, waterproof mattresses, bedside tables and other fixtures and equipment (TV, telephone, computer, etc.) are disinfected with 5% chloramine (or household bleach 10%) for 1 h.

Textiles, reusable equipment and waste: follow described above recommendations. Unused disposal equipment that has been inside the isolation unit is disposed of as infectious waste.

After manual disinfection, all rooms and ventilation systems are gassed once more. This is done in collaboration between the ward, housekeeping/technical and infection control personnel. To treat with gas disinfection before and after manual disinfection is recommended to reduce the infectious airborne agent (aerosols and re-aerosols) in the unit.

After the recommended effect period of the disinfectant, the rooms are cleaned with ordinary detergent, water and clean equipment.

There are many discussions concerning the degree of airborne transmissions and how to protect personnel, especially against dangerous infections; see the background information [1, 9, 16–20, 27–50] (Fig. 19.1).

Isolation regimens should not prevent treatment but be included in the diagnosis and treatment.

NB! Good hand hygiene is important! It prevents the spread of infection!

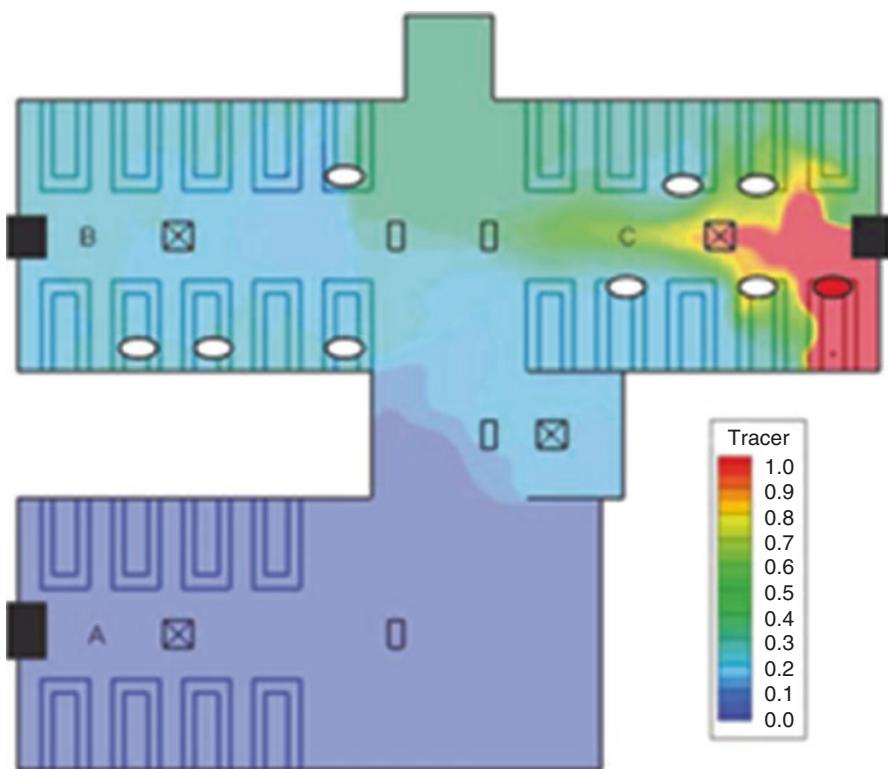


Fig. 19.1 Example: possible aerosol transmission in an outbreak with influenza virus. Airborne transmission with airborne indicator in an intensive unit. Distribution in rooms of generated, normal concentrations of hypothetical, virus-borne, marked aerosols—like droplet nuclei—in a level of 1.1 meter over the floor, traced with an instrument. A defined airflow was used. Three HEPA filters in the unit were estimated to be 100% effective concerning filtration of droplet nuclei and are shown as black boxes on the figure. Four inlet channels are shown with rectangular X and four outlets with small rectangular filled boxes. Infected patients are defined by white ovals and index patient with a red oval. *Source:* Wong BCK, Lee N, Li Y et al. Possible Role of Aerosol Transmission in a Hospital Outbreak of Influenza. *Clin Infect Dis* 2010; 51:1176–1183 [45]

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Protective Isolation

20

Abstract

Protective isolation is used in healthcare institutions for patients with increased susceptibility to infections, deliberately or not, like transplants, cancer treatments, premature new-borns, extensive burns and other immune-impaired patients. Extensively treated intensive patients are also infection prone and extremely exposed to infections when placed in large bays with other patients. Since one out of three patients in hospitals has infections that may be transferred to others directly on the same room or indirectly via staff and equipment, it is important to take special care of the weakest patients that may have a poor ability to resist infections. Protective isolation is a very good, effective and economic alternative to hospital infections, increased length of stay and overuse of antibiotics.

Keywords

Immunosuppression · Transplantation · Cancer treatment · Infection susceptible
Protective isolation · Protective environment · Protection · Isolate · Healthcare personnel · Control

20.1 Purpose

To prevent transmission from an infectious patient to other patients, personnel, visitors and the environment and to protect patients with impaired immune defence against infection [1–8].

20.2 Comprise

- All patients having contagious disease that can easily be transferred directly or indirectly via contact, blood and body fluids, air/droplets or via equipment, textiles and surfaces.
- All patients with significant reduced infection defence or otherwise infection vulnerable and who should be protected against infection.

20.3 Responsibility

Hospital management should ensure necessary capacity and type of isolating units: contact- and air-droplet isolates and protective isolates. Updated isolation routines, adequate protective equipment—including PPE—routines for disinfection of rooms and surfaces and disinfectants and hand hygiene facilities should be available.

Department management should implement isolation procedures, train the use of PPE, control the use of routines and provide sufficient stock and capacity of PPE and means for disinfection and hand hygiene.

The staff should follow current guidelines for treatment of patients with infections and for patients that should be extra protected against infections.

20.4 Protective Isolation

Isolation is needed to stop the spread of infections in healthcare institutions [1, 2, 9–23] Protective isolation is to stop microbes from infecting a patient with increased susceptibility to infections [9–11, 19, 22, 24–26]. The environment of infection-prone patients is needed to be very clean to reduce the load of microbes from other patients, staff, equipment, air, visitors, food, water, ventilation, textiles, etc. Guidelines for protective environment of special patients with allogeneic haematopoietic stem cell transplant (HSCT) are made “to minimize fungal spore counts in the air and reduce the risk of invasive environmental fungal infections” (CDC in 2004 and 2007) [9, 19].

20.5 Background Information

See Chap. 21

20.6 Practical Measures

Protective isolation (blue sign) is used for patients with increased susceptibility to infections because of treatment or/and disease, to reduce the risk of transmission of infectious agents via contact with infected equipment, other patients, staff or visitors [22, 24–33].

Actual disease/condition needing protective isolation:

- Agranulocytosis.
- Neutropenia; <0.5 in granulocytes, or rapidly falling number of <2.
- Burns that do not require treatment in a specialized unit.
- Patients with severely weakened immune system due to the treatment with immunosuppressant, antineoplastic agents or radiation (cancer or leukaemia) should be considered.

20.6.1 Protective Isolate Unit

Single patient room with large anteroom/sludge, including wash basin and a separate bathroom with decontaminator, total area: 30–35 m². The patient room should be large enough so that staff, visitors, equipment, etc. do not come too close to the patient [22, 27] Floor heating system should be installed in bathrooms and patient rooms.

Ventilation and air pressure. Positive air pressure is recommended (approximately +10 to +25 pascal) against nearby rooms and outside pressure. The rooms should be well sealed (walls, floors, ceiling, windows, electric outlets) [19, 23, 24]. HEPA-filtered/sterile air supply is required in severe, prolonged neutropenia. HEPA-filtered air should be taken directly to the patient room—from the ceiling or high up on the wall. The air should be pretreated as concerning temperature and humidity. Avoid excessive air flow which can be uncomfortable for the patient. Exhaust is going out at the floor level or bathroom. There are at least 12–14 air changes per hour. Pressure ratio is checked daily (manometer). Avoid through-put closet that can interfere with the pressure balance. All doors should always be closed due to the positive air pressure.

Robust inventory, walls and floors. All fixtures and equipment must withstand disinfection with strong disinfectants and must be cleaned easily and satisfactorily. There should be no wood or other building materials which may easily be cracked, be broken and store niches for infectious agents.

In *allogeneic* stem cell transplantation, it is recommended that the patient room should have >12 air changes per hour and HEPA-filtered air (>99% which removes particles >0.3 micron diameter). For *autologous* stem cell transplantation, the same is recommended for patients with prolonged neutropenia. The incoming air flow should be regulated and come from the ceiling or high up on the wall and exhausted on the floor level without any “short circuits.” It is recommended that there is a thorough sealing around windows, cable outlet, doors, etc., as well as emergency power to keep the pressure up during a power outage.

All construction activity around the room where there are infection-susceptible patients should be carefully planned because of the release of fungal spores, etc. from building structure in connection with construction work.

Patients with compromised immune systems should not be placed in rooms with water damage and rot in the walls, and a risk of fungal growth, or where there is construction.

20.6.2 Protected Against Infections

The patient must be protected from other patients with ongoing infections or drainages.

The patient must be informed of good hand hygiene and good personal hygiene and the use of hand disinfectant.

NB! Staff or visitors with respiratory infection or other infections should not ordinarily have access to the patient room!

20.6.3 Visitor

There should no more than two visitors at a time and should not be visited by people with infections. Visitors should go directly to the ward office, sign up on arrival and do not stay anywhere else in the department. This is to prevent hospital infection.

- Visitors follow the same procedures as staff with hand hygiene and attire and must be trained in this.
- NB! Jewellery and wristwatch should be removed.
- Do not use the patient's hand basin, toilet or shower.
- It is not permitted that visitors bring with them flowers, fresh fruits or vegetables because of the risk of microbial contamination.
- Visitors can bring their brand new newspapers, books and CDs but should contact the staff first.

20.6.4 Putting on Infection Control Equipment

The following should be accomplished *before* entering the isolate.

- *Hands and forearms* are washed with soap and water or alcohol. They should be clean when in contact with the patient or the equipment to use. Wounds on hands should be bandaged with waterproof bandage; wear gloves.
- *Clean uniform* when entering the patient room.
- Put on a *clean care gown* with long arms and sleeves and buttoned behind (often blue "clean colour"). Change after each shift and more often if needed.
- *Separate gown* (often yellow) used for infection and the administration of cytostatic.

- *Cap* that covers the hair and ears.
- *Surgical masks* tied behind the head and neck. Clamp over the nose and make sure it is firm and with the right side out.
- *Room-bound shoes* that can be disinfected/autoclaved—loaded in container for used shoes after use. Disinfected after each shift.
- *Hand hygiene* before entering.
- *Sterile gloves* when caring for CVK or other equipment that penetrates the skin/mucosal.

20.6.5 Undressing of Infection Control Equipment in the Lock

- Hand hygiene.
- Carefully remove the gown. In the case of infection, the gown is discarded after each use.
- Clean care gown is inspected and discarded after each shift or more frequently if there are spills. Hung on its peg for used gown with *inside out*.
- Gowns used by visitors, doctor visits, physiotherapist, laboratory staff, etc. are discarded immediately after use.

20.6.6 Personal Hygiene for the Patient

The patient should be encouraged to ask for help and instruction from the nurse.

- *Daily shower* with clean, mild soap and warm water; use a new soap unit each time, and eventually help with whole-body wash. Begin at the top of the cleanest areas and finish at the bottom; first in front, then behind. Let the water run down all the time.
- *Dry well* in all skin folds, including between the toes, and use a neutral, mild skin cream—new unit each time. If the skin is sore, use a hair dryer to dry.
- *Afterwards, the shower cabinet is washed* by the staff, using hot water—as hot as possible—to remove biological materials and microbes, and rinse thoroughly before shower. No one should use the shower or toilet other than the patient—not even visitors. The shower head and hose are hung in place afterwards.
- *Infusion site* for central or peripheral blood catheters, drainages, etc. are well protected during showering and carefully sterilized afterwards.
- *In lavatory*, use disposable gloves, disinfect the seat prior to use and dry off the alcohol with a clean, soft toilet paper before sitting down, or—optionally—cover the seat with clean toilet paper. Use disposable gloves and wipe genitalia from the front to the rear. Wipe finally with wet gauze moistened with 1 mg/mL chlorhexidine and throw gauze in a separate disposal box. Each pad and wipe is used only once. Wash your hands afterwards. After finishing the process, disinfect your hands.

20.6.7 Oral Hygiene

To avoid infections, a good oral hygiene is important. The nurse guides the patient with regard to oral hygiene. Only disinfected equipment should be used (new toothbrush and tooth glass each time and new tube of toothpaste every day). It is important to minimize sores in the oral mucosa.

20.6.8 Patient's Belongings

Packed and sent home or disinfected with alcohol, decontaminated or machine washed. Should not have contact with money which may be contaminated.

20.6.9 Textiles

Textiles should have a high degree of purity and be ordered and delivered directly from the textile department/laundry to the isolation unit. The textiles should be laundered at high temperatures ($>80^{\circ}\text{ C}$), placed in clean plastic bags and transported directly to the isolation unit—without intermediate storage in the ward textile room or on trolleys/in the hallway, exposed to microbes. Clean clothes should be delivered every day or more often when needed. Textiles can be stored in a clean cupboard in the sluice or on the patient's room but must be replaced every 24 h when the cupboard is cleaned and disinfected. It is also used in procedures for dry sterilization of textiles immediately before use. Preferably, the patient uses the hospital's laundry, which is washed with high temperature and changed daily. Private cloths may be used if washed daily at $>60^{\circ}\text{ C}$.

Soiled textiles are removed as quickly as possible and treated according to general guidelines.

20.6.10 Reusable Equipment

Equipment should have a high degree of purity. It must be clean and taken directly from a clean stock without intermediate storage trolley/in the hallway. It can be stored in clean cabinets in the sluice for 24 h and subsequently cleaned while the cabinet is washed and then disinfected. Used equipment is treated according to general guidelines.

Before X-ray devices and other large equipment are taken into the room, it is washed over with soap and water, followed by disinfection. Remember to wash and disinfect the wheels.

20.6.11 Crockery/Cutlery

Regular dishes/cutlery are treated as ordinary washing at $\geq 85^{\circ}\text{ C}$.

20.6.12 Food

The patient's hands are washed before meals. It should be in consultation with the attending physician in each case considered whether the patient should get raw vegetables or fruits. By granulocytopenia <0.5, the patient should have only cooked vegetables. Avoid raw fruit (or wash and peel the fruit). NB! Ice cubes and water may contain relatively large amounts of gram-negative bacteria and are not advisable to use!

The food should be ordered directly from the main kitchen with the message of very high cleanliness in the processing, packaging and transport to the ward. The food must be kept secure under very clean conditions—not openly available on the ward kitchen.

20.6.13 Waste

Waste should be treated as ordinary household waste. Cytostatic drug waste is treated separately.

20.6.14 Syringes/Needles

Follow general guidelines.

20.6.15 Examination/Treatment

Examination/treatment in other wards should be avoided, and if done it entails thorough information to relevant staff, and requisition should be labelled with information of the patient's susceptibility to infections. The patient should be examined/treated in a clean area, and the staff working should not have ongoing infections. Patients should not remain on the waiting areas along with other patients/relatives.

20.6.16 Bringing the Patient, Only When Needed

Staff transporting and receiving the patient must be informed about the patient's susceptibility to infection so that the patient can be spared for staff with ongoing infection. The staff following the patient (transfer) should have clean clothes, have good hand hygiene and use a surgical face mask. Transportation of patients should not go through the wards with infected patients. The patient is taken directly into the treatment room and brought from there directly back to the isolation unit. The patient uses a surgical face mask.

20.6.17 Books

Patients can borrow *new* books on patient library. Wipe books with alcohol before it is put into the room.

20.6.18 Flowers

No flowers on the patient's room due to growth of bacteria and fungi on the flowers.

20.6.19 Daily Care of the Patient

The patient must be cared for so that the personal hygiene is good. Good oral hygiene, often with the help of a trained nurse, is an important infection prevention measure. The patient should have a good hand hygiene, especially handwashing after using the toilet and before and after all meals.

20.6.20 Daily Cleaning

Daily cleaning is performed with ordinary detergent, water and *clean equipment*. The cleaning staff should follow the same precautions and routines as for the nursing staff. Thoroughly clean and dust daily, and rinse the filters of the bathroom weekly, in consultation with the nurse. This is important to minimize the risk of infection by dust accumulation and bacterial growth.

Nurse disinfects all tables and surfaces, off and on switches, TV, computer, telephone, bed, mattress, desk, nightstand, lamps, as well as all public contact points daily.

20.6.21 Terminal Cleaning: When the Patient Leaves the Unit

The isolation unit should be thoroughly cleaned and disinfected, including all rooms and surfaces to get rid of resistant strains between patients [23, 34–39]. This is very important. All loose equipment, disposables, fabrics, etc. should be removed. Reusable equipment should be gas disinfected for inner parts [38]. Gas disinfection process may be recommended before a new patient is treated in protective isolation [38, 39].

NB! Good hand hygiene is important! It prevents the spread of infection!

Isolation regimens should not prevent treatment but be included in the diagnosis and treatment.

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Background Information: Isolation Routines

21

21.1 Isolation

The isolation of patients with suspected or documented infections—to not spread to others—has been discussed for hundreds of years. Guidelines are many, methods are different, attitudes show vide variations, routines and procedures are still changing, regulations by law may be absent, and some healthcare professionals may be afraid of adverse outcomes of isolation [1–44]. Microbes that are spread in the environment, on the hands and equipment are invisible. The invisible agent does not call on attention before the infection; clinical disease, hospital infection or nosocomial infection is a factum that can be registered [23, 28, 29, 35–37]. How to stop the transmission is often “to believe and not believe” in infection control.

21.2 History

Isolation comes from the Latin word *isolare*, from *solus* meaning alone. *Isola* means a “deserted” island, including *Isola* outside Venice, Isola di Santa Maria di Nazareth, where the first permanent quarantine hospital—nazaretto changed to Lazaretto (Lazarus)—was created in 1423 [45]. It was the bubonic plague or the Black Death (1347–1352) and leprosy which triggered the need for isolation or quarantine that protected against people who were sick. Quarantine (from Italian *quaranta* = 40) was introduced in Southern Europe ca. year 1400, to isolate presumed infectious ships, persons, goods, food and equipment from other places at quarantine stations for 40 days, i.e. double the incubation period for most serious infectious diseases, also in our time.

In Norway, isolation was created primarily for leprous patients, probably by King Magnus Lagabøter in Bergen, ca. 1270, later on for the Black Death (approximately 1350), the white plague; tuberculosis, from the mid-1800s, at sanatoriums

like Luster in Sogn and Glitre in Akershus or in separate isolation buildings at the hospital, like epidemic buildings at Ullevål Hospital.

Despite academic controversy about “infection or not” from the late 1700s to the 1860s, the isolation treatment was used for presumably “infectious diseases” like typhoid, cholera, scarlet fever, diphtheria, smallpox, plague, etc. Patients were isolated in hospital, at home or in own local epidemic houses in the country. Chronic carriers of typhoid bacteria (*Salmonella typhi*) were isolated alone at home or at the counties epidemic house by themselves (Smitteborg, “infection castle” in Skreia, Norway, is still a local name). The epidemic houses had access control and were monitored by the healthcare board mayor. Hygiene and infection control were very important since they had few curative agents. It was prepared vaccines and carried out partly or complete mass vaccinations against some infections.

Pulmonary tuberculosis was treated at sanatoriums in the mountains or at coast hospitals. The patient did not come home until he was free from infection. During outbreaks of typhoid fever, diphtheria or scarlet fever, the patients were isolated in separate sick barracks or at home. To be a carrier of an infectious disease could lead to work prohibition and isolation. Schools were closed intermittently during outbreaks, and posters were put on houses with infectious disease as a warning. Disinfection of houses, clothing and all of its contents was completed after the termination of the isolation period, using chlorine and sulphur smoke. Carbolic acid and hydrochloric acid were also used where sulphur fumes treatment failed. Bedding, clothing and fixtures that could not be washed or disinfected were often burned, with a financial compensation for this “outlay.” Patients who broke the isolation routines could be penalized and committed to further isolation. The society’s need went first before each individual’s needs [46].

During the 20 years from 1911 to 1930, among approximately 2.4 million inhabitants in Norway, there were a total of 2,146,702 cases of acute laryngitis and bronchitis, 470,099 with acute gastroenteritis, 181,752 with “croup pneumonia,” 89,100 cases of diphtheria, 75,000 with scarlet fever, 71,000 with rheumatic fever, 15,000 with typhoid and paratyphoid fever, 5300 with poliomyelitis and 3200 with dysentery! [46]

Knowledge of infection, sanitation and housing conditions (less overcrowded), clean water, good personal hygiene, vaccinations and nutritional status were factors mitigating epidemic outbreaks beginning of the twentieth century. This demonstrates that most infectious diseases can be prevented and controlled, even without antibiotics.

In 1937, before the breakthrough of the penicillin, there were the most important precautions against infectious diseases in Norway: [1] isolation of the source of infection, [2] disinfection, [3] vaccination, [4] quarantine, [5] food hygiene and [6] eradication of insects [46]. Airborne infection was estimated as “the most important form of spreading infections” which may be correct even today [46, 47].

The last 125 years of isolation treatment carried out in Norway have been in separate houses and buildings until ca. 1960 when most infectious diseases were integrated into appropriate wards for the underlying diseases. In 1970 there was still

isolate buildings where all kinds of infections were taken care of and with good routines. Today, this type of isolation is gone, with exception of some buildings in preparedness for strict isolation.

21.3 Hospital Infections that Should Be Treated in Isolates

In each third to fifth hospital bed, there is an infected patient, and each third patient is treated with resistance-driving antibiotics today [28, 29, 35, 48]. Isolation units are therefore of great need.

In Norway with 5.5 million inhabitants, ca. 900,000 patients are treated annually in hospitals and about 50,000 receive hospital infections, resulting in at least 450,000 extra days in hospitals because of infection. Hospital infections with *Staphylococcus aureus* occur in 2% of the patients [28, 29]. Isolation treatment is laborious and expensive (ca. 10,000 NKR or 1400 USD per day). Out of the 13,700 somatic beds in Norway in 2013, hospital infections charged ca. 20% of these, which would generate a need for ca. 2740 infection beds. However, the somatic bed capacity in Norway is steadily being reduced, which creates several problems in the healthcare.

21.4 New and Old Microbes Increase the Need for Isolates

There is an increased need of isolates for patients with infections, especially due to pulmonary tuberculosis, MRSA, VRE, *Clostridium difficile* (CD), multiresistant gram-negative bacteria and other “multidrug-resistant organisms” (MDRO) [23, 24, 36, 37, 48–51]. Global incidence of entero-pathogenic bacteria and imported resistant agents increases, and there is an ongoing microbial spread via food, animals, fish, water, supplies and the environment [48, 51].

New knowledge of transmission, robustness and ability to survive in the environment may reinforce the methods for isolation. CD, originally defined as contact transmission, may also spread through the air [52]. CD problem increases, particularly in the United States where half a million patients are infected each year and 29,000 of them died in 2011 [53]. A special dangerous CD type (NAP1) is detected [53].

The incidence of new respiratory viruses like *Human metapneumovirus*, bocavirus, *Human coronavirus*, etc. increases. For the first time in more than 100 years, a highly pathogenic virus as Ebola has been introduced to Norway and to other countries in Europe. Pandemic-actual viruses such as SARS, MERS, different types of bird flu, new outbreaks of Ebola and other viral haemorrhagic fevers show the need for isolation and emergency preparedness [30–34].

Children’s diseases, who disappeared with vaccinations, like whooping cough, mumps, rubella and measles, are now increasing with outbreaks in areas with high vaccination rate in America and Europe [1]. From 2014 to 2015, Europe had more

than 22,000 measles cases [54]. By hospitalization, these need airborne infection isolation units.

Noro-, rota- and sapoviruses and other types of virus gastroenteritis are highly infectious with vomiting and producing of aerosols, i.e. airborne infection. Growing global outbreaks of norovirus may cause fast and widely spread of gastroenteritis among patients and personnel in health institutions and cause inactivity and stop of new admissions [55, 56].

21.5 Particular Issues Around Infection and Isolation

The closure of wards or hospitals. Outbreaks often end with the closure of the ward, as shown in one study, median in 14 days [16]. Geriatric wards are usually closed during outbreaks. The most frequent cause is outbreaks of norovirus, 44%, $p < 0.001$ and influenza/parainfluenza, 38.5%, $p < 0.001$ [16].

Intensive care units (ICU) are often particularly vulnerable to infection. Cross-contamination between such patients is normal [57]. In a 16-bed ICU for adults, 430 patients were followed for 3950 patient days and cross-transmission was followed by genetic typing of the microbes [57]. A total of 40 episodes of cross-transmission was demonstrated and dominated by *Pseudomonas aeruginosa*, other gram-negative bacilli and *S aureus*. Cross-transmission was associated with understaffing, use of nasogastric tube, ventilator and other multiple patient-to-nurse contacts and immune-compromised patients [57]. Patients treated at understaffed ICUs were three times more likely to be infected; immunosuppressed had four times greater risk, and bronchoscopy-treated patients led five times higher risk [57]. Intensive units often have no isolates, and if they have, they are not so much used because of staff shortages.

21.6 Lack of Infection Isolates

Airborne infection isolation units will quickly be economic by more control over the spread of infection, fewer extra days in hospitals and fewer sick leave for personnel, as was demonstrated during the SARS epidemic [33]. The larger outbreaks of infectious childhood diseases require more isolation for airborne infections [58]. The same goes for whooping cough which 10 years ago was an unknown phenomenon in Norway and now in widespread child and adult disease [59]. Imported infections are increasing, and hospital infections like wound infections, respiratory tract infections and antibiotic-associated diseases are also increasing.

In the 1980s, the State Board of Health in Norway recommended that the number of isolation beds should be 10% of the hospital's total bed numbers and the ICU 25% [60]. At Ullevål Hospital, 5% of the beds were airborne infection isolates, and 3% contact isolates in 2008 [22, 28, 29].

21.6.1 Airborne Infection Isolation Units: “High-Level Isolation Rooms”

In 2009, a European investigation was done as regards the number of “high-level isolation rooms” (HIRs), i.e. airborne infection isolation units with negative pressure (not defined) with at least 6 air changes per hour and sluice (anteroom) [61]. This is a unit intended for high-risk infections like haemorrhagic viral infection, SARS, the starting phase of pandemic influenza, XDR (extended drug-resistant) tuberculosis, anthrax, plague, biological terrorism, etc. [61]

In all, 16 European network countries (EUNID) with 211 hospitals and about 1790 isolation beds participated. Many of these had fewer than 6 air changes per hour [61]. The total proportion of airborne infection isolates (HIR) per country were calculated per million inhabitants. The largest proportion of these isolation units were detected in Luxemburg, 31.5 per million; followed by Finland, 28.4; Sweden, 25.9; Ireland, 15.1; Denmark, 14.3; Italy, 12.3; and Estonia, 11.2 per million inhabitants. Spain, the Netherlands, Germany and the United Kingdom had the lowest share, 0.2, 0.2, 0.3 and 1.7 per million inhabitants, respectively [61].

Most countries used HEPA filter for air extraction from the isolates (9 out of 11). Among 13 countries, 4 had localized airborne isolates (HIR) to own buildings or wards, in 4 was HIR in the same ward as other patient rooms, and in 5 both solutions were adopted [61]. A total of 342 HIRs were equipped for intensive care, most in Italy (245 beds) and in Denmark (40 portable beds) [61].

After year 2000, HIRs have been used in Europe to approximately 10 imported haemorrhagic fever cases and 33 confirmed SARS cases.

In the United States, there are three “high-level isolation units” (HLIU), placed at the same level as laboratory with biosafety level (BSL) 3 and 4, in separate buildings, with limited and controlled access, negative air pressure and special treatment of sewage and garbage [62].

21.6.2 Isolate: Design and Function

Isolates rely on “evidence-based design,” i.e. knowledge of the construction, design, materials, equipment, furnishing, standards, etc., which are considered as core elements of the infection prevention [63]. Solid evidence of the spread of infection is used to control good environmental measures, disinfection and proper use of the isolates [64–66].

Infection isolation involves admittance of the patient to a separate room with disinfection/bathroom, sluice or anteroom (see Fig. 21.1). It is always an advantage with some negative pressure of infection isolates—even for contact infection—to avoid spread of infections outside the isolate.

A *contact isolate* has sluice, patient room and disinfection/bathroom, about 35 m². The sluice should be at least 6 m² with room for bed or stretcher and wash

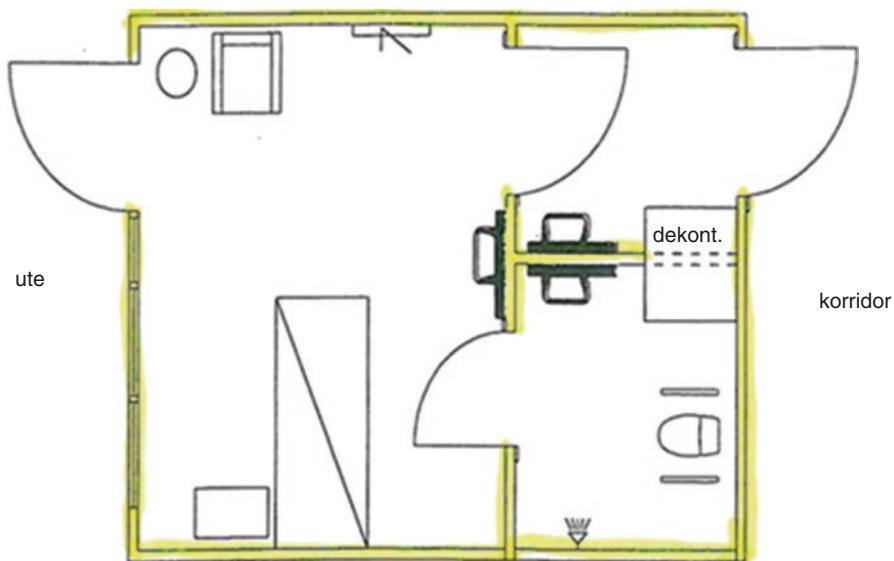


Fig. 21.1 Isolation unit with sluice, patient room, bathroom, throughput decontaminator. Source: BM Andersen. Handbook in hygiene and infection control for nursing homes and long-term care facilities 2013, Akademika Forlag, Oslo

basin. It shall have a defined clean side, space for clean clothes and unused PPE and a dirty side, for infectious waste and infectious waste bags or containers.

Patient room should be at least 20 m², with the head end against the wall and about 2 m free zone on both long sides and from the foot end, to avoid too close contact with the patient.

Disinfection room, combined with bathroom, 8–10 m², contains shower, toilet and wash basin, with plenty of space to be able to help the patient as needed. It should also be equipped with decontaminator, preferably a well-sealed, throughput decontaminator from disinfection room to the sluice. In throughput decontaminators (or autoclaves), infected equipment can be put in from the disinfection room and removed decontaminated in the sluice. All throughput systems should be assured with complete sealing against air leakage. It should only be opened from one side at the time, i.e. interlock. Avoid throughput cabinets between the sluice and disinfection room.

All isolation unit surfaces must be smooth, robust and withstand disinfectants, both liquid and dry gaseous form. Avoid tiles, gaps and joints where dirt can form the basis for growth and biofilms of microbes which may prevent effect of disinfection.

There should be at least eight air changes per hour (> six air changes [61]), which is important to remove the infectious agent in the room air. Incoming air must enter on the wall or ceiling; air extraction shall go out by the floor (15 cm above), preferably in the disinfection room. The isolate should have separate ventilation system so

that the infection does not come across to other patients by setbacks in joint ventilation ducts. Intake air should be a certain distance from the air outlet. HEPA filters should be set on air outlet, and procedures for maintenance and control should be established.

Airborne infection isolate is provided and formed as for a contact isolate. The isolate should be organized for direct access from outside. In addition, the controlled and defined negative pressure is graded down from the sluice to the disinfection-bathroom compartment [22]. Pressure is usually, -16 to -25 pascal relative to the corridor and the adjacent rooms. In the sluice there is 6 – 10 pascal, in the patient room -16 to -25 pascal and disinfection room -25 pascal. The air will then be drawn from the cleanest room (sluice) to the dirtiest room (disinfection room), if the doors are closed.

The most stable, controlled negative pressure may be made by doors opened outwards from the patient room to the sluice and further from the sluice to the corridor (see Fig. 21.1). The vacuum will suck the door even tighter to the door frame to hinder air leakage. Interlocked doors should be used so that only one door at a time may be opened into the patient room. The stability is dependent on the number of air changes per hour. The minimum and most stable is 6 air changes per hour (6–12) [19, 22, 61]. Each air exchange reduces the pathogenic agents in the air substantially. All air expelled exits at the floor (15 cm above) and is gathered into an outgoing ventilation channel from the disinfection compartment. Avoid “shortcuts” of the air circulation.

As for contact isolates, airborne infection isolates should have separate ventilation systems with no setbacks in ventilation ducts; external intake of air over the roof should be well away from the external air outlet over the roof, and all air from the unit is HEPA filtrated. Procedures for maintenance, disinfection and control of filters and ducts should be established.

Cohort isolation of several patients with the same infectious agent may be appropriate. It is a good initiative during pandemics. The SARS epidemic released a rapid learning process where the Chinese built—within a week—a dedicated SARS hospital for 1000 patients in Beijing [33]. In a study from Brazil, all patients with proven MDROs (multidrug-resistant organisms) were transferred to a 34-bed unit for isolation treatment by a trained personnel, where personnel, patients and family were weekly taught about how to handle MDRO's by a special team [67]. After the intervention, the MDRO rate was significantly reduced, specially by the reduction of VRE. Isolated patients had at least the same good treatment quality as not isolated patients [67]. In Norway, cohort isolation was utilized in Trondheim during the first national outbreak of MRSA (1970–1974). A total of 144 patients were infected (including 15 personnel), and 48 died (31.6%) directly or indirectly from the hospital epidemic [68]. The control of the outbreak came first when infected patients and personnel were cohort isolated in a separate isolation ward [68].

Barrier care of one infectious patient among other patients without infections on the same bedroom in dormitory is not recommended.

21.6.3 Disinfection and Cleaning

A good standard of patient isolates depends on good daily cleaning and a thorough disinfection by termination of the isolation. Long-time surviving bacteria, viruses and fungi should not be a risk for the next patient to be isolated, which may happen [69, 70]. MRSA, multiresistant *Acinetobacter baumannii* and other MDROs are contaminating bedding, bed and environment for months, if not removed [71].

Disinfection of rooms and isolates are often not well enough done [64]. The terminal disinfection, removal and disinfection of all equipment in the room and disinfecting of all surfaces are important. Disinfectants (liquid) that are effective against all microbial agents are chloramine 5%, household bleach 10% or peracetic acid for 1 h. Treatment with hot water ($>85^{\circ}\text{C}$) for 10 min is a very effective disinfection of equipment and textiles. Different types of gas or steam disinfection (hydrogen-peroxide dry gas, chlorine gas, formaldehyde gas) may be effective for equipment and room disinfection [72–75]. Note that there is yet no gas treatment that is documented to kill *Mycobacteria* [76].

21.6.4 Proper Patient in the Right Place

The isolates are often used incorrectly. In the same ward and at the same time, patients without infection are placed on the isolates while infectious patients are not isolated. Although defined isolate treatment is determined and PPE used, it turns out that the patient is walking freely around in the ward, not really isolated. Knowledge and practices increases understanding of disease control measures.

Some patients that are both prone to infection and have serious infections, like cystic fibrosis patients, should be treated in isolates [77].

21.6.5 Side Effects of Isolation

Depression, anxiety and anger get less visits and information by health professionals; more often fall injuries or other injuries, inferior care, etc. are claimed to be side effects of isolation [41, 43]. However, patients previously depressed and anxious at admission suffer no more under an isolation stay [39]. There is not shown differences between isolated and non-isolated patient, according to the patient's view of treatment, on the contrary [42]. But the patient satisfaction is the highest among those who are well informed [38]. Most studies show that contact time with the medical doctor is approximately equal for isolated and non-isolated patients and approximately equally frequent [40, 43]. Although MRSA or VRE infected patients, in one study, had more frequent falls and pressure ulcers, this was not reduced by removing the contact isolation, so that it was likely other factors which could contribute to such complications [78].

21.6.6 Additional Costs for Transmitted Infections

Outbreaks are very costly and take up significant resources and healthcare for other patients [79]. A patient infected with MRSA was at Ullevål University Hospital, Norway, estimated to generate an additional charge of 526,000 NKR (ca. \$75,100), including extended length, spread to a hospital employee, screening tests and antibacterial treatment in 1999 [36]. In 2002, in connection with a MRSA outbreak in neonatal ward at Ullevål, the calculated additional costs were 375,000 NKR (ca. \$53,500) per MRSA-positive patient, including isolation expenditure, disinfection and cleaning, screening and extra days in the hospital [24]. Active screening and isolation of patients with MRSA are significantly and markedly cheaper for the healthcare than uncontrolled transmission which can result in serious infection and death [80].

21.6.7 Anchoring Isolation Procedures in Laws, Regulations and Guidance

Anchoring isolation procedures in laws is essential to the implementation of isolation. Norway has several laws, regulations and guidance to control infections in healthcare facilities [2–7]. International studies have laid the basis for the Norwegian isolation measures and techniques [9–14, 17–20, 27]. A number of studies regarding the design and function of isolation units exist [25, 26, 63–66]. Simply to place patients in single rooms provides noticeable improvement in the spread of infection [81].

21.6.8 Implementation and Execution: Failing?

The implementation of good isolation measures and compliance is often weakened by confusion, lack of written procedures, lack of training, competence and under-staffing. A number of other factors also influence the attitude of healthcare professionals with regard to follow the hospital's infection control procedures, not least professional disagreement about the procedures.

- In emergency wards in the United States, only 45% of the wards used contact protection (gloves and gown) upon receipt of patients with diarrhoea or faecal incontinence, 84% for suspected CD, 49% for purulent skin infections, 79% for suspected MRSA and 63% by multiresistant gram-negative rods [21].
- It may be a big difference between what staff and others say they do and what happens in reality [82]. Among 470 persons who entered isolates, the compliance was higher by strict isolation infections (65%) than with other infectious conditions [83]. Visitors followed the measures better than personnel (88% versus 41%) [83]. The compliance with isolation procedures increased significantly when more time was spent with the patient, being a visitor, and when the patient was on a strict isolation [83]. The study pointed out the danger of increased

demands for doctors and nurses due to savings can result in adverse effects such as reduced compliance with key routines as isolation [83]. Morgan et al. observed 7750 visits of a healthcare professional to isolated and non-isolated patients. Patients on contact isolation had 36% fewer visits and 18% less contact, and there were fewer visitors than non-isolated patients [84]. However, the staff implemented significantly more frequent handwashing after visit in isolates, 63%, than by visits with non-isolated patients, 47% [84].

- During the MRSA outbreak with ca 150 patients in Trondheim, Norway, 1970–1974, Kvittingen et al. described problems that may occur during epidemic and endemic conditions as “doctors more or less wholehearted support and scepticism to the measures made by the Hygiene Committee, discussions concerning the virulence and resistance development, what to do when a local outbreak paralyzes the department completely, information problems, lack of qualified personnel, etc.” [68, 85]. They stressed that “larger hospitals should dispose well-planned isolation opportunities, both for patients who are infectious spreaders and perhaps equally important, to protect patients with reduced infection defence,” and that “personnel in management positions (should) provide effective and loyal support for infection control personnel” [68].
- This was a very important observation done for more than 40 years ago. It is still causing major problems during outbreaks and endemic situations when there may be a choice between shortcut thoughts about “economy” and infection control. Still, impression and experience is that staff working directly with the patients have great respect for contact and airborne routines, at least in Norway.

21.6.9 Isolation Regimes and Recommendations

Isolation regimes and interpretation of these are an almost perpetual discussion which changes with endemic and epidemic conditions, economy and guesswork. Although isolation of patients with infectious diseases has been used for hundreds of years, there is little evidence in terms of endemic conditions [19–22]. The Norwegian isolation regimes are based mostly on guidelines from CDC [9–12, 17–21]. In addition, an increasing number of guidelines are focusing on special isolation factors [19, 64–66, 69–73, 86].

CDC's isolation guideline is graded from high evidence, highly recommended as the IA, to no recommendation and unresolved questions or professional disagreement [19]. Category IC is included in the legislation for patients and caregivers [19]. Classification into categories is essential for the most important infection control measures in hospitals. “These recommendations are designed to prevent transmission of infectious agents among patients and healthcare personnel in all settings where healthcare is delivered. As in other CDC/HICPAC guidelines, each recommendation is categorized on the basis of existing scientific data, theoretical rationale, applicability and, when possible, economic impact” [19]. The CDC recommendations are changed over time [9–12, 17–19].

CDC/HICPAC system recommendations in categories in correspondence with investigations, theory and economic possibility; quoted [19].

Category IA	Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, Or epidemiological studies
Category IB	Strongly recommended for implementation and supported by some experimental, clinical or epidemiologic studies And a strong theoretical rationale
Category IC	Required for implementation, as mandated by federal and/or state regulation or standard
Category II	Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale
No recommendation	Unresolved issue. Practices for which insufficient evidence or no consensus regarding efficacy exists” [19]

Siegel JD et al. 2007 Guideline for isolation precautions

21.7 Administrative Responsibility for Isolation Treatment

CDC's isolation guideline refers to the administrative responsibility around isolation treatment [19]. The hospital's management is responsible for ensuring the implementation of good practical measures and to be the driving force in the hospital's infection control preparedness. This should particularly be done with regard to isolate patients, an extra burden, and also for the economy. Enough isolate capacity is to be provided in relation to citizens, patient categories, type of hospital activity and endemic/epidemic conditions. The isolates must be of good quality and design, and it should be enough airborne infection isolation units [19].

Some of the CDC-recommended administrative responsibilities are quoted here: [19]

Citation: “Healthcare organization administrators should ensure the implementation of recommendations in this section:

1. Incorporate prevention of transmission of infectious agents into the hospital's patient- and occupational safety programs. *Category IB/IC.*
2. Make prevention of transmission of infectious agents a priority for the healthcare organization. Provide administrative support, including fiscal and human resources for maintaining infection control programs. *Category IB/IC.*
3. Include prevention of healthcare-associated infections as one determinant of bedside nurse staffing levels and composition, especially in high-risk units. *Category IB/IC.*
4. Include infection control in daily treatment and care of patients. *Category IB.*
5. Delegate authority to infection control personnel or their designees (e.g., patient care unit charge nurses) for making infection control decisions concerning patient placement, transport and transfer -based precautions. *Category IC.*

6. Involve infection control personnel in decisions on facility construction and design, determination of airborne isolates and protective environment capacity needs, and environmental assessments. *Category IB/IC.*
7. Ensure -- to provide clinical microbiology laboratory support, including a sufficient number of medical technologists trained in microbiology, ---for monitoring transmission of microorganisms, planning and conducting epidemiologic investigations, and detecting emerging pathogens. Identify resources for performing surveillance cultures, rapid diagnostic testing for viral and other selected pathogens, preparation of antimicrobial susceptibility summary reports, trend analysis, and molecular typing of clustered isolates ---- use these resources according to facility-specific epidemiologic needs, in consultation with clinical microbiologists. *Category IB.*
8. Provide -- resources to meet occupational health needs related to infection control -- evaluation and management of healthcare personnel with communicable infections. *Category IB/IC.*
9. In all areas where healthcare is delivered, provide supplies and equipment necessary for the ---Standard Precautions, including hand hygiene products and personal protective equipment (e.g., gloves, gowns, face and eye protection). *Category IB/IC.*
10. Provide ventilation systems required for a sufficient number of AIIRs (as determined by a risk assessment) and protective environments in healthcare facilities that provide care to patients for whom such rooms are indicated, according to published recommendations. *Category IB/IC.*
11. Involve infection control personnel in the selection and post-implementation evaluation of medical equipment and supplies and changes in practice that could affect the risk of HAI. *Category IC.*
12. Develop and implement policies and procedures to ensure that reusable patient care equipment is cleaned and reprocessed appropriately before use on another patient. *Category IA/IC.*
13. Develop and implement systems for early detection and management ----of potentially infectious persons at initial points of patient encounter in outpatient settings (e.g., triage areas, emergency departments, outpatient clinics, physician offices) and at the time of admission to hospitals and long-term care facilities (LTCF). *Category IB.*
14. Develop and implement policies and procedures to limit patient visitation by persons with signs or symptoms of a communicable infection. Screen visitors to high-risk patient care areas (e.g., oncology units, hematopoietic stem cell transplant [HSCT] units, intensive care units, other severely immune-compromised patients) for possible infection. *Category IB.*
15. Identify performance indicators of the effectiveness of organization-specific measures to prevent transmission of infectious agents (Standard and Transmission-Based Precautions), establish processes to monitor adherence to those performance measures and provide feedback to staff members. *Category IB” [19]. Citation ended.*

A good and active hospital management is of major importance to stop the outbreak [23, 24, 37, 49, 50, 68, 87, 88]. Ransjø et al. attached the importance to the activity of the hospital management during outbreaks of multidrug-resistant microbes in Sweden [87]. In Norway, an outbreak of VRE by a dialysis department spring 2011, at Ullevål University Hospital, was expected from the department's critical building condition [23]. After great effort from the staff, the outbreak stopped within 14 days [23]. A structural rehabilitation started then, with expansion of bed numbers, assisted by the hospital management. One year later, all patients were VRE negative [23]. A number of outbreaks at Ullevål's premature intensive care unit during years have been linked to chronic understaffing, overcrowding, part-time work, lack of infection control practices and isolates, lack of information and a lack of management responsibilities [24, 37].

The responsibility of the hospital management to prevent and combat outbreaks of infection should be clearly stated in the hospital's infection control program.

21.8 Contact Isolation: "Contact Precautions" (CP)

CDC defines contact isolation, using gown and gloves when in contact with patients infected with resistant bacteria like MRSA and other MDROs (multidrug-resistant organisms), and single rooms are recommended [19].

Direct contact contamination occurs when microbes are transmitted from an infected person to another without the “intermediate stage” in the environment. Microbes transferred to the hands can further spread to the own mouth, nose, hair, ears, clothing, etc. [89] Healthcare personnel is likely to be a “source, vector or a victim” of infections like MRSA [90, 91].

Patients bring their own microbes into the hospital, with often large contact before a known infection [92–96]. Therefore, rapid tests are recommended where possible to detect pathogens [80, 97].

Indirect contact contamination happens when the microbes are transferred to an object in the environment and from there transmitted to other objects or people. Infectious patients themselves will have the agent on the body and clothes and transmit it to the environment. The undetected microbes can spread quietly and calmly in many directions via equipment, rooms, surfaces and missing/incorrect procedures [98]. This is often a large and persistent environmental problem and a threat to other patients [23, 24, 37, 49, 50, 57, 68–72, 87]. The most typical spread occurs when people with contaminated hands are depositing microbes on equipment, machinery, knobs, door handles, uniforms, other textiles, furniture, toys, etc. [89–91]

Fellow-patients on the same room are highly susceptible to infection [16, 20, 23, 24, 37, 57, 96–99]. Infection can be spread further via equipment (BP apparatus, stethoscope, medicine tray, blood sugar test equipment, journal, etc.) and the personnel's uniform. It is often brought to the ward office, to service rooms and to other personnel or patients. A long “domino” chain of infections may follow infectious agents not stopped by simple hygienic measures and isolation [98].

Contact infection may also be an airborne infection from patients coughing and sneezing by certain aerosol procedures, when cleaning the surfaces, by bedding and by strong air currents (e.g. by rapidly opening and closing doors) which dislodges dust from the lamps, shelves, etc. [44, 46, 47, 52, 100–102] Therefore, a daily good housekeeping and good routines for final disinfection in isolates is very important to reduce the burden and risk of pathogenic microbes [22, 74].

Contact infection prevention (CP)—recommended by CDC [19].

Some citations selected from Siegel et al. 2007; CDC guideline for isolation, where recommendations are in categories where IA is strongest recommendation.

Selected citations: [19] “

1. In *acute care hospitals*, place patients who require CP in a single-patient room when available. *Category IB*.
2. When single-patient rooms are in short supply, apply the following principles for making decisions on patient placement: ---- Place together in the same room (cohort) patients who are infected or colonized with the same pathogen--. *Category IB*.
3. Wear gloves whenever touching the patient's intact skin or surfaces and articles in close proximity to the patient (e.g., medical equipment, bed rails). Don gloves upon entry into the room or cubicle. *Category IB*.
4. Wear a gown whenever anticipating that clothing will have direct contact with the patient or potentially contaminated environmental surfaces or equipment in close proximity to the patient. Don gown upon entry into the room or cubicle. Remove gown and observe hand hygiene before leaving the patient-care environment. *Category IB*.
5. Patient transport. In *acute care hospitals and long-term care and other residential settings*, limit transport and movement of patients outside of the room to medically-necessary purposes. *Category II*.
6. When transport or movement in any healthcare setting is necessary, ensure that infected or colonized areas of the patient's body are contained and covered. *Category II*.
7. Remove and dispose of contaminated PPE and perform hand hygiene prior to transporting patients on CP. *Category II*.
8. Don clean PPE to handle the patient at the transport destination. *Category II*.
9. Handle patient-care equipment and instruments/devices according to Standard Precautions. *Category IB/IC*.
10. In *acute care hospitals and long-term care and other residential settings*, use disposable noncritical patient-care equipment (e.g., blood pressure cuffs) or implement patient-dedicated use of such equipment. If common use of equipment for multiple patients is unavoidable, clean and disinfect such equipment before use on another patient. *Category IB* [19].”

Selected citation ended.

21.9 Airborne and Droplets: Isolation

Spread of pathogenic infectious agents through the air and droplets requires a defined negative pressure ventilation isolate and a system which reduces airborne infection in the patient's room. It is best done by air replacement 6–12 times an hour [19, 61].

The cause of airborne, pathogenic microbes may include:

1. Transmitted to the air from infected airways by coughing, sneezing, sputum, watery eyes, talking, shouting, singing, etc., caused by influenza, parainfluenza and other respiratory viruses, tuberculosis, staphylococci, pneumococci, gram-negative rods, etc. [12, 19, 22, 46, 47]
2. Transmitted to the air from infected gastrointestinal tract by vomiting, e.g. norovirus, rotavirus, sapovirus and entero-haemorrhagic *E. coli* (EHEC).
3. Transmitted by splash and spray from pus, blood, tissue- particles, etc. in tiny droplets, particularly during surgery, punctures, suction, diathermy, gastroscopy, etc. [103, 104]
4. From splashes and spills by invasive, aerosol-generating procedures like bronchoscopy.
5. From accidents and spill by insertion or replacement of catheters in the blood and the urinary tract.
6. By rapid removal of the bandage from pus and discharging wounds.
7. By raise up of infected dust, skin cells and other contaminants by activities that create air currents, often in poorly cleaned rooms [44].
8. Re-aerosolized pathogens from used textiles and equipment in the patient room or where these contaminated items are brought, for instance, to the ward's disinfection room or to the laundry. By massive contamination and poor routines for washing equipment and hospital textiles, this may cause a special problem of re-aerosols [105].
9. Construction activity of all types without measures against airborne infection is influencing the airborne spread of bacteria, virus and fungi. This must be taken into account when rebuilding and repairing buildings and ventilation ducts etc. [22, 105]. If ignored, it may cause large problems like the outbreak of *Bacillus cereus* among 171 patients, most with sepsis, during 6 months of a large construction project next to the hospital [105]. Air samples showed growth of large quantities of *Bacillus* inside the hospital, the units and also isolates, and hospital textiles were heavily contaminated [105].

On a daily basis, the human inhales 10,000 particles or more via airways; many of these are bacteria, viruses and fungi but mostly come up again without causing disease.

A solid documentation shows that airborne infection may occur at a variety of infectious diseases [12, 22, 31, 47, 52, 54, 58, 59, 85, 100–119]. Rooms with MRSA-infected cases may have larger numbers of MRSA bacteria in air samples

than in samples from surfaces [113, 114]. MRSA may even be spread to nearby located rooms, to patients not infected [113, 114]. The few existing units for airborne infection isolation mean that most patients, except for pulmonary tuberculosis, most often are admitted to contact isolation or single-patient rooms, with the use of PPE corresponding to airborne infection: gloves, infection-protecting gown, cap and surgical mask and sometimes room-bound shoes [22].

Airborne Precautions (AP)—recommended by CDC [19].

Some citations selected from Siegel et al. 2007; CDC guideline for isolation. Recommendations are in categories where IA is strongest recommendation.

Selected citations: [19]

“

1. In acute care hospitals and long-term care settings, place patients who require Airborne Precautions in an AIIR (airborne infection isolate rooms) that has been constructed in accordance with current guidelines. *Category IA/IC.*
 - (a) Provide at least six (existing facility) or 12 (new construction/renovation) air changes per hour.
 - (b) Direct exhaust of air to the outside. If it is not possible to exhaust air from an AIIR directly to the outside, the air may be returned to the air-handling system or adjacent spaces if all air is directed through HEPA filters.
 - (c) Whenever an AIIR is in use for a patient on Airborne Precautions, monitor air pressure daily with visual indicators (e.g., smoke tubes, flutter strips), regardless of the presence of differential pressure sensing devices (e.g., manometers).
 - (d) Keep the AIIR door closed when not required for entry and exit.
2. When an AIIR is not available, transfer the patient to a facility that has an available AIIR. *Category II.*
3. In the event of an outbreak or exposure involving large numbers of patients who require Airborne Precautions:
 - (a) Consult infection control professionals before patient placement to determine the safety of alternative room that do not meet engineering requirements for an AIIR.
 - (b) Place together (cohort) patients who are presumed to have the same infection(based on clinical presentation and diagnosis when known) in areas of the facility that are away from other patients, especially patients who are at increased risk for infection (e.g., immune-compromised patients).
 - (c) Use temporary portable solutions (e.g., exhaust fan) to create a negative pressure environment in the converted area of the facility. Discharge air directly to the outside, away from people and air intakes, or direct all the air through HEPA filters before it is introduced to other air spaces. *Category II.*
4. Place the patient in an AIIR as soon as possible. If an AIIR is not available, place a surgical mask on the patient and place him/her in an examination room. Once the patient leaves, the room should remain vacant for the appropriate time, generally 1 h, to allow for a full exchange of air. *Category IB/IC.*

5. Instruct patients with a known or suspected airborne infection to wear a surgical mask and observe Respiratory Hygiene/Cough Etiquette. Once in an AIIR, the mask may be removed; the mask should remain on if the patient is not in an AIIR. *Category IB/IC.*
6. Restrict susceptible healthcare personnel from entering the rooms of patients known or suspected to have measles (rubeola), varicella (chickenpox), disseminated zoster, or smallpox if other immune healthcare personnel are available. *Category IB.*
7. Wear a fit-tested NIOSH-approved N95 or higher level respirator for respiratory protection when entering the room or home of a patient when the following diseases are suspected or confirmed:
 - (a) Infectious pulmonary or laryngeal tuberculosis or when infectious tuberculosis skin lesions are present and procedures that would aerosolize viable organisms (e.g., irrigation, incision and drainage, whirlpool treatments) are performed. *Category IB.*
 - (b) Smallpox (vaccinated and unvaccinated) --- *Category II.*
 - (c) No recommendation is made regarding the type of personal protective equipment (i.e., surgical mask or respiratory protection with a N95 or higher respirator) to be worn by susceptible healthcare personnel who must have contact with patients with known or suspected measles, chickenpox or disseminated herpes zoster. *Unresolved issue.*
8. In *acute care hospitals and long-term care and other residential settings*, limit transport and movement of patients outside of the room to medically-necessary purposes. *Category II.*
9. If transport or movement outside an AIIR is necessary, instruct patients to wear a surgical mask, if possible, and observe Respiratory Hygiene/Cough Etiquette. *Category II.*
10. For patients with skin lesions associated with varicella or smallpox or draining skin lesions caused by *M. tuberculosis*, cover the affected areas to prevent aerosolization or contact with the infectious agent in skin lesions. *Category IB.*
11. Healthcare personnel transporting patients who are on Airborne Precautions do not need to wear a mask or respirator during transport if the patient is wearing a mask and infectious skin lesions are covered. *Category II.*
12. Exposure management immunize or provide the appropriate immune globulin to susceptible persons as soon as possible following unprotected contact (i.e., exposed) to a patient with measles, varicella or smallpox: *Category IA.*
 - (a) Administer measles vaccine to exposed susceptible persons within 72 h after the exposure or administer immune globulin within 6 days of the exposure event for high-risk persons in whom vaccine is contraindicated.
 - (b) Administer varicella vaccine to exposed susceptible persons within 120 h after the exposure or administer varicella immune globulin (VZIG or alternative product), when available, within 96 h for high-risk persons in whom vaccine is contraindicated (e.g., immune compromised patients, pregnant women, newborns whose mother's varicella onset was <5 days before or within 48 h after delivery.

- (c) Administer smallpox vaccine to exposed susceptible persons within 4 days after exposure.” Citation ended.
- “--The environmental recommendations in these guidelines may be applied to patients with other infections that require Airborne Precautions”. Selected citation ended.

21.10 Strict Isolation for High-Risk and Dangerous Pathogens

Particularly dangerous or unknown infectious agents with high mortality need special treatment in high-risk isolates with separately, controlled ventilation and disinfection of air extraction/waste/water, etc. or in buildings separated from other patients and without common ventilation [22, 30–34].

During the Ebola epidemic from March 2014, health professionals and patients were not protected well enough since the WHO recommended procedures for close contact/droplet infection [120]. The WHO excluded risk of airborne transmission of Ebola, even though it was documented to be transferred via air to primates [120, 121]. The uncertain infection control procedures of WHO were upgraded from September to October 2014 by the WHO and CDC, from contact/droplet infection 1 metre from the patient to strict isolation, but still without measures against airborne infection [121, 122]. The principle of “prevention is better than cure” was not in use.

The same happened in connection with SARS in 2003 where WHO was recommending a low infection control level, contact/droplets 1 metre from the patient, and had to raise the disease control level up to strict isolation ca. 2 months later on [33].

High-risk infections are recorded almost daily around the world, like the pneumonic plague in Madagascar, outbreaks (partly nosocomial) of multidrug-resistant tuberculosis in all parts of the world and nosocomial outbreaks of Crimean-Congo haemorrhagic fever in Germany after import of ill US soldier from Afghanistan [123–125]. Nearly each day, there are reported new cases of avian influenza, MERS, various haemorrhagic viruses or other dangerous microbes [1, 31–34].

Since 1945, there has been no need for strict isolation in Norway, with the exception of the imported healthcare professionals with Ebola in autumn 2014.

21.11 Protective Isolation

Risk of infection may occur when patients with greatly reduced infection defence are coming into contact with infected equipment, textiles or other patients, staff or visitors who have infection or are carriers of possible pathogenic microbes [19, 22, 126].

The following conditions are particularly vulnerable to contamination, agranulocytosis, neutropenia; <0.5 in granulocytes or rapidly decreasing number < 2, severe burns, patients with severely weakened immune system due to the treatment with immunosuppressive, chemotherapy or radiation (transplants, cancer or leukaemia).

This heterogeneous group is growing due to a more advanced treatment and more cancer and transplant cases. They should be protected against infection from “outside” by treatment in protective isolation in a clean room with anteroom or sluice and with HEPA-filtered air in a positive pressure room [19, 22, 126–131].

CDC recommends that by allogeneic haematopoietic stem cell transplantation (HSCT), the patients should be treated in protective isolation, especially to protect against fungal infections such as *Aspergillus*; *Category IB*. [19]

“As defined by the American Institute of Architecture, air quality for HSCT patients is improved through a combination of environmental controls that include [1] HEPA filtration of incoming air, [2] directed room air flow, [3] positive room air pressure relative to the corridor, [4] well-sealed rooms (including sealed walls, floors, ceilings, windows, electrical outlets) to prevent flow of air from the outside, [5] ventilation to provide ≥ 12 air changes per hour, [6] strategies to minimize dust (e.g., scrub-able surfaces rather than upholstery and carpet, and routinely cleaning crevices and sprinkler heads), and [7] prohibiting dried and fresh flowers and potted plants in the rooms of HSCT patients. The latter is based on molecular typing studies that have found indistinguishable strains of *Aspergillus terreus* in patients with haematologic malignancies and in potted plants in the vicinity of the patients” [19].

- In protective isolate should intake air be HEPA filtered which removes 99.97% of particles larger than or equal 0.3 μm in diameter; *Category IB*. [19]
- The room should be at positive pressure relative to the corridor with a pressure difference of 12.5 pascal or more; *Category IB*. [19]
- The pressure should be monitored visually every day; *Category IA* [19].
- The room must be sealed so that no outside air to seep in; *Category IB*. [19]
- There should be a minimum of 12 air changes per hour; *Category IB*. [19]
- Use smooth surfaces, avoiding textile furniture and the like, and perform good cleaning; *Category II* [19].
- Do not use carpeting in corridors or rooms in the area; *Category IB*. [19]
- The patient should be at least possible out of the room, the necessary examinations, etc., to be implemented in the shortest possible time; *Category IB*. [19, 22, 126, 130, 131]
- If necessary, use respiratory protection if out of isolation; *Category II* [19, 130].
- Staff are using adequate infection control equipment if the patient has infection; *Category IA/IB*. [19]
- Patients with respiratory infection—at the same time they need protective isolation—should be transferred to a defined airborne isolate. If HEPA filters are lacking on the air intake to the airborne infection isolation units, a portable system of the HEPA filter may be used in the room to remove fungal spores and bacteria; *Category II* [19].

Avoid transfers outside the isolate [130, 131]. A retrospective, case-control study of immunocompromised patients in Switzerland showed that when invasive fungal infection occurred, the mortality was over 20% [131]. An outbreak of fungal infection among 29 patients on a haematological department showed that the more often

the patient was transferred to other departments/was outside the isolate, the more frequently he was infected with invasive fungi [131]. With more than five patient transfers outside protective isolates, the risk of fungal infection was sixfold higher than if staying in protective isolation. If the patient was transferred during neutropenia, the risk increased by nearly sevenfold [131].

Building activities. Fungal spores are always released during construction activity and may become airborne also in risk areas where severely immunocompromised patients are located [105, 126, 130]. Infectious agents may be spread via air, textiles and equipment with deposition of fungal spores and other microbes during the construction period. Fungal spores follow air currents far away [105]. Construction activity must therefore be coordinated with appropriate departments and wards so that the patient area is shielded. Air from construction places should not leak into patient areas and be taken out directly from the building in such a way that it does not re-enter through the systems for intake of air.

Leakage of water in buildings. Fungal growth in patient room walls is due to neglected maintenance of buildings for many years and usually comes from water leakage from the old pipes, roof leaks or poorly maintained bathrooms. Patients should not stay in rooms with suspected fungal growth and decay!

Control of fungi should be implemented in protective isolates and storages for such isolates once a year or more frequently when suspected water leaks and rot. The requirement is 0 fungal spores per 1000 litres of air using the SAS-slit sampler.

Patients must be protected against infections during care and treatment [19, 22, 132–134].

Cleaning and disinfection of rooms, surfaces and equipment between infection susceptible patients must be extra careful since many—at the same time—have serious infections, including resistant bacteria. Despite a good cleaning, abundant amounts of microbes may be detected in the environment and the equipment after cleaning [135, 136].

21.12 Protecting Staff Against Serious Infection

Healthcare professionals who treat infectious patients may be highly exposed to infection, although they really should be protected [3, 6–8, 19, 22, 137, 138].

At the beginning of the SARS epidemic in 2003, 90% of SARS patients were the hospital personnel who had taken care of the first SARS patients [33]. During the Ebola outbreak in 2014, healthcare workers were again severely attacked by the disease and death in the first phase, until a more protective personal protective equipment system was in place [34, 120–122]. There is still a great variety in international guidelines in terms of personal protection equipment (PPE) by Ebola virus for healthcare workers [121]. The WHO, United Kingdom and CDC defined Ebola as non-airborne infection in 2014 and still does the same in 2017 [121]. None of these recommended respiratory protection for *suspected* Ebola infection in August–September 2014, at least half a year after the start of the epidemic. Only the United Kingdom recommended respirator mask for *confirmed* Ebola. There was no covering of the head or neck, not either during aerosol-generating procedures!

In October 2014, the CDC upgraded the PPE measures to strict isolation measures for proven Ebola infection, while the earlier PPE measures were recommended for suspected Ebola infection (Table 21.1) [120–122].

Table 21.1 Recommend use of infection control equipment; PPE (personal protective equipment) in Ebola virus guidelines from the World Health Organization (WHO), United Kingdom (UK) and the Centers for Disease Control and Prevention (CDC), USA (Source: Andersen BM *Hospital Healthcare* 2015; March [121])

Comparing the recommended PPE equipment by Ebola infection in guidelines from the WHO, United Kingdom and CDC in 2014 [120–122]

	WHO 2014 ^a	UK 2014 ^b	CDC 2014 ^c	CDC 2014 ^d
	September	September	August	October 20
<i>Spread of Ebola infection</i>				
Direct contact?	Yes	Yes	Yes	Yes
Indirect contact?	?	Yes	Yes	Yes
Airborne infection?	No	No	No	No
<i>The use of PPE by:</i>				
<i>Suspected cases of Ebola</i>				
Eye protection?	Yes	Yes	Yes	
Gown?	Yes	Plastic apron	Yes	
Gloves?	Yes	Yes	Yes	
Face masks/surgical masks	Yes	Yes	Yes	
Respirators/N95/P3 mask, etc.	No	No	No	
Hair/head/neck protection?	No	No	No	
Specific shoes/shoe covers?	Yes	No	No	
<i>Confirmed cases of Ebola</i>				
Eye protection?	Yes	Yes	Yes	Yes
Gown?	Yes	Yes	Yes	Yes
Gloves?	Yes	Yes	Yes	Yes
Face masks/surgical masks	Yes	No	Yes	No
Respirators/N95/P3 mask, etc.	No	Yes	No	Yes
Hair/head/neck protection?	No	No	No	Yes
Specific shoes/shoe covers?	Yes	No	No	Yes
<i>Aerosol-generating procedures</i>				
Respirators/N95/P3 mask, etc.	Yes	Yes	Yes	Yes
Hair/head/neck protection?	No	No	No	Yes
Specific shoes/shoe covers?	Yes	No	Yes	Yes

^aWHO. Interim infection prevention and control guidance for care of patients with suspected or confirmed filovirus haemorrhagic fever in healthcare settings, with focus on Ebola. September 2014

^bUK, the Department of Health. Management of hazard group 4 viral haemorrhagic fevers and similar human infectious diseases of high consequences. September 2014

^cCDC. Infection prevention and control recommendations for hospitalized patients with known or suspected Ebola haemorrhagic fever in US hospitals. August 2014

^dCDC. Guidance on personal protective equipment to be used by healthcare workers during management of patients with Ebola virus disease in US hospitals, including procedures for putting on (donning) and removing (doffing). October 20, 2014

During the pandemic flu in 2009, Norwegian health authorities did not allow the staff at hospitals to use respirator masks (P3 masks) when taking care of the flu patients; they should use surgical masks [138]. Exceptions were for aerosol-generating procedures. The same health authorities went public and said that surgical masks did not have any protective effect! [138]

Recurrent problems are that the health authorities are not able to see the importance in protecting health professionals who are—and will always be—the front-line workers, even at the most serious infectious diseases [137]. Governments that are not willing to take care of their healthcare employees create unnecessary fear and reluctance to make a good contribution during outbreaks. If the disease is not as dangerous as SARS and Ebola, a highly contagious pandemic influenza or a large norovirus outbreak could paralyse the healthcare system when a high number of the staff get sick at the same time. By preventing disease transmission to health professionals, the hospital can be operatively enough to handle properly other serious diseases such as traffic accidents, myocardial infarction, stroke, etc., even at large-scale epidemics.

In spite of problems concerning isolation and prevention of spread of emerging and new serious infections, new guidelines are now appearing, which works with reduction of infection control in severely affected countries with endemic infections [139, 140].

21.13 CDC Isolation Guidelines - Overview - Selected by the Author

Administrative responsibilities: The hospital management should ensure implementation of the following recommendations

	Isolation guidelines - selected from CDC	
	Measures	Category
1	Include infection prevention measures in the safety program for patients and the working environment	IB/IC
2	Preventing the spread of infection—a priority for the hospital Administrative support, resources for maintenance of the infection control program	IB/IC
3	Securing enough qualified infection control personnel to operate and be responsible for the hospital Infection control program	IB/IC
4	Include infection control in daily treatment and care of patients	IB
5	Delegate responsibility for infection control personnel for disease control as where positioning the patient with	
	Infected patients and the transport and transfer of patients with infection	IC
6	Involve infection control personnel in the building, construction and design, insulation capacity, Airborne isolate protective insulation and ventilation conditions, air changes, etc.	IB/IC

Administrative responsibilities: The hospital management should ensure implementation of the following recommendations

7	Secure laboratory support-microbiology to contact tracing, documentation of disease transmission	
	Between patients, surveillance cultures, rapid testing, reports of antibiotic sensitivity,	
	Molecular typing by outbreaks, etc.	IB
8	Resources for the follow-up of health professionals with regard to vaccine and post-exposure	
	Organization of treatment personnel with infections/infectious carriers, etc.	IB/IC
9	All places that deliver health services should have enough infection control resources, hand hygiene agents,	
	PPE, gloves, coat and face and eye protection	IB/IC
10	Multipurpose articles to be properly cleaned and disinfected prior to use on a new patient	IA/IC
11	Establish systems for early detection of infection and location of patients with infection	IB
12	Establish procedures to limit infectious visitors, especially this should be investigated	
	For visitors to patients with severe renal infection or defence—High-risk patients	IB
Siegel a 2007 guideline for isolation. Recommendations in categories where IA is strongest recommendation [19]		

Contact infection prevention. Selected from the CDC guideline 2007

Measures	Category
1 Place the patient in a single room or cohort of another patient with the same pathogen	IB
2 Gloves when handling the patient, equipment and rooms. Put on gloves before going into the room	IB
3 Infection gown when handling the patient, equipment and room. Put on before going into the room	IB
4 Remove infection gown and gloves and perform hand hygiene before leaving the area	IB
5 Limit patient transport outside the isolation ward	II
6 If necessary, patient transport in clean bed with clean equipment and covered with clean cloth	II
7 Do not transport the patient with applied infection control equipment (PPE); wash your hands before transport	II
8 Wear clean PPE for processing and handling of the patient where this is obtained (X-ray, etc.)	II
9 Use the most disposables. Reusable equipment must be disinfected before the next use	IB
Siegel a 2007 guideline for isolation [19]. Recommendations in categories where IA is strongest recommendation	

(continued)

Airborne infection—prevention—selected from the CDC guideline 2007

Measures	Category
1 Place the patient with defined or suspected airborne infection in airborne isolate	IA/IC
2 At least six (lower) or 12 (new) air changes per hour	IA/IC
3 Vent be directly optionally HEPA-filtered air	IA/IC
4 Daily monitoring of the under pressure in airborne infection isolation units, several ways, keep doors closed	IA/IC
5 Lacking airborne infection isolation-transferable to another hospital with airborne infection isolation (especially tbc)	II
6 Cohort of patients with the same proven infection is possible	II
7 Restriction for personnel who are not immune (measles, etc.) or vaccinated against agent (BCG)	IB
8 Respirators/respirator N-95 with fitting test used for guidelines, or a gag	IB
9 Current vaccines or immunoglobulin to exposed non-immune, quickly	IA
Siegel a 2007 guideline for isolation. Recommendations in categories where IA is strongest recommendation [19]	

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Part IV

Patient Care



Personal Hygiene and Care of Patients

22

Abstract

Biological material such as urine, stools, other secretions/excretions and microbe-rich skin shedding are potentially infectious and favour conditions for growth and spread of bacteria. Poor hand and body hygiene increases the spread of bacteria like gram-negative rods and staphylococci in the environment and between personnel and patients. Inadequate care for the patient is a risk of spread of infections. The treatment and care of patients should be performed with respect, care and thoroughness with regard to hygiene and infection protection and in accordance with the patient's desire and well-being. Care should be done at fixed appointments as part of the daily rhythm, and the work should be performed professionally, calmly and systematically and should be well planned.

Keywords

Personal hygiene · Patient care · Washing · Skin flora · Skin cells · History of hygiene · Transmission · Protection · Healthcare personnel · Control of microbial agents

22.1 Purpose

To ensure a good personal hygiene and well feeling for bedridden patients, to reduce the burden of microbes and to reduce the risk of infection.

22.2 Comprise

Bedridden and very sick patients and all other patients who need help and assistance with personal hygiene. All staff who take care of patients [1].

22.3 Responsibility

The hospital management must ensure policies, equipment and resources that enable respectful care of the patient and enough time for hygienic care [2–4].

Department management must ensure that employees are trained in good personal hygiene, including hand hygiene, and that patients receive proper hygiene offerings [5–7].

Employees must comply with procedures and ensure optimum daily care and treatment of patients.

Visitors should follow the procedures for good personal hygiene and hand hygiene when visiting the hospital [5–7].

22.4 Practical Measures

1. Patients not confined to bed are assisted in daily showers or body washings.
2. Make sure that bandages over surgery and other wounds do not get wet!
3. Bedridden patients are washed daily—whole body wash in bed every morning (depending on physical condition).
4. Greatest need for washing is the patient's face, ears, hands, armpits, back, genitalia, anus and feet.
5. More frequent wash if there is incontinence or diarrhoea and after use of the bedpan, diapers, etc.
6. Absorbent diapers are changed frequently to prevent urinary tract infection.
7. The patient should have help and supervision when using toilet chair in the room or when visiting the toilet room. Many need help with cleaning, hand hygiene and moving in the toilet.
8. Hand hygiene is carried out after toilet visits/use of bedpan and before and after meals. Staff is helping with the patients' hand hygiene.
9. Check that the patient is offered a disinfectant such as a wet wipe and inform about the use.
10. Help with oral hygiene—at least two times/day—see separate chapter.
11. Care of the bed every morning and evening and more often in sick or febrile patients.
12. New patient clothes (hospital) daily or more often when needed and all fabrics should be washed at high temperatures [8, 9]. See chapter on textile processing.
13. Bed linen are changed every day or more often when needed (fever, incontinence, etc.).
14. Bedridden patient should often be turned over in bed and helped to sit up and to move around if possible; necessary physical therapy and other activities are needed to recover faster, avoiding blood clots, atelectases, pressure ulcers, ulcer infections, etc.—see chapter on pressure ulcer.

22.4.1 Personal Hygiene for a Bedridden Patient

Wash the patient from top to bottom and from cleanest areas to the dirtiest, and change water and wash cloths on the way.

Clean wounds and infected wounds should be treated differently and should be treated extra carefully after the wash. Avoid soap residues that may irritate the skin, and eventually wash with clean water. Dry gently but thoroughly over each area, before the next area is washed, and cover the area with a dry cloth.

The staff should have a clean uniform, perform good hand hygiene and not have any transmittable infections [10–13].

Equipment: washbowl, wash cloths, towels, liquid and mild soap in a small container which is only used by the patient, a neutral, non-allergic skin cream used only by the patient and other necessary equipment. Disposable plastic can protect against moisture during the washing procedure.

- Patient-bound, waterproof care coat with long sleeves and cuffs and hand hygiene before work starts. Gloves are changed along the way.
- Clean the nightstand and wash or use alcohol wipe over the nightstand where the equipment can stand.
- Clear away unnecessary equipment in the bed, and do not take off the covers if the patient has a tendency to freeze. If it is warm in the room, quilt, unnecessary pillows, etc. can be removed before covering the patient with a bedsheets. Use folding screen. Do not use the floor as a relief.
- If the patient washes himself, wholly or partly, make everything to use easy to reach.
- The wash water should be tempered as the patient wants it.

22.4.1.1 Oven Wash

- Place towel under the patient's chin and wash face, ears and neck.
- The shirt is, abdomen and underarms washed without wetting the sheets—use towel to protect from moisture. Wipe well under the breasts of women.
- Place towel lengthwise under one arm during the wash and wash the hand in plenty of water. Do the same on the other side.
- Turn the patient on the side, put the towel along the back and wash the back down to the seat.
- Put on clean, warm and dry clothes.

22.4.1.2 Wash Thighs, Legs and Feet

- Change to clean water.
- Fold the covers to one side and cover with plastic and towel under the lower extremity. Wash from the groin down on the thigh—lift up to reach the back and finally the leg. Wash well and dry thoroughly between the toes. Dry well in all skin folds especially and between toes and inspect if it is sore.
- Walk on the other side of the bed and carry out the same washing procedure.

22.4.1.3 Down Wash, Pelvis

- Change to clean water and new gloves.
- Fold the quilt aside and wash the front top downwards passing the urethral opening and dry thoroughly.
- Turn the patient on the side and wash from the seat towards the perineum and around the anus. Dry well and inspect if there is a danger of pressure ulcers.
- Help the patient to a good resting position.
- Take off the gloves and perform hand hygiene.

22.4.2 Check and Clean

- Check pillows, quilt, sheets and mattress, and consider change of linen if it is wet or dirty.
- Bring the used washbasin, diapers, towels, cloths, etc. to the decontamination room. The washbasin is decontaminated, and towels, cloths, etc. are thrown for washing. Do not leave used equipment in the patient room.
- Hand hygiene afterwards.
- Patient's equipment such as combs, glasses, etc. are cleaned separately every day.
- Disinfect and wipe over the nightstand and other tables used.
- Remove the care coat and hang it with the outside out if in the patient's room.
- Hand hygiene before leaving the room.

22.4.3 Care of a Patient with Infection

- Take care as above with infection control equipment recommended (see contact, air, blood contamination isolation) Chaps. 14–21.

22.4.4 Hand Hygiene for Patient and Personnel

Patients, personnel and visitors should carry out good hand hygiene. Bed/wheelchair patients must receive frequent offers [5–7]. Avoid touching your face, nose or hair during care of the patient [14].

22.4.5 Blood Glucose Measurement and Other Control: Risk of Blood Infection

Check that all equipment is clean. Measuring instruments are disinfected between each use. Multiple dose units are not used [15–18]. Do not expose the wad of cotton wool, patches, etc. for blood contamination. Single-use equipment is used only

once. Everything in contact with wounds and sterile mucous membranes must be sterile, including cotton wads and bandages [19].

22.4.6 Medical Equipment to Be Reused to a New Patient

It shall be cleaned and decontaminated inside and outside [20]. Make best practice routines for cleaning, disinfection/sterilization of reusable equipment for patients with chronic respiratory diseases, dialysis, immunosuppression, infusion therapy and wound drainage.

Be critical concerning purchase of expensive medical equipment that cannot be cleaned and disinfected inside. Use only equipment that has an official documentation or certificate of control and disinfection/sterilization. In Norway, we have official treatment centres for larger equipment that may be difficult to clean/disinfect.

22.5 Background Information

A personal good hygiene and daily cleaning were part of a decent life more than 2000 years ago. But from the Middle Ages until the 1880s, personal hygiene and cleaning were largely neglected in Europe. Hygienic regulations are ancient and found among others in the third book of Moses (Leviticus) of Pentateuch. Clean water and food, good personal hygiene, good nutrition and good living conditions were central to ancient Egypt, Greece and other countries around the Mediterranean [21, 22]. Already 4500 BC, there were well-developed and efficient water and sewage systems in Niniveh and Babylon [21]. In Israel it was recently found more than 3000-year-old water tunnels, described in the second book of Samuel (5: 6–9). The Roman Empire had millions of aqueducts and a variety of bathing terms that were widely used for bath and body wash. Egypt had public meat control approximately 2000 years BC, and there was a public order on hand and body wash and on isolation and disinfection if suspected infectious diseases like leprosy. At this time, hand and body wash was “considered to be of the utmost importance in order to preserve health, and it was partly rigorous rules about how often—the common people would wash themselves” [22].

With Christianity, hygienic attitude disappeared, and the Middle Ages became a dark time with numerous epidemics and a large number of deaths. Personal hygiene was “considered as an obstacle to the salvation of the soul”; priests and saints were full of lice and never bathed [23]. The historian Troels Frederik Lund (1840–1921) described the hygiene in the Nordic countries around the 1500s: washed maximum of once per week, used the same underwear all year, slept in “heaps” in the same bed and ate with dirty hands of the same dish. This created epidemics which “corrected generation after generation to death and raised the knowledge to deeds”. He felt that it was in the field of hygiene that medical science celebrated its “most undisputed victory” [23, 24].

Epidemics of the Black Death (plague) went all over Europe, and after 1350, approximately 26 million people died from this disease. Entire rural communities, also in Norway, were eradicated. The major infectious diseases, like plague, cholera, diphtheria, tuberculosis (the white plague), syphilis, smallpox, contagious meningitis, malaria, puerperal fever and flu, laid the agenda for all social activity. In the seventeenth century, smallpox took the life of about 400,000 people every year. Infections that went from hand-to-hand, body-to-body, contaminated equipment to clean equipment, and via contaminated air were the most common types of infection, well known from ancient times [24].

In the 1890s, one in four people in Kristiania (Oslo, Norway) had an epidemic disease each year, such as diphtheria, typhoid fever, diarrhoea, cholera, scarlet fever, puerperal fever, malaria or leprosy. Many – 40–60% – died, especially of tuberculosis, bronchitis, meningitis, diarrhoea and cholera. As late as in 1924, the biggest cause of death in Norway was tuberculosis, 8000–10,000 new cases each year. Over 20 years from 1911 to 1930, there were a total of 89,100 cases of diphtheria, 75,000 with scarlet fever, 71,000 with rheumatic fever, 15,000 with typhoid and parathyroid fever, 5300 with poliomyelitis and 3200 with dysentery among just about 2.4 million inhabitants! [21]. Eventually, the number of new cases went down and in 1934 died about the same number of cancers than of tuberculosis. Health professionals—nurses and doctors, with families—were infected, and mortality was often high.

New knowledge of infection placed great emphasis on hygiene and infection control, since there were few curative remedies [24]. Improved sanitation and living conditions (less dense lived), clean water, good personal hygiene, vaccinations and better nutrition condition were factors that curbed the epidemic outbreak from the beginning of the twentieth century [25]. This shows that infections may be prevented and controlled and that good general and personal hygiene is central to this work.

With more modern, effective antibiotic treatment from the 1940s “disappeared” the infections and thus also the interest in personal hygiene and infection protection [24]. Cleanliness work was forgotten for nearly 50 years until new and old infections came back from about 1980–1990s. The story repeats itself.

22.5.1 Personal Hygiene Is a Good Preventive Health Work

Haakon Natvig (formerly professor of hygiene at Oslo University) wrote in 1964 that the society should invest more in preventive health work, but it could often be difficult to get the authorities to realize the importance and necessity of this [22]. “Primitive populations, child of nature, and plain people live in the moment and—does not worry about what may come. The culture people, on the other hand, are looking forward and seek to protect themselves in time, against potential dangers, whether it would be for crop failures, lack of food, floods, colds, enemies or epidemics”.

Preventive work often results in that nothing happens or that deterioration is prevented, that infectious diseases and resistant microbes do not spread in the society and that tuberculosis is still a disease for the few, i.e. the “silent results” [22].

22.5.2 Modern Medicine

Modern medicine is based on infection preventive work. Good personal hygiene is essential for successful treatment, especially because today's patients are often in a more bad condition than before, are getting shorter stays in hospitals, are becoming more vulnerable because of overcrowding and understaffing and are increasingly victims of infections. The personal is chronic pressed for time; it is less time for good care, personal hygiene and treatment in hospitals. Most people who get bed-ridden manage little to help themselves in hospitals.

Inadequate care for the patient may degrade the body and soul and is also a risk of spread of infections. The treatment of patients should be performed with respect, care and thoroughness with regard to hygiene and infection protection and in accordance with the patient's desire and well-being. Care should be done at fixed appointments as part of the daily rhythm, and the work should be performed professionally, calmly and systematically and should be well planned.

22.5.3 The Human Loose Skin Cells and Spreads Particles

Man changes the skin—the body's largest organ—at least 1000 times during life. Within 14–48 days, the skin cells grow from the deeper layers, fall off and new ones emerge. A total of 30,000–60,000 dead skin cells are released from the body per minute, 600,000–1 million per hour and more than 500 million a day, in quantity, approx. 3.6 kg during the year and approx. 18 kg or more during life. Dead skin cells are released as small particles of dust around the human body and are laid as a track where you go. Dead skin cells are the main ingredient in house dust in up to 97% of cases, including studied in day care centres for children [26]. In addition, trillions of mites of different types are following humans both in bed, on the skin and other places. They eat dead skin cells, setting this out in faeces and eating it again. On 10% of loose skin particles, bacteria are present in the number of 5–12 per particle. Good personal hygiene and washing textiles and environment reduce skin particles, bacteria and mites to an acceptable level.

A whole, healthy skin protects against all types of infections, except for a few parasites that go through the skin. The skin has a smooth and soft antimicrobial barrier with fat, fatty acids and cholesterol. Low pH = 5 (acid cover), salt concentration rising from sweat; temperature above 30 °C; sebum and normal flora; all are making up an ecological system protecting against the establishment of more dangerous bacteria as *Staphylococcus aureus* [27, 28]. Normal flora is constituted by different white staphylococci that have their predilection sites, dominated by *Staphylococcus epidermidis*, 10^{3–4} per cm² [29, 30]. Diphtheroids, anaerobic bacteria (*Propionibacterium acnes*), gram-negative rods, *Candida* (yeast) and mites (Demodex) are common findings. More or less human pathogenic microbes are coming on the skin during the day, most often as a transient, loose flora.

The greatest amount of bacteria are found on the forehead (half million per cm²), around the ears, the head (1–6 million per cm²), axillae and nose opening

(1–10 million per cm²), the upper back (10,000–100,1000 per cm²) and palmar side of hands, arms, chest (1000–10,000 per cm²), etc., with variation between genders [31]. Also hair and beard may contain large amounts of microbes.

The rich skin flora around the head and neck is essential and should be taken into account during work in sterile situations, with infected and immunosuppressed patients, operative activity, wound care and care of the catheters. There will always be shedding of free skin particles from naked skin.

22.5.4 Infection Source/Transmission Routes

Biological material such as urine, stools and other secretions/excretions are potentially infectious and favourable conditions for growth of bacteria—especially intestinal flora—but also urine. Control of cleaning the room, surfaces, bed linen and other equipment like mattresses is very important to reduce the transmission of resistant bacteria and fungi between the patients [32, 33]. Poor hand and body hygiene increases the spread of bacteria like gram-negative rods and staphylococci in the environment and between personnel and patients [5–7, 10–14]. Personnel should never use uniform sleeves to *cough hygienically* in hospitals! [34]. This method that was recommended during the pandemic flu in 2009 has never been evidence-based and may be a risk concerning spread of infections [34].

22.5.5 Blood Glucose Measurements and Other Routine Controls of Blood

Among the elderly, there are many who need frequent blood glucose monitoring. Serious blood infection occurs with the use of infected equipment in patients [15–18]. An effective barrier against cross contamination in health institutions is important. Cotton wads, plaster, etc., collected in a common box brought from patient to patient during blood glucose, and other measurements, have a high risk of being blood contaminated. Most blood drops are not visible, and most of the splashes from needles are also usually invisible.

22.5.6 Recycling and Maintenance of Medical Technical Aids

The use of patient-related technical aids is increasing in the healthcare system. This includes equipment for respiratory (ventilator, CPAP, oxygen concentrator), dialysis sets, drainage systems, wound drainage, etc. [20]. Mechanical and electric equipment draws air with dust and microbes from the patient's room. This may result in large amounts of dust, microbes, skin cells, particles, etc. collected in the inner parts of the equipment—blown out into the room and in the airways of the next patient [20]. Before reuse in a new patient, also the inner parts of such equipment

should—at a minimum—be cleaned, decontaminated and checked. This is, for instance, done at the public equipment aid centres in Norway [20].

22.5.7 Deficit in Hospital Care Quality in Most Countries Associated with Nurse Workload

In a large study from 12 countries in Europe (488 acute care hospitals) and from the United States (617 hospitals) in 2012, it found that deficit in care quality was common in all countries studied [34]. The focus was set on improvement on hospital work environments to improve safety and quality in hospital care and to increase patient safety [35]. Participants were—together—ca 45,000 nurses and 150,000 patients. The United States had the lowest rate of patients to professional registered nurses and to total staff, 5.3 and 3.6, respectively. The corresponding figures for the 12 European countries varied between 5.4–13.0 and 3.3–10.5, respectively [35]. Germany seemed to have the highest rate of patients to nurses (13 patients per nurse) and the highest workload for professional registered nurses, while Norway had the lowest workload (5.4 patients per nurse) [35]. A substantial proportion of nurses in all European countries reported quality of care deficits, high nurse burnout, job dissatisfaction and intention to change job. Patients in hospitals with a high workload on nurses were less likely to rate their hospital highly and to recommend their hospital, and burnout in nurses was associated with less satisfaction in the patients [35]. This situation—with high workloads on nurses—is associated with a higher risk for deficit in patient care and safety, including nosocomial infections.

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Abstract

Good oral hygiene helps to maintain teeth and prevent caries, preventing infections and lesions around the teeth or in the oral mucosa, especially in intensive patients and elderly patients. Poor tooth status with deep holes, dental prosthesis and other affections of mouth and oral mucous membranes, present a risk, especially in patients with diabetes, rheumatoid arthritis, prosthetics or other foreign matters, in cancer patients, patients receiving cancer medicine or steroids, or by hypoxia.

Keywords

Oral hygiene · Oral mucosa · Infection prevention · Dental plaque · Stomatitis · Dental prosthesis · Pneumonia · Oral care in unconscious or terminal ill patients

23.1 Purpose

Good oral hygiene cleans the teeth and mucous membranes of leftovers and dental plaque and helps to preserve the teeth and prevent periodontitis or stomatitis.

Poor oral hygiene leads to favourable conditions for growth of unwanted, abnormal mouth flora, predisposing for pneumonia and sepsis in patients with compromised immune systems and in unconscious patients.

23.2 Comprise

Bedridden and very sick patients and all other patients who need help and assistance with personal hygiene, including oral hygiene.

All staff who take care of the patients.

23.3 Responsibility

The hospital management must ensure policies, equipment and resources that enable respectful care of the patient and time enough to oral hygiene.

Department management must ensure that patients receive proper oral hygiene.

Employees must comply with procedures and ensure the patients optimum daily care and oral hygiene.

23.4 Practical Measures

23.4.1 Mouth Care Assistance in Patients with their Own Teeth

Equipment: Disposable mug, soft toothbrush, small single tube of toothpaste, mouthwash, towel, cellulose fabric, waste bag, spatulas and waste container. Optionally in addition, hydrogen peroxide 1%, glycerol 70%, sterile wad of cotton wool, artery tweezers, sterile mouth brush and sterile water.

Performed: minimum morning and evening

- Wash the hands and wear gloves before helping the patient.
- Use patient bound care coat at the risk of spills and surgical cap at risk of splashing.
- In patients with infections, use mandatory protective equipment.
- Towel under the patient's chin.
- Patient's teeth are brushed gently with toothbrush/toothpaste on all surfaces.
- If possible, allow the patient to rinse and spit out himself.
- Inspect the oral cavity.
- If stomatitis occurs, see below.
- Hand hygiene.

Other measures:

- After meals it may be useful to rinse the mouth with water and use the toothpick or dental floss.
- Pineapple (unsweetened) containing the enzyme pineapple-ananase, which break down food particles in the mouth.

23.4.2 Mouth Care in Patients with Dental Prostheses

All types of prosthesis, whole or partial, are removed and cleaned $\times 2-3$ daily.

Equipment: Disposable mug, soft toothbrush, small single tube of toothpaste, towel, cellulose fabric, waste bag, spatulas, waste container, hydrogen peroxide 1%, glycerol 70% and sterile wad of cotton wool. Special brushes for partial dentures,

sterile sponges, lockable sterile tweezers or sterile mouth brush, sterile water, chemical liquid detergent and chlorhexidine dental gel 1%.

Only use sterile sodium chloride 0.9% and sterile/disinfected equipment in severe immunodeficiency and in the unconscious patient.

Performed: minimum morning and evening

- Hand hygiene and use gloves.
- Use patient bound care coat at the risk of spills.
- Towel under the patient's chin.
- Prosthesis is taken out, cleaned with toothbrush and toothpaste and placed in clean tooth glass.
- The oral cavity is cleaned well with sterile wad of cotton wool on lockable sterile tweezers, soaked in sterile water or with hydrogen peroxide 1%, eventually sterile, disposable brush.
- Lips are lubricated with lip balm or white Vaseline.
- Dental prosthesis is stored after cleaning overnight in clean dental glass with water or sterile saline and rinsed thoroughly before use the next day.
- Tartar on the prosthesis is removed in vinegar solution 7%, ratio: 1 part water and 1 part of vinegar.
- Discolouration of the prosthesis can be removed by adding the prosthesis in a glass of water with two to three tablespoons chlorine 1 hour, brush and rinse well afterwards (check with the dentist).

23.4.3 Stomatitis

Equipment as above:

- Hand hygiene and use gloves.
- Use patient bound care coat at the risk of spills.
- Soft toothbrush.
- Cleaning of the mouth and teeth, eventually prosthesis.
- Mouth rinse with physiological saline.
- Eventually, mouthwash fluid or chlorhexidine 0.2% × 2 daily.
- Mouth rinse with physiologic saline after each meal.
- Follow the dietary guidelines by mouth soreness.

23.4.4 In Case of Fungal Infection

Equipment as above:

- Hand hygiene and use gloves.
- Use patient bound care coat at the risk of spills.

- Thorough cleaning of the mucosa, with sterile sponges/sterile forceps or sterile disposable brush.
- Teeth and possibly dentures cleaned $\times 2$ daily.
- Prosthesis is taken out before the treatment with fungicide and thoroughly cleaned before insertion.
- Antifungal agents such as Mycostatin oral suspension or Fungizone suction tablets.
- Regular assessment by a doctor or dentist if fungal infection occurs.

23.4.5 In Unconscious or Terminal III Patient

- Perform oral hygiene four times daily or as needed.
- Put the patient in a lateral position or head turned to the side.
- Cover with plastic towel under your head.
- Hand hygiene and use gloves.
- Use patient bound care coat at the risk of spills.
- Brush the teeth if possible.
- Rinse the oral cavity with humidified (sterile water), sterile sponges on lockable sterile tweezers, optionally disposable sterile oral brush (used only once).
- Glycerol 70% applied to the tongue and in the mouth and lip balm applied to the lips.

23.4.6 Cleaning of Equipment for Oral Care

- Disposable mug or new dental glass/mug every day.
- In patients with oral infections, decontaminate the equipment after each use.
- The toothbrush is rinsed in hot water, thoroughly cleaned and dipped in undiluted Corsodyl, stored in a clean container between each mouth care and replaced as needed.

23.4.7 Avoid the Following at Standard Mouthpiece

- Forceps—can easily cause damage in the oral cavity.
- Glycerol—causes dry mouth.
- Lemon—acid may cause damage to the teeth.
- Hydrogen peroxide—abnormalities in the oral cavity.
- Toothpaste containing neutralizing chemicals that inhibit the disinfecting effect of Corsodyl/chlorhexidine. Zendium fluoride cream may be used.
- Tap water is *not* used for oral care to intensive/postoperative patients or patients with compromised immune systems.

NB! *Disposable equipments* (plastic mugs, mouth brushes, etc.) are disposed of after care.

23.4.8 Mouth Brush Requirement

- Sterile packed.
- Dry or moist.
- Single package.
- The head of the swab must not be easy to loosen.
- Approximately 15 cm long.

The packaging shall be marked with CE, standard label for sterile products, single-use symbol, production date and expiry date.

23.5 Background Information

Good oral hygiene helps to maintain teeth and prevent caries, preventing infections and lesions around the teeth or in the oral mucosa, especially in intensive patients and elderly patients [1–10].

Poor tooth status with deep holes and other affections of mouth and oral mucous membranes, present a risk if diabetes, rheumatoid arthritis, prosthetics or other foreign matter, in cancer patients, patients receiving cancer medicine or steroids, or by hypoxia [11, 12].

In plaque it is up to 10^{11} microorganisms per mg, and in deep holes and periodontitis, between 200 and 500 different types of bacteria can be found, dominated by anaerobic bacteria and gram-negative rods [11]. Bacteria are easily entering into the bloodstream and may spread to other organs such as the heart (endocarditis), joints (prosthesis and the like), lungs, etc. [11, 12].

In normal oral and dental status, small amounts of largely harmless microbes enter the bloodstream and rapidly secreted via the kidneys, during a normal tooth-brush. By instrumentation such as extraction of teeth, root filling, scaling, etc., larger amounts will pass into the blood, without having any problem for most people, with exception for risk patients [11].

Good oral hygiene prevents upper and lower respiratory tract infections in unconscious patients, patients on respirators, patients with immunodeficiency diseases and in patients who cannot themselves perform good oral hygiene [13, 14].

Poor oral hygiene easily leads to pneumonia in case of impaired immune system [13–16]. Oral decontamination with chlorhexidine 0.12% may reduce postoperative pneumonia from 9% to 3%, and the effect of good oral hygiene is especially observed in ventilator patients [17–21]. Bacteria from the oral biofilm can be aspirated into the respiratory tract and there initiate local and systemic infections from

pneumonia to sepsis [14]. Oral bacteria, poor oral hygiene and periodontitis are associated with lower respiratory tract infections in patients with reduced resistance against infections and in elderly patients with dysphagia and dry mouth [13, 15, 22–25].

23.5.1 Dry Oral Cavity

It may occur because of the increased drug use, a poor general condition, age changes and some diseases that cause reduced saliva secretion in the oral cavity. This may cause sore mucous membranes and increases the risk of infection [13, 22].

23.5.2 Stomatitis

Stomatitis is an important starting point for sepsis in patients with haematological diseases, cancer, severely impaired immune system, diabetes, rheumatoid arthritis, corticosteroid therapy or cytostatics [11, 23].

23.5.3 Fungal Infection

Candida albicans (often white coating in the mouth) easily occurs under prosthesis during poor oral hygiene, after radiation therapy to the head/neck region and by cancer chemotherapy. Prolonged antibiotic treatment and change of oral flora are predisposing for fungi. The mucous membrane below is usually mild bleeding and an entrance to infection [11, 12].

23.5.4 Infections Other Places

Poor oral hygiene can lead to pneumonia in patients having difficulty in swallowing or aspirating [13–16]. In this way, gram-negative bacteria, fungi and other bacteria from the oral cavity may reach the lower airways [13, 22].

Water from the spring is always containing gram-negative rods. Use therefore sterile saline 0.9% in severe immunodeficiency and in the unconscious patient [22].

Mouth brushes should be sterile. Contaminated equipment introduced in the oral cavity has led to catastrophic respiratory infections for the patient. Unsterile, contaminated mouth brushes led some years ago to a large, national outbreak of lower respiratory tract infections with *Pseudomonas aeruginosa* and other gram-negative bacilli among hundreds of patients in Norway [26].

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Wound Care: Skin and Soft Tissue

24

Abstract

At least 6% of hospital patients may have infections in the skin and soft tissue. Elderly patients often have infections and lesions associated with scratching and eczema. *Staphylococcus aureus* is the predominant cause, and methicillin-resistant *S. aureus* (MRSA) may be frequent in endemic areas. Erysipelas and impetigo are most often caused by group A or B streptococci. Shingles (herpes zoster) is relatively frequently occurring in elderly or immune-compromised and may be secondary infected by bacteria. Skin and deeper infections may be caused by using contaminated equipment or liquids. In 2012, 14,000 Americans got infections in the skin, joints and spinal canal of a methylprednisolone contaminated with different types of fungi, and more than 100 died. The treatment of wounds in healthcare is always an aseptic procedure. Tap water and bathing water may contain bacteria like *Pseudomonas aeruginosa* and other multidrug-resistant gram-negative bacteria and should not be used to clean wounds.

Keywords

Wound care · Wound hygiene · Aseptic procedures · Infection prevention · Change of dressings

24.1 Purpose

To establish good hygienic and infection control routines for wound treatment and avoid spread of microbes to the environment.

24.2 Comprise

All patients with different types of wounds, including burns, the person that is taking care of the patients and the procedures for handling equipment and waste used in the treatment of these patients.

24.3 Responsibility

The hospital management should ensure policies, equipment and resources that enable aseptic-sterile wound care.

Department management should ensure that guidelines and procedures are implemented in the ward.

Employees should comply with procedures and ensure an optimum daily wound care.

Physician is responsible for the indication and routines for wound treatment, as well as the scope, frequency of shift of bandages and the type of eventually drugs used in the treatment.

24.4 Practical Measures

24.4.1 Change of Bandages on a Clean Wound

Equipment: Sterile shift set, gloves, sterile gloves, sterile saline (0.9% NaCl), sterile dressings and swabs, sterile ointments, disinfectants for wounds, plaster, waste bag. Put everything on a clean, disinfected board [1–3].

- Patient-bound (or patient associated) clean care coat with long sleeves and cuffs, a surgical mask and cap and hand hygiene before work starts.
- Clean the nightstand, and disinfect the nightstand where the equipment can be placed.
- By non-sterile gloves, take off carefully the outer bandage and put it into the waste bag.
- Take off the gloves.
- Perform hand hygiene.
- Open sterile shift sets, and add saline and disinfectants to sterile sponges/swabs—aseptically.
- Put on sterile gloves.
- Sterile tweezers are used to remove the inner bandage on the wound and eventually wipe with sterile sponges/swabs—start from the clean wound and a little beyond.
- Next, use sterile tweezers in washing the wounds with sterile sponges/swabs and saline – one stroke each time from clean to unclean—avoid granulation tissue.
- Wipe gently from the wound edges and beyond with sterile tweezers.

- Ointment, wound powder, etc. which are added to the wound and around the wound should be sterilized and handled aseptically.
- Put on a new sterile bandage.

24.4.2 Check and Tidy Up

- Tidy up the equipment and waste bag—treated as infectious.
- Disinfect and wipe up the tables, etc.
- Take off the gloves, and disinfect the hands.
- Remove the care coat (take back), hang it outside out if in the patient room and take off the mask and hood.
- Perform hand hygiene before leaving the room.

24.4.3 Change of Bandages on an Infected Wound

- Check the infection status and measures: contact, air or contaminated blood?
- Put on appropriate infection control equipment: coat, gloves, surgical mask and cap.
- Carry out the wound procedure as above with recommended *infection control equipment*.
- All equipment, textiles, etc. from the patient's room are treated as infectious waste, contaminated textiles or reusable equipment for decontamination.

24.5 Background Information

Nosocomial wound and soft tissue infections—not related to surgery—may be 0.3–0.5% in hospitals and 1.3–1.7% at a nursing home as shown in Norway [4–7]. In addition come 3–5% from patients hospitalized for wound infections occurring outside hospital, resulting in that at least 6% of hospital patients may have wound infections [4, 5]. Elderly patients often have infections and lesions associated with scratching and eczema [8].

Staphylococcus aureus is a dominant cause of wound infection. Methicillin-resistant *S. aureus* (MRSA) may be a frequent cause in endemic areas. Erysipelas and impetigo are most often caused by group A or B streptococci. Shingles (herpes zoster) with larger and smaller wounds is relatively frequently occurring in elderly or immune-compromised and may be secondary infected by bacteria.

Gram-negative rods like *E. coli* often colonize wounds without being the cause of infection. Some resistant bacteria like *Pseudomonas aeruginosa* and other resistant bacteria may become both environmental problems, nosocomial problems and problems concerning treating of the wound [9]. Gram-negative rods often come from non-serious treatment of the wound with tap water and from dirty hands and bandages, equipment and injections [9].

Scabies is registered among nursing home patients and observed to be easily spread in hospitals [10, 11]. Exhausted people with infected wounds may be infected with resistant bacteria and with hepatitis or HIV, in connection with non-sterile injections [12].

Skin and deeper infections may occur after injection with contaminated equipment or contaminated liquids [13, 14]. In 2012, 14,000 Americans received injections in the skin, joints and spinal canal of a methylprednisolone (factory manufactured) which contained different types of fungi. Almost 800 patients were sick, and more than 100 died of the infection [14, 15].

The change of bandages on wounds is always an aseptic, i.e. sterile, procedure. Tap water and bathing water may contain bacteria like *Pseudomonas aeruginosa* and other resistant gram-negative bacteria and should not be used to clean wounds [9, 16].

The size and type of wound determine the type of wound care and treatment. Diabetic ulcers and pressure sores are often specially treated with different regimens, often in combination with surgery and in cooperation with dermatologists. These are not discussed in this chapter.

Extensive burn injuries are treated at special burns centres. Competence in infection control and in sterile treatment of burns is a basic part of a successful treatment. Burns are always an extra risk for development and spread of multidrug-resistant organisms (MDRO) in the hospital, among patients, personnel and environment, especially when there is admission of patients from areas with a high prevalence of resistant strains [17–20]. The special wound treatment is not included here. However, the outcome of serious burn injuries is strongly associated with sterility, personal and general hygienic conditions and a proper and preventive infection control [17–20].

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Prevention of Infected Pressure Sores

25

Abstract

All patients may be predisposed to pressure sore and infected sore because of immobilization, blood circulation impairment, reduced resistance to infections and other illnesses. Pressure sore may occur in all types of healthcare and is most often a problem among elderly. The incidence and infection of pressure ulcers are good indicators of the quality of care and treatment of patients. Many guidelines have been made for preventing pressure ulcers, indicating that this is a continuing problem in healthcare, especially because of serious complications. In the United Kingdom, it is estimated that about half a million people develop pressure ulcers each year and 1 of 20 acute inpatients get pressure ulcers after admission. In the United States, approximately one million each year may get pressure sore. Prevention is very important, by inspection, risk assessment, skin care, pressure relief, prophylactic change of positions, turning the patient, special mattresses and a good hygiene and infection control.

Keywords

Bedsore · Ulcer · Pressure sore · Wound care · Hygiene · Aseptic procedures · Infection prevention · Skin care · Pressure relief · Infected bedsore

25.1 Purpose

To reduce the number and severity of pressure sores (ulcers, bedsore) and complications related to this condition, like infections, osteomyelitis, sepsis and—in worst case—death.

25.2 Comprise

All patients may be predisposed to pressure sore and infected sore because of immobilization, blood circulation impairment, reduced resistance to infections and other illnesses. Pressure sore may occur in all types of healthcare and is most often a problem among elderly. This procedure does not include guidelines for general wound treatment.

25.3 Responsibility

The hospital management should ensure policies, guideline, equipment and resources to protect vulnerable patients against pressure ulcers.

Department management should ensure that procedures and equipment are implemented in the ward.

Employees should comply with procedures, prevent and control development of pressure sores, promote wound healing and prevent infections.

25.4 Practical Measures

The incidence of pressure ulcers and infection of pressure ulcers are good indicators of the quality of care and treatment of patients in hospitals and nursing homes. Many guidelines and procedures have been made for preventing pressure ulcers, both internationally and nationally, indicating that this is a continuing problem in healthcare [1–15].

25.4.1 Risk Assessment

- Patients with impaired mobility or activity are evaluated concerning risk for pressure ulcers [2–4, 13–16].
- A “Braden scale” can be used to assess the risk factors [17].

25.4.2 Skin Care

- At risk of pressure sores is the skin status examined at admission and daily thereafter, after major surgery or by changes in the patient’s general condition.
- Bony prominences are especially examined with respect to persistent reddening or discoloration.
- The skin should be cleaned when it is exposed to urine/faeces.
- If the patient has little control over urine and faeces, should measures for incontinence be implemented.
- Use mild soaps without perfume.

25.4.3 Pressure Relief

- Turn the patient, and use pillows to relieve areas exposed to pressure, at least [4]:
 - Every 2 h if bedridden. In addition, encourage the patient to move in bed—if possible [4].
 - Hourly, if in a wheelchair, and every 15 min shift of the position—if possible [4].
- The use of pressure-relieving mattress should be implemented as part of a comprehensive plan [4–7, 18, 19].
- When pressure ulcers occur, use special mattresses for pressure relief.
- When shift of position, direct pressure on bony prominences should be avoided by using pillows and other utilities.
- *Massage of bony prominences and use of rubber ring must be avoided!*
- When moving the patient, use lifting apparatus and other utilities such as slip sheets.
- Backrest should not be above 30°.

Nutrition and food are important [20].

25.4.4 Measures When Infected

Necrotic tissue provides ideal conditions for the development of infection, prolonged inflammation and delayed healing. Rinsing and debridement with removal of necrotic tissue (mechanical, autolytic, surgery) is required to prevent infection. The choice of method depends on the patient's condition and access to skilled personnel. When rinsing noninfected pressure ulcers, avoid the use of antiseptic medicaments and antibiotics. Recommended is a sterile treatment of the sore with a tempered, sterile saline 0.9%.

- If the wound is infected, autolytic agents should not be used.
- Surgical revision should be evaluated when the wound is infected.

25.4.4.1 Infection Control in a Small Pressure Ulcer

- Follow the written procedure for wound care.
- If the patient has a small, infected sore, a good control over secretion from the wound, and no known pathogenic bacteria present in the sore, a single room for the patient is not necessary if the patient understand the importance of good hygiene.
- Do not put the patient along with patients with impaired defence against infections or cases that are going to or have been operated.
- Patients with wounds infected with *Staphylococcus aureus*, MRSA or other resistant bacteria should be isolated in single rooms and treated as infected.
- Patients with problems that may cause transmission of infection should have a private room.
- Disinfect hands before wound care.

- Use surgical mask, cap, gloves and disposable infection coat with long sleeves in wound care.
- Used bandage, infection coat and other single-use equipment are put in the yellow waste bag.
- Contaminated textiles are placed in a bag for infected textiles.
- Gently undress the infection control equipment (PPE) without contaminating yourself or the uniform.
- Thorough hand hygiene before leaving the room.
- The patient is recommended to perform frequent hand hygiene.

25.4.4.2 Infection Control of Large Ulcers/Excess Secretion

- Follow the written procedure for wound care.
- The patient should be isolated as contact infection in a single room if:
 - The wound infection area is so large that it cannot be completely covered by a bandage.
 - The dressing does not capture all pus.
 - There is uncontrolled secretion.
- Identify the cause of the pressure ulcer, and define the treatment program.
- Sampling of tissue from the walls or bottom of the ulcer, after carefully rinsing the pus and secrete in the wound, gives the best specimen for microbial diagnosis.
- In case of antibacterial therapy:
 - Avoid local treatment with antibiotics.
 - Initiate antimicrobial agents but only after resistance patterns.
- Hand disinfection before wound care.
- Use PPE, surgical mask, cap, gloves and disposable infection coat with long sleeves.
- Used bandage, infection coat and other single-use equipment are put in the yellow waste bag.
- Contaminated textiles are placed in a bag for infected textiles.
- Gently undress the PPE without contaminating yourself or the uniform.
- Hand hygiene before leaving the room, even after use of gloves.
- Thorough and often hand hygiene of the patient.
- Visitors should follow routines for contact regime, and they should wash their hands before leaving the room.

NB! Do not contaminate your hands when packing the waste. Always perform handwashing before leaving the room/sludge and, eventually, hand disinfection.

25.5 Background Information

Ulcers are *skin damage caused by repeated and continuous pressure and result in the damage of underlying tissue* [21–23].

During excessive pressure, the pressure ulcer can evolve quickly—within a day—and at a low pressure in the same place, it takes longer for signs of arising pressure ulcers [6, 21]. Elderly over 70 years often have a thin skin and are therefore more susceptible to pressure damage by immobility [2–5, 12]. Infection of the pressure sore is detected by pus, secretions and clinical signs (rubor, calor, dolor) of infection. Bacteria detected in bedsores, ulcers or other wounds without clinical signs are usually not considered infectious, only as bacterial colonization. Wound infections are frequent causes of complications and may at worst lead to sepsis with fatal results.

The occurrence of bedsores varies. In the United Kingdom, it is estimated that about half a million people develop pressure ulcers each year and 1 of 20 acute inpatients get pressure ulcers after admission. [3] In the United States, approximately one million each year may get pressure sore [2]. Prevalence varies, 3.5–69%, with the highest proportion in patients with acute illnesses and with an incidence of 2.7–29% [2, 23–28]. Nursing homes have a lower prevalence and incidence [29–31].

25.5.1 Infected Bedsores

Infections in bedsores in Oslo were found to be 0.1–0.2% in hospitals and 1.3–1.6% in nursing homes and homes for the elderly [32, 33]. The dominating causative microbe in infected bedsores is *Staphylococcus aureus*. Other bacteria like enterococci, *Escherichia coli*, *Pseudomonas* species or other gram-negative bacilli and anaerobic bacteria (particularly in large, deep wounds) may often colonize the wound. The real infection sits in the wall of the ulcer, while a variety of bacteria colonize in pus, secretions and tissue. Therefore, proper sampling for microbial diagnosis is important.

The patients are infected from their own flora in the upper respiratory tract, skin or intestinal tract, the staff's hands and clothes, contaminated equipment, bandages, ointments or carriers in the environment.

25.5.2 Complications from Infected Bedsores

- Sepsis that may increase mortality to 55% [12, 34]
- Cellulite
- Osteomyelitis and arthritis
- Cancer development in chronic wounds—“Marjolin ulcer” (aggressive cancer type)

Studies from the United States show that up to one third of patients with bedsores die during hospitalization and more than half die in the next 12 months. Patients with pressure ulcers in hospitals have four to five times greater risk of dying than similar patients without bedsores [35].

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Part V

Respiratory Infections



Prevention of Respiratory Infections

26

Abstract

Respiratory infections are common in the population. Lower respiratory tract infections are mostly preceded by upper respiratory infection, having a short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly patients. Hospital-acquired pneumonia (nosocomial pneumonia) may occur in ca 2% of admitted patients. Among intensive care patients, the rate is very high, 5–30%. Nosocomial pneumonia is related to degree of emergency, intensive activity, surgical procedures, isolation conditions, understaffing, poor hygiene, seasonal outbreaks and endemic and epidemic conditions in the community. Ventilator-associated pneumonia is a serious complication that may be prevented. Nosocomial pneumonia increases hospital stay, 7–14 days, represents an additional cost of at least 25,000 USD per patient, and has a crude mortality of 30–70%. Prevention is done by a good general hygiene and barrier against transmission of infected air and droplets. A significant reduction of respiratory infections is documented for cases both inside and outside healthcare institutions, by proper use of infection control.

Keywords

Hospital-associated pneumonia (HAP) · Community-associated pneumonia (CAP) · Nosocomial pneumonia (NP) · Ventilator-associated pneumonia (VAP) · Infection control · Airborne infections · Aseptic procedures · Infection prevention

26.1 Purpose

To prevent the development of nosocomial pneumonia (NP) and other respiratory infections in patients admitted or treated at the hospital [1–21].

26.2 Comprise

Patients, personnel and visitors at the hospital must be protected against airborne infections. All patient-related equipment, medical devices, textiles, water and drainage, ventilation, food, waste, etc. should be protected against transmission of pathogenic microbes that may cause serious respiratory infections [21].

26.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

26.4 Practical Measures

There are many international guidelines that focus on the prevention of pneumonia in hospitals [1–3, 16–37].

General preventive measures include good hand and cough hygiene and good hygiene in the care and treatment and isolation of infectious patients.

Prior examination before hospitalization prevents the spread of infection, especially during epidemics [21]. Pre-contact with the patient's physician, the patient, relatives or others provides useful information on respiratory infections, like flu.

26.4.1 General Measures

- *Written procedures for hand hygiene*; concerning training and control of the staff's use of hand hygiene between patients, before clean and after unclean work situations, clean and unclean equipment and before and after use of gloves. The training and reminding of hand hygiene should be repeated one or more times each year in each ward.
- *All medical equipment* used on patient's airways should be sterile or at least disinfected.

- *The prevalence of nosocomial* respiratory infections in the unit should be checked and monitored by prevalence surveys.
- *Cough hygiene* for personnel, patients and visitors. Hold a disposable paper in front of your mouth while coughing or sneezing, discard it immediately afterwards in the appropriate waste container and wash or disinfect the hands [38]. If the patient has respiratory infection and is coughing, put a surgical mask on him/her during transport. Visitors must perform proper cough hygiene (cough in disposable paper that is discarded and then wash the hands). Do not cough in your elbow bend and sleeves or use your own clothes or uniform like handkerchief! [38].
- *Environmental hygiene.* Daily cleaning; removal of dust, loose particles and biological material from floors, fixtures and equipment. Spills and dust promote the growth of microbes in the environment and the risk of re-aerosols of microbes to air. Re-aerosols of infectious agents can be inhaled as air contaminants and deposited on furniture and equipment as contact contaminants on bedside table, bed linen, uniform, etc. Disinfect common contact points daily.
- *Visitors* should implement hand hygiene, follow procedures and avoid visits if they have respiratory tract infection or other contagious disease [39].

Personnel with communicable disease should be on sick leave.

Respiratory infection is contagious. If having an upper respiratory tract infection like a cold, sick leave may be assessed by the head doctor of the department. If going to work in the department, use a surgical mask in work that may involve a risk to patients or staff. There is no access to patients with impaired infection defence!

Personnel with acute respiratory infections like influenza, pulmonary tuberculosis, other contagious respiratory infection, group A streptococci, pertussis or other airborne disease, should not work in hospitals until free of the infection.

26.4.2 Patient with Respiratory Infection: Prevent Transmission

- Patients with respiratory infection should be isolated, at least in single rooms.
- Resistant bacteria in respiratory tract or other localizations or if suspected of pulmonary tuberculosis: place the patient in isolation for airborne infections and use respirators (P3 mask) for suspected tuberculosis (see section on isolation).
- Contact with healthcare abroad; isolate for airborne infections until negative control samples; check for MRSA, VRE and antibiotic-resistant gram-negative rods.
- Exposed for MRSA last 12 months in or outside the country/state, or previously -MRSA positive; -airborne isolated until negative control samples.
- Use PPE: surgical mask, cap, gown and gloves before entry to rooms with patients with untreated/undiagnosed respiratory tract infection. Hand hygiene before and after glove use.
- Use surgical mask on the patient with cough and sputum, during transport, hospitalization, etc.
- Help to cough up, chest physiotherapy; use PPE and face shield/goggles.
- Avoid uncontrolled spread of respiratory secretions and sputum.

- Avoid unnecessary antibacterial therapy.
- Good oral hygiene for all patients.
- Good sampling technique promotes adequate treatment [40, 41].

26.4.3 Prevent Postoperative Respiratory Infection

- The shortest possible hospital stay, preoperative stay and intubation.
- Breathing exercises—deep breathing—in advance and afterwards, particularly in abdominal or thorax surgery.
- Good overall oral care, see chapter on oral hygiene.
- Good hand hygiene between patients, before and after care of respiratory equipment, sampling equipment, examinations and between unclean and clean procedures.
- Adequate glove use. Hand hygiene before and after glove use!
- Use patient-bound care coat with long sleeves when caring for patients, and shift for each watch or more often if contaminated.
- Care bedridden patient with good hygiene, turning immobile patients to prevent pressure sores (see separate section).
- Avoid intubation through the nose which can cause sinusitis.
- Fast awakening from anaesthesia and rapid mobilization.
- Aspiration of airways with tracheal catheter (see separate section).
- Continuous sub-glottis suction—if intubated—which removes secretions from the upper respiratory tract and reduces the risk of early VAP (ventilator-associated pneumonia).
- Not flat couch—30–45 degrees in supine position.
- Adequate treatment of pain, assistance to cough and regular chest physiotherapy (see separate section).
- Avoid uncontrolled coughing; cough hygiene.
- Avoid vomiting/aspiration in awakening phase.
- Avoid unnecessary drain, especially tubes or drain through the nose, etc.
- Avoid unnecessary respirator equipment, etc.
- Avoid bacterial colonization from the intestine. Get early start of the intestinal function by enteral nutrition. Aspiration is prevented by raising the headboard; food and drink in small portions or with tube placed in jejunum for immune nutrition.
- Sterile treatment of respiratory tract from the trachea and down by all procedures.
- Avoid unnecessary use of antibacterial agents.

26.4.4 Ventilator Patient and Equipment

- Written guidelines should be present and updated for ventilator patients [27–30, 32–36, 42].
- Respirator patient and all associated equipment are protected against infection.

- The patient is placed in a separate and clean room with good ventilation to protect against aerosols, etc., from suction, coughing, etc.
- Use of microbial filter in ventilation circle is discussed; it is often used in connection with the ventilator and patient.
- Cleaning, disinfection, sterilization and maintenance of all types of respiratory equipment (see separate section).
- Always use sterile equipment and sterile liquids for the treatment of respiratory tract.
- Avoid liquid and secretions in the ventilation circle, and prevent that condensation overflows in patient's airways.
- Do not replace ventilation circle too often (2–7 days).
- When using HME, changed this at least once per day.
- Sterile conditions by suction from the airway (see separate section).
- Chest physiotherapy and mobility (see separate section).
- Water from the spring may have gram-negative bacteria, legionella or bacteria-carrying amoebas and is not intended for intensive care patients or immune-compromised [43].
- Patients with VAP can get reactivation of herpes virus in the respiratory tract; this may pose a risk of transmission [44].

26.4.5 Other Actual Measures

- Vaccination— influenza vaccine to selected elderly patients (without adjuvants).
- Pneumococcal vaccine to patients without the spleen or impaired immune status, as well as to people with heart-lung problems by the age of 65 years [29, 45–52]. Children may also be protected by the vaccine [53].
- Antibacterial prophylaxis—special indications (drowning, aspiration, frostbite, etc.).
- Check the water quality with regard to *Legionella* ($\times 1/\text{year}$) and colony count of gram-negative coliform bacteria every month.
- Do not place the sink/washstand too close to the patient due to splashes and aerosols.

26.5 Background Information

Lower respiratory tract infection “is cough, fever and purulent sputum, irrespective of the result of expectorate culture and/or pulmonary radiographs. If purulent sputum does not occur, but lung X-rays show typical infection image, is the diagnosis still reported as infection” [3–5]. This definition is originally from the CDC and is modified to Norwegian conditions by the Norwegian public health [4–14, 16–19]. More recent definitions from the CDC are also used by some hospitals in Norway [15, 20].

Patients may be admitted *because* of a respiratory infection or *because* of another disease like infarct, having in addition a respiratory tract infection. Both cases are potential sources of infection in the hospital environment.

26.5.1 Definitions

- CAP is community-associated pneumonia caused *outside the healthcare*.
- HCAP (HAP) is healthcare-associated pneumonia that occurs in hospitals, nursing homes, homecare, dialysis, etc.; nosocomial infection [21, 46–54]. Nosocomial respiratory tract infections occur up to 30–90 days after admission to hospital or other health institution. Pneumonia may occur in patients, personnel, visitors, service personnel and others who handle material, equipment and textiles from healthcare institutions. It is often older patients or young children who get nosocomial pneumonia and who need hospital treatment [46–54].
- *Respiratory tract infection*: acute inflammation of the respiratory tract caused by microbes.
- *Upper respiratory tract (URT) infection*: the nose, sinuses, ears, pharynx and larynx (rhinitis, sinusitis, otitis, pharyngitis, laryngitis), relatively rarely occurring in hospitals, except outbreaks of sore throat.
- *Lower respiratory tract (LRT) infections*: trachea, bronchi and lung tissue (tracheitis, bronchitis, pneumonia). Lower respiratory tract is a sterile, semi-critical area. All technical equipment introduced, passing the patient's vocal cord, is a risk to the patient. Surgical patients and patients on assisted ventilation are therefore very susceptible to lower respiratory tract infection.
- *Nosocomial pneumonia (NP)* might be difficult to distinguish from other lower respiratory tract symptoms occurred during or after hospitalization. Typically, NP occurs 2 days or more after admission and is not in the incubation period at admission.
- *Ventilator-associated pneumonia (VAP)* develops usually after more than 2 days after endotracheal intubation. The risk of VAP is found to increase by 3% per day for the first 5 days, 2% per day from days 5 to 10 and then 1% per day [27, 52].
- *Ventilator-associated complications (VAC) and ventilator-associated events (VAE)* are more advanced methods that may detect deterioration of a ventilated patient [25, 34–36].
- *Nosocomial lower respiratory tract infection*: there are a number of recent definitions that include bronchitis and various stages of chronic obstructive pulmonary disease, not further discussed here [29].
- *Carrier of pathogenic microbes*: individual with bacterial colonization of the upper airways without signs of infection. The bacteria can cause individual infections and may be the source of infection to others.

26.5.2 Criteria for Nosocomial Pneumonia: CDC 1988 [16]

The criteria are often difficult to clarify, but include the following:

1. Auscultation of the chest—not normal + one of the following findings:
 - (a) Recent purulent expectorate or increased secretion.
 - (b) Changed nature of sputum.
 - (c) Microbes isolated from blood culture.
 - (d) Pathogenic microbe isolated by trans-trachea aspiration, bronchial test or biopsy.
 - (e) Isolation of virus or virus antigens in the respiratory tract.
 - (f) Detected specific IgM or four times IgG titre increase in pairs.
 - (g) Histopathological findings.
2. X-ray result: new infiltrate or progression, densification, caverns or pleural liquid + one of the following: see (a)–(g) as above.
3. The patient has two of the following symptoms: apnoea, tachypnoea, bradycardia, wheezing respiration, rhonchi or cough + one of the following: see (a)–(g) as above [16].

26.5.3 Prevalence

Hospital infections occur in 3–21% (mean 8.7%) of all cases, and 0.5–11% may get nosocomial lower respiratory tract infection [1–3]. In Norwegian hospitals, approximately 1–2% of the patients get nosocomial pneumonia, related to the degree of emergency and intensive activity, surgical procedures, isolation conditions, seasonal outbreaks, endemic and epidemic conditions in the community, etc. [4–15]

Respiratory infections are common in the population [1–3, 23]. Lower respiratory tract infection is mostly preceded by upper respiratory infection, short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly subjects.

Pneumonia outside healthcare, CAP. In the United States, approximately 915,000 people, usually older than 65 years of age, get pneumonia every year. And the CAP together with influenza constitutes the seventh leading cause of death in the United States [2, 23, 31]. Vaccination against influenza and pneumococci is highly recommended for certain age groups and categories of patients in the United States [23]. Occurrence in Norway is unknown due to a lack of registration.

Nosocomial lower respiratory infection affects 15–20 per 1000 hospitalized patients, and 20–45% dies from infection.

Nosocomial pneumonia increases hospital stay for the patient 7–14 days and represents an additional cost of approximately 25,000 USD per patient [25–27]. Incidence in the United States is estimated to 5–15 cases per 1000 hospitalizations and 5–15% of ICU (intensive care unit) patients [27, 35]. It is dominant in the ICU

and the cause of more than 50% of consumption of antibacterial agents in the unit [27]. Mortality is estimated at 30–70% (crude mortality) in 2005 [27].

In Norway, nosocomial lower respiratory infection accounts for approximately 25% of hospital infections [8, 11, 15].

26.5.4 Microbes: Respiratory Infections

Many types of microbes cause lower respiratory tract infection. Aetiological agents are often difficult to detect, and in severe cases it can be a polymicrobial flora [27]. Sampling is required; blood culture, cultivation of sputum, quick tests for influenza and other viruses, legionella and pneumococcal, urine antigen tests, fungal cultures, tuberculosis and atypical mycobacteria in bronchial aspirate, etc. [23] Invasive sampling gives usually no more than a good quality sputum [55]. One gram preparation of sputum may be useful [56].

In cases of pneumonia occurring outside the hospital, aetiologic agent is detected in only about 25% [57]. Bacteria associated with respiratory tract infections, like pneumococci, are still sensitive to common antibiotics in Norway [58, 59]. However, patients from abroad are often colonized with more resistant microbes, including penicillin-resistant pneumococci.

The oral cavity has a rich arsenal of 100 different aerobic and anaerobic bacteria, including pneumococcus and *Haemophilus influenzae* which could be more pathogenic if introduced into the sterile area below the vocal cords. This may occur by aspiration, intubation, lack of cough reflexes and poor oral hygiene. In the frontal third of the nose mucosa, there is often a rich growth of staphylococci and gram-negative bacteria, while in the back part (nasopharynx) of the nose, the mucosa is almost sterile. Upper respiratory infection with rhinovirus and other respiratory viruses may quickly spread to the lower respiratory tract with secondary bacterial invasion.

26.5.5 Hospital Flora

One day after hospitalization, the patient may have “new flora” in the upper respiratory tract, gastrointestinal tract, skin and mucosa, transferred from the hospital’s food, environment, water, equipment, hands, etc. Hospital flora is promoted by antibiotics that remove protective normal flora and can cause severe lower respiratory tract infection.

26.5.6 Epidemics: Respiratory

Epidemics in society may affect infections in the hospital. Outbreaks of influenza usually increase the rate of hospitalization and thus the risk of nosocomial infection. This was observed during the pandemic influenza in 2009. Epidemics in that society may influence hospital admittance and infection control:

- *Mycoplasma pneumoniae*—ca. each fourth year.
- *Chlamydia pneumoniae*—annually.

- Influenza—annually +10–50–100-year larger outbreaks.
- Legionella—local epidemics (water, aerosol).
- RSV—annually (children's section and nursing homes).
- Metapneumovirus—annually.

26.6 Important Microbial Causes of Pneumonia

	Nosocomial	Community
Gram-negative rods:		
– <i>Klebsiella pneumoniae</i>	60%	(elderly)
– <i>Enterobacter</i>	10%	
– <i>E. coli</i>	10%	
– <i>Pseudomonas aeruginosa</i>	15–20%	
– <i>Acinetobacter</i>		
– <i>Proteus, Serratia, Burkholderia</i>		
<i>Staph. aureus</i>	10%	2–10%
Pneumococci	5%	50–90%
Streptococci		
– Note group B streptococci! (neonates)	+	–
<i>Haemophilus influenzae</i> (obs elderly!)	(+)	10–20%
Anaerobic bacteria (aspiration)	++	
<i>Moraxella catarrhalis</i>	(+)	(children)
<i>Legionella</i>	(+)	(+)
<i>Mycoplasma</i> (mild “walking pneumonia”)	(+)	5–18%
<i>Chlamydia pneumoniae</i>	(+)	2–3%
Respiratory syncytial virus, RSV	+++	2–8%
Influenzae A, B	++	0–8%
Metapneumovirus	+	+
More seldom		
Fungi (<i>Candida, Aspergillus, Pneumocystis</i>)	IMMS	
Virus (CMV)	IMMS / PO	

IMMS immunosuppressed, PO postoperative

26.6.1 Risk of Resistant Bacteria (MDRO = Multidrug-Resistant Organisms)

Well-known risks in hospitals:

- Antibacterial treatment during the last 90 days [23].
- Admitted in hospital for 5 days or more.
- Hospital or other healthcare facility with a high prevalence of resistant microbes.
- Treated abroad.
- Previously been colonized or infected with resistant bacteria.
- Prolonged chronic disease and/or immunosuppressed [23].

- Prolonged mechanical ventilation—“late-onset VAP”.
- Poor control or airborne infections. *Acinetobacter*, *Pseudomonas* and other resistant bacteria may spread as nosocomial epidemics among patients [60–63].

26.6.2 Gram-Negative Rods—Respiratory Tract Infections

- *Intestinal and environmental*; gram-negative bacteria are normal in the intestines, perineum, lower extremities, sometimes on the hands and less frequently above the belt site. Antibiotics select for the presence of gram-negative bacteria in the throat. Gram-negative rods are normal environmental flora in uncooked foods, wet areas, equipment, clothes, bandages and flowers [63].
- *Water and water sources of various kinds* are usually contaminated with gram-negative rods and rarer legionella- and bacteria-carrying amoebas [64, 65].
- *Transmitted*; via contact (hands, equipment, textiles, food, water) and aerosol, dust and particles.
- *Lifetime in environment*: varies—infinity in wet areas and 7–14 days–10 months or more, in dry areas for certain types.
- *Problems with gram-negative, especially for intensive and acute wards* with a high use of antibacterial agents and thus the risk of resistance against antibiotics.
 - Colonize early tracheal tube/trachea.
 - Problem with ventilator treatment and cleaning and production of biofilm.
 - Frequently coming up from the intestine via the ventricle.
 - Frequently involved in postoperative pneumonia.
 - Resistance development against disinfectants.

Escherichia coli is the most common cause of postoperative nosocomial pneumonia, with increasing number of resistant strains in hospital, like the ESBL (extended spectrum beta-lactamase activity) often imported from abroad and spread in hospitals [63].

Enterobacter cloacae and other *Enterobacter* species vary in frequency and may have “epidemic” behaviour, in a department or hospital. It is associated with intensive treatment and major surgery and may often develop resistance [63].

Klebsiella pneumoniae is a common cause of nosocomial pneumonia in severely ill patients, after major surgery and prolonged intensive treatment, and may become highly resistant (ESBL and other mechanisms) [63]. It is also associated with high alcohol consumption [63].

Pseudomonas aeruginosa is a common cause of nosocomial pneumonia with a high mortality and is particularly associated with severely ill patients, major surgery, prolonged intensive care and spread through colonized flowers, equipment, wet areas, environment and infected water and can become highly resistant [60–63].

Acinetobacter baumannii is most often multidrug resistant and may survive in dry environment for months and year. *Proteus* sp., *Serratia marcescens* and other species

of *Klebsiella* and *Pseudomonas* are less common, but with a tendency to develop resistance. These, mostly environmental contaminants, may occur as a result of high consumption of selective antibacterial agents, poor hand hygiene, a heavy environment flora, contaminated equipment and airborne infections (aerosols)! Findings should initiate a review of hygienic procedures and isolation conditions [63, 66].

Burkholderia cepacia (BC) and other *Burkholderia* species are very resistant bacteria, especially found in patients with cystic fibrosis (CF). All patients must be protected from this type of infection. BC infection must be treated by contact and airborne isolation [67]. In a hospital outbreak, 52 patients got infection by BC; most of them had no CF, and five patients died [67].

26.6.3 Gram-Positive Cocci

Staphylococcus aureus is a relatively common cause of nosocomial pneumonia, introduced from the upper respiratory tract (nose), hands, wounds, equipment, etc. During influenza periods it may cause secondary invasion to the lungs. The bacteria persist in a dry condition about 3 months in the environment. *S. aureus* may cause serious lung abscesses, and patients with suspected staphylococcal pneumonia should be airborne isolated!

Methicillin-resistant *S. aureus* (MRSA) survive more than 10 months in the environment and may cause serious, fatal infections. The patient should be isolated as contact and airborne infection. In the United States, there is a growing incidence of nosocomial pneumonia caused by MRSA [68].

Streptococcus pneumoniae (pneumococcus) comes usually from the patient's own respiratory flora and causes approximately 5% of the postoperative pneumonias that occur after uncomplicated surgery. "Early pneumonia" occurs <4 days after admission in former lung-healthy patients. The infection is spread by contact, droplets or airborne, and the prevalence in hospitals is increasing [69–73]. Patients with penicillin-resistant strains of pneumococci in the respiratory tract should be isolated as airborne infections.

26.6.4 Other Bacteria

Anaerobic bacteria from the upper airway may invade via aspiration and are most often penicillin sensitive. Abscess formation in the lungs is a rare complication.

Legionella pneumophila is a waterborne bacterium, resistant to 65° or even higher temperature. Legionella is associated with severe lung infections (Legionnaires' disease) after inhalation of contaminated aerosols. There are quick tests like antigen testing of urine. Legionella control of water is important in health-care institutions [21, 74].

Moraxella catarrhalis is associated with ventilator treatment, steroid therapy, transmission by close contact between patients, "early pneumonia" <4 days after admission, chronic lung disease and lung cancer.

Haemophilus influenzae may be ampicillin resistant and have relatively often epidemic behaviour among weak patients and patients in nursing homes. “Early pneumonia” may occur <4 days after operation and often—at the same time—similar infections in staff. It is associated with chronic lung infection and uncomplicated surgery. Outbreaks of non-typeable *H. influenzae* may occur [75].

Mycoplasma and *Chlamydia pneumoniae* are contagious within the family, but rarely observed as epidemics in hospitals.

Waterborne amoebas can carry therapy-resistant bacteria [64, 65].

Atypical mycobacteria can be detected in the tap water.

26.6.5 Virus

Respiratory tract viruses are usually very contagious and can lead to a high mortality in healthcare institutions [76–83].

Respiratory syncytial virus (RSV) is mainly causing lung infections in infants during yearly winter epidemics in and outside the hospital in the period of November to March. Nosocomial infection is very common in healthcare institutions, and RSV patients should be isolated for airborne infection. There is a high and rapid spread of RSV among infants—up to 30% or more may be infected in a ward. This has been reduced to <5% by using PPE, like gown, gloves, surgical mask and cap and also by including cohort treatment (collecting children with the same infection) and airborne isolation. RSV transmission by droplets and air may trigger epidemics among the elderly and persons with impaired immune system.

Influenza virus A, B: Type A is usually causing autumn and winter epidemics in nursing homes, retirement homes and hospitals. Prophylactic vaccine has varying effects [82]. No effective virus therapy. The patient is isolated as airborne and droplet infection. *Staphylococcus* or pneumococcal pneumonia is relatively often following after influenza, especially among elderly and weak patients [76].

Human metapneumovirus, *Boca virus*, etc. may cause protracted respiratory infections [76, 80, 81].

26.6.6 Vaccination

Pneumococcal and flu vaccine have some varying effect and coverage [29, 30, 53, 71, 72, 76, 82]. Vaccination can prevent hospitalization and probably infarction and stroke among older persons [83, 84].

26.6.7 Common Pathways of Infections

26.6.7.1 Own Oral Flora and Skin Flora

Biofilm, periodontitis, poor oral hygiene and selective antimicrobials may predispose for lower respiratory tract infections [85–91]. Poor personal hygiene is also associated with risk of lung infections.

Factors influencing airborne transmission:

- Humidity increases survival of bacteria in the environment.
- Particle size is important for carrying capacity and tissue capacity. A particle of $12.5 (+/- 5) \mu\text{m}$ can carry 2–11 bacteria. Small particles, $<5 \mu\text{m}$, may float in the air in several hours, 1–2 m or more from the source of infection. The smaller the particles are, $<3 \mu\text{m}$, the further down the airways they may reach.
- Normally, the number of microbes and particles breathed into the lungs per day is ca. 10,000.
- Sneezing when having colds: ca. 20,000 rhinovirus particles are released into air.
- A carrier of *S. aureus* has bacteria most commonly in the nose, throat, skin/hands and perineum (men usually more than women). A nasal carrier of *S. aureus* emits 1–100 *S. aureus*/m³ air, and the same does a carrier of MRSA.
- Tuberculosis (*Mycobacterium tuberculosis*); patient with untreated tuberculosis emits usually 30–50 bacteria/day to the air, i.e., approximately 1 bacterium per 400 m³ of air.

Source of air contamination:

- Infected patient/staff.
- Biological particles and particle dust from disposable items.
- Infected dust/aerosols.
- Skin cells and particles constitute a large proportion of “grey dust” which is released in large amounts from patients, staff and visitors. Thirty thousand to 60,000 dead skin cell particles per minute are released from normal humans; one million per hour and more than 500 million per day. About 10% of the particles may carry bacteria with 5–12 bacteria per particle. Over time they may fall down on surfaces, equipment and floors and are also pulled by air into machines and other equipment that goes on air cooling.
- Inventory/floor, flowers/plants, bath/shower.
- Droplet infection and infected condensate in the ventilation circle, nebuliser, water-moistening machines, suction systems.
- Infected ventilation system or air-conditioning that emits aerosols, dust and microbes from filters.

Source of infection from equipment/contact:

- Personal carrier state.
- The patient’s immediate environment.
- Bed, sink, tables, curtains, lamp, call cord.
- Bronchoscope, spirometer.
- PC keyboard phones, mobile phones, common touch points for personnel.
- Respirator equipment.
- BT apparatus, stethoscope, other examination equipment.
- Infected water, gram-negative bacteria, *Legionella*, atypical mycobacteria and amoeba-associated bacteria.

26.6.8 Registration of Respiratory Tract Infections

Infections are registered according to definitions [16]. However, the methods for registering are changing, resulting in not comparable findings over time [15, 16, 20].

26.6.9 Surveillance

Pneumonia can be followed with “syndrome monitoring”: increased absenteeism, increased number of hospital admissions, increased sales of respiratory and fever relievers, increased number of physician visits, etc. [92]

26.6.10 Disease, Mortality, Costs and Risks

Community-associated pneumonia (CAP). The clinical and economic burden of pneumonia in Europe is high, affecting people over 65, more often men than women, and mortality varies, 1–50%, especially at high age and impaired general condition [93]. The illness is dominated by pneumococci that often may be penicillin resistant and which have the worst long-term prognosis [93]. In the United States, CAP leads to 4.2 million contacts with physicians each year and is the eighth leading cause of death. CAP causes ca. 1700 hospitalizations per 100,000 inhabitants per year, and 10–20% of them are admitted to intensive care units [94]. The costs are high, more than 17 billion USD each year [94]. In England there is increasing admittances to hospitals due to pneumonia [95].

Nosocomial pneumonia, healthcare-associated pneumonia (HCAP/HAP). The mortality varies between hospitals, patient categories and the proportion of intensive patients, but is estimated to be:

- Twenty to forty-five percent of all patients.
- Fifty percent of patients with bacteraemia in addition.
- Most deaths in the winter season, especially very cold winters.
- Ten percent of VAP patients may die (attributable mortality) [35].
- Pennsylvania Healthcare registered in 2007 nosocomial pneumonia in 0.2% of the patients, increased mortality in 21.1% (compared with non-infectious), 17 extra hospital days and about 160,000–180,000 USD in extra expenses per patient (mean) [96].
- Among 436,000 patients hospitalized with pneumonia, 34% had nosocomial pneumonia, while the rest had pneumonia starting outside hospitals and in other health services (CAP). Nosocomial pneumonia had a higher rate of death; 11%, than non-nosocomial pneumonia; 5%; $p < 0.001$ [97].

Nosocomial pneumonia may increase admission period by approximately 9 days and has up to 50% mortality. With a daily cost of 2000–3000 USD per patient in an

intensive unit, a nosocomial pneumonia would charge the hospital with extra expenses of 18,000–27,000 USD per patient [98, 99].

26.6.10.1 Risk of Lower Respiratory Tract Infection

- Inhalation of infectious and aspiration.
- Poor oral hygiene with biofilm formation.
- Elderly people and children under 5; people who smoke; ASA classification over 2; obesity and diabetes; epilepsy, alcoholism or dysphagia.
- Chronic cardiovascular diseases, kidney disease, immunosuppressed due to therapy or disease (including HIV).
- Pre-existing lung disease; atelectasis, pneumothorax, chronic obstructive lung disease, etc.
- Poor cough reflex and poor cough hygiene.
- Postoperative patients, particularly after thoracic-abdominal surgery (pneumococci, *Haemophilus influenzae*) [100–102].
- Mechanical ventilation in intensive units; particularly at low staffing, high operating pressure, high consumption of broad-spectrum antibacterial agents, many patients in the same room, etc.
- Vomiting with aspiration, nasogastric drainage with growth of intestinal flora and the growth of gram-negative bacteria from the environment and the intestinal in the upper airway.
- Prolonged postoperative period, immobility, decreased consciousness, dysphagia, reduced cough reflex, decreased cilium activity and increased mucosal adhesion.
- Impaired stomach acid secretion and ascending growth of intestinal bacteria.
- Infected or colonized respirator equipment, endotracheal equipment/tracheal, stoma with invasion of oral flora.
- The use of non-sterile respirator equipment (non-sterile kept disposal tubes or reusable equipment without disinfected of inner parts).
- Local factors, such as poor cleaning, contaminated water (*Pseudomonas aeruginosa* and other gram-negative rods, atypical mycobacteria, *Legionella*), ventilation systems (*Acinetobacter*, staphylococci, MRSA), infection carriers in the environment (gram-negative, resistant bacilli, MRSA, viral infections, etc.).
- Contact with birds (psittacosis).
- Recently stay in a foreign hospital/hotel or exposed to steam from cooling towers (*Legionella*).
- Contact with patients with influenza and other respiratory viruses (secondary invasion by pneumococci/*S. aureus*; high mortality).

26.6.10.2 Pathogenesis

- Inhalation of infectious +/– mucous secretions (virulence) from the upper airways down to alveoli.
- The mucosal affection spreads directly/indirectly/through pores to nearby located alveoli, causes interstitial infiltration with pus and secrete, and often simultaneously the occurrence of bacteraemia.

- From 4–7 days of infection, there is production of specific antibodies against the infectious agent.
- The spontaneously course is with “crisis”, temperature fall and termination of bacteraemia.

26.7 Ventilator-Treated Patients and VAP

Ventilator-associated pneumonia (VAP) is prevented in different ways at intensive units in Europe [32]. Only about 40% have single rooms for the patients, 31% are using sub-glottis drainage, and 24% follow routines for change of the respiratory circle. In all, 90% are intubated orally, 84% use noninvasive mechanical ventilation and 82% are using HME (heat and moisture exchangers). In 74%, the patients are screened regularly for MDRO (multidrug-resistant organisms), 93% use contact isolation measures for MDRO, 83% are isolating patients with MDRO, and 80% use patient-bound gown and disposable gloves at each bed with MDRO patients [32].

There are many guidelines used to prevent VAP [33–36, 42, 103, 104].

- VAP usually starts 48 h after endotracheal intubation. Endotracheal intubation damages mucosal tissue, increases biofilm formation and changes ciliar activity and phagocytosis activity [25, 27].
- VAP occurs early (2–3 days) in approximately 50% of the cases or later >72 h in progress.
- *Early symptoms* (within 4–5 days) are most often caused by pneumococci, *Haemophilus influenzae*, *Moraxella* and *Staphylococcus aureus*.
- *Late symptoms* (after 5 days): most often various gram-negative bacilli, *Staphylococcus aureus*, anaerobes, fungi, etc.
- VAP leads to prolonged and excessive consumption of antibacterial agents, prolonged hospital stays and significantly increased lethality, perhaps more than 10% [35].
- VAP is strongly associated with low staffing, high working pressure, reduced infection control, cross contamination and high consumption of antibacterial agents [25, 27, 35]. Adequate and qualified workforce reduces the occurrence of VAP and length in ICUs [25, 27].

26.7.1 Contamination and Colonization Initiates VAP, Some Studies:

- Early contamination of the ventilator tubes is detected after 2 h in 33%, after 12 h in 64% and after 1 day by 80% of the cases [105].
- Colonization with extern flora occurs in 14.3% of the patients after about 4 h and in 28% after 19 h [106].
- Nosocomial pneumonia may develop in 5.3% after 1 day, 12.4% after 2–5 days, 36% after 6–10 days, 54% after 10–20 days and about 80% after 21–25 days on a respirator [107].

- One week on a respirator; 70–90% are colonized with hospital flora in respiratory and gastrointestinal tract, and 60% have respiratory infection.
- Two weeks on a respirator: 80% have or have had one or more respiratory infections [107].

When the patient's ventilator circle and airways are colonized with bacteria, he/she will more rapidly develop VAP **than** if he does not become colonized [108]. In a patient study, it was shown that 23% of those who were colonized developed pneumonia, compared with only 3.3% of those who were not colonized [108].

26.7.2 Other Causes of Infection

- Immobility.
- Aspiration—important for the development of VAP.
- General condition greatly reduced.
- Decreased consciousness and dysphagia.
- Vomiting with aspiration.
- Nasogastric drainage with growth of intestinal flora.
- Growth of gram-negative bacilli in upper respiratory tract.
- Broad spectrum, selecting antibacterial therapy [41].
- Decreased acid secretion, escalating growth of intestinal bacteria.
- Respirator equipment infected and biofilm formation covering growth of microbes.
- Mouth brushes, etc. infected.
- Nebuliser infected.
- Suction apparatus equipment/trachea-stoma infected.
- Bacterial invasion of the lungs by reducing cough reflex, ciliar activity and increased adhesion to mucosa.
- Decreased lung immune defences.
- Ventilator-associated trachea-bronchitis prolongs treatment time and may increase mortality [109].
- Infected embolus from other organs—haematogenous.
- Infected blood.
- Intravenous catheter infection.
- By trachea intubation for anaesthetization, it is shown that 3.4% of the patients may secrete virus in the respiratory tract [110]. This may be spread by poor hand hygiene.

26.7.3 Airborne Infections in the Intensive Care Units (ICUs)

Open ICU areas promote airborne transmission of microbes. Since 95% of the droplets from the respiratory tract are small (average diameter of 50 µm), they are drying in during 0.4 s and are then spread rapidly in the air and the environment [111, 112]. Some particles reach far down the airways. Dyer et al. showed that bacteria may

splash from the ventilator system and reach in living condition more than 10 m away from the source and expose other patients, staff and visitors to infection [113]. Infected anaesthesia circle may generate air transmission of both bacteria and viruses with long survival in the environment, particularly with frequent cough and explosive aerosol production [114].

26.7.4 Tracheal Tube, Biofilm and Bacteria

Tracheal tubes are always covered with biofilm during use, and at least 50 mg dry weight of biofilm is detected in 75% of the tracheal tubes used in ICU patients [115]. The bacterial load is up to one million per cm length of the tube [115].

VAP is prevented by:

- All patient-associated respiratory equipment is treated sterile. Ventilator equipment must be decontaminated-sterilized also of inner parts between patients [116]. Gas disinfection may be used but have no significant effect on mycobacteria [117].
- Good general hygiene and knowledge of transmission routes. Specific training reduces the incidence of VAP and length of stay at the ICU, mortality and costs [118].
- Good routine and experience are associated with the decreased incidence of VAP. At 31 US hospitals, 154–400 beds, median 284, VAP was significantly more often present in the smallest hospitals than the larger ones; MRSA was a dominant issue, along with *Pseudomonas* and *Klebsiella* [119]. Compared with tertiary teaching hospital participating in CDC registration in the United States, the incidence of VAP was not higher in local hospitals than in the tertiary teaching hospitals [119].
- Avoid intubation; use noninvasive positive pressure ventilation if possible.
- Minimize sedation—spontaneous awakening of defined patients.
- Early mobilization.
- Use sub-glottis drain, if possible, to prevent VAP and reduce intensive stay.
- Elevation of the head end of 30–45°.
- Change ventilation circle only when necessary (secretions, infection). By increasing the period between changes, VAP was significantly reduced from 11.9/1,000 ventilator days by replacing 2-day interval, compared to 3.3/1000 and 6.3/1000 at 7-day and 30-day intervals. VAP was reduced, as were the costs [120–122].
- The use of microfilter in ventilation circles is not clarified [3, 26, 123].
- Good oral hygiene, possibly with the use of chlorhexidine [35]. A good oral hygiene reduces VAP [124].
- Good personal hygiene; bedridden patient needs extra personal care and washing to prevent unnecessary growth of gram-negative bacteria.
- VAP—bundles and VAP—“team”—specialized in mechanical ventilation procedures may reduce VAP infections [3, 26, 34–36].

- A large enough staffing and expertise is essential [27, 35].
- VAE and VAC will not be discussed here, but detects more complications and higher mortality than when using the VAP criteria [34, 36, 125].

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Chest Physiotherapy and Mobilization: Postoperatively

27

Abstract

Lung physiotherapy and early mobilization prevent the development of respiratory infections in surgical patients. The lungs, bronchi and trachea are sterile, semi-critical areas. All technical items introduced by the patient's vocal cord like intubation are a risk to the patient. Sterile treatment of respiratory tract from the trachea and down is central in all procedures. For best effect, protective measures should be started preoperatively, particularly at risk of complications due to loss of lung function and chronic obstructive pulmonary disease (COPD) and by surgery of the abdomen or thorax. Breathing exercises from the deep airways are important before and after surgery and especially for abdominal/thorax operations. These procedures are followed up by a physiotherapist. Fast awakening is essential for rapid mobility and cough reflex. Adequate pain management supports the ability to cough and rapid mobilization. The patient should be placed at least 30° in the supine position to avoid complications. Avoid intubation; if possible, use non-invasive positive pressure ventilation—CPAP.

Keywords

Respiratory infections · Lung physiotherapy · Mobilization · Postoperative · Infection prevention · Pneumonia · Sterile procedures

27.1 Purpose

To prevent the development of nosocomial pneumonia (NP) and other respiratory infections in patients treated at the hospital [1–21].

27.2 Comprise

All patients that need chest physiotherapy and mobilization, especially postoperatively. All physiotherapists working with patients that need protective measures postoperatively [21].

27.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

27.4 Practical Measures

The lungs, bronchi and trachea are sterile, semi-critical areas. All technical items introduced by the patient's vocal cord are a risk to the patient [3, 23]. Pulmonary physiotherapy and early mobilization prevent the development of respiratory infections in surgery patients.

27.4.1 General Measures

- Breathing exercises involving the deep airways are important before and after surgery and especially for abdominal/thorax operations and should be monitored by a physiotherapist.
- Fast awakening is essential for rapid mobility and cough reflex. The patient should have early assistance and help to cough.
- Adequate pain management supports the ability to cough and mobility.
- Rapid mobilization, not laying flat—being in at least 30 degree in the supine position to avoid complications.
- Sterile treatment of respiratory tract from the vocal cord and down is central in all procedures.
- Avoid intubation; if possible, use non-invasive positive pressure ventilation—CPAP [3, 23].

Ventilated patients (see separate section) should be taken care of in separated, well-ventilated rooms because of the generation of aerosols by suction, coughing, etc. Sterile conditions are required for all respiratory tract treatment, sterile liquids, sterile PEP (positive expiratory pressure) bottles and other sterile equipment directly associated with lower airways. This includes procedures for the replacement of sterile equipment and fluids. Bacteria grow quickly (after 6–18 h) in sterile water.

27.4.2 Special Measures

Pain inhibits the patient's respiration and cough reflex and increases the risk of infection from stagnation of respiratory secretions.

- Identify the burden of pain at rest by asking the patient to breathe deeply if he/she is awake.
- If painful, evaluate the use of analgesics before mobilization, chest physiotherapy, etc. This is important.
- It is optimal relief when the patient says it is acceptable pain level.

PEP mask and PEP-flute are common standards and used for stimuli of respiration. This is the “dry processes” that do not cause infection if the equipment is for single use and disposable.

Physiotherapy is important for to strengthen lung capacity and coughing capacity and prevents atelectasis.

- Handwashing before and after contact with the patient and use of gown with long sleeves and cuffs, surgical mask and cap by examination and treatment.
- Personal hygiene is important. Protect the face, clothing and hair against infection from cough and sputum because of close contact with very many patients during the working day, and eventually use visor or face shield in case of risk of splatter.
- If risk factors like cardiopulmonary disorders, obesity, age, smoking, preoperatively impaired mobility, etc. are present, contact the physiotherapist during the first postoperative day and always before transfer to the ward.
- Physiotherapist usually evaluates the need for PEP-aid, breathing exercises or other respiratory measures, circulation-enhancing exercises, strength and flexibility training, assistance for the mobilization and follow-up after transfer to the ward.

Mobilization is carried out by the nurse as a set routine for patients following elective abdominal or thoracic surgery and other surgery and prevents postoperative respiratory infections and other complications.

- Mobilized in the evening of the day of surgery—if the clinical condition allows it—or the next morning if the patient is operated late in the day.
- Mobilization—progression:

- Highly supine with upper body raised. Good posture in the bed with hips in the bed's hip bend, no or few pillows behind the patient's back and bent knees.
- Sitting at bedside.
- Stand on the floor.
- Sitting in the armchair.
- Walk on the floor, possibly with assistance.
- Patients with laparotomy and with high activity should be mobilized to and from the bed via a lateral position to spare the abdominal wall and to avoid hernia.
- Patients are encouraged to own activity.
- If inability to mobilize, move your legs in bed, and bend up/down your ankles and knees.

Postoperative patients are laid with raised head end (at least 30°) in the supine position if not contraindicated (drop in blood pressure, etc.)

Use of CPAP (continuous positive airway pressure) is applicable if there is increasing need of oxygen and/or radiologic-proven atelectasis. Use CPAP instead of respirator when possible [3, 23]. CPAP is prescribed by a physician.

- CPAP replaces PEP system.
- CPAP should have the same sterile requirements for use and hygiene control as other ventilation equipment.
- Sterile gloves are used when air passage to balloon is shut off.
- CPAP equipment is cleaned and disinfected between each use and covered when in storage. The inner, inaccessible machine parts that draws air from the room and accumulates dust and particles should be disinfected with dry gas of hydrogen peroxide between patients [24].

27.5 Background Information

Lower respiratory tract infection “is cough, fever and purulent sputum, irrespective of the result of expectorate culture and/or pulmonary radiographs. If purulent sputum does not occur, but lung X-rays show typical infection image, is the diagnosis still reported as infection” [3–5]. This definition is originally from the CDC and is modified to Norwegian conditions by the Norwegian public health [4–14, 16–19]. More recent definitions from the CDC are also used by some hospitals in Norway [15, 20].

Patients may be admitted *because* of a respiratory infection or *because* of another disease like infarct, having in addition a respiratory tract infection. Both cases are potential sources of infection in the hospital environment.

27.5.1 Definitions

- CAP is community-associated pneumonia caused *outside the healthcare*.
- HCAP (HAP) is healthcare-associated pneumonia that occurs in hospitals, nursing homes, homecare, dialysis, etc.; nosocomial infection [21, 25–33].

Nosocomial respiratory tract infections occur up to 30–90 days after admission to hospital or other health institution. Pneumonia may occur in patients, personnel, visitors, service personnel and others who handle material, equipment and textiles from healthcare institutions. It is often older patients or young children who get nosocomial pneumonia and who need hospital treatment [25–33].

- *Respiratory tract infection*: acute inflammation of the respiratory tract caused by microbes.
- *Upper respiratory tract (URT) infection*: the nose, sinuses, ears, pharynx and larynx (rhinitis, sinusitis, otitis, pharyngitis, laryngitis), relatively rarely occurring in hospitals, except outbreaks of sore throat.
- *Lower respiratory tract (LRT) infections*: trachea, bronchi and lung tissue (tracheitis, bronchitis, pneumonia). Lower respiratory tract is a sterile, semi-critical area. All technical equipment introduced, passing the patient's vocal cord, is a risk to the patient. Surgical patients and patients on assisted ventilation are therefore very susceptible to lower respiratory tract infection.
- *Nosocomial pneumonia (NP)* might be difficult to distinguish from other lower respiratory tract symptoms occurred during or after hospitalization. Typically, NP occurs 2 days or more after admission and is not in the incubation period at admission.
- *Ventilator-associated pneumonia (VAP)* develops usually after more than 2 days after endotracheal intubation. The risk of VAP is found to increase by 3% per day for the first 5 days, 2% per day from days 5 to 10 and then 1% per day [31, 34].
- *Ventilator-associated complications (VAC) and ventilator-associated events (VAE)* are more advanced methods that may detect deterioration of a ventilated patient [23, 35–37].
- *Nosocomial lower respiratory tract infection*: there are a number of recent definitions that include bronchitis and various stages of chronic obstructive pulmonary disease, not further discussed here [38].
- *Carrier of pathogenic microbes*: individual with bacterial colonization of the upper airways without signs of infection. The bacteria can cause individual infections and may be the source of infection to others.

27.5.2 Criteria for Nosocomial Pneumonia: CDC 1988 [16]

The criteria are often difficult to clarify, but include the following:

1. Auscultation of the chest—not normal + one of the following findings:
 - (a) Recent purulent expectorate or increased secretion.
 - (b) Changed nature of sputum.
 - (c) Microbes isolated from blood culture.
 - (d) Pathogenic microbe isolated by trans-trachea aspiration, bronchial test or biopsy.
 - (e) Isolation of virus or virus antigens in the respiratory tract.
 - (f) Detected specific IgM or four times IgG titre increase in pairs.
 - (g) Histopathological findings.

2. X-ray result: new infiltrate or progression, densification, caverns or pleural liquid + one of the following: see (a)–(g) as above.
3. The patient has two of the following symptoms: apnoea, tachypnoea, bradycardia, wheezing respiration, rhonchi or cough + one of the following: see (a)–(g) as above [16].

27.5.3 Prevalence

Hospital infections occur in 3–21% (mean 8.7%) of all cases, and 0.5–11% may get nosocomial lower respiratory tract infection [1–3]. In Norwegian hospitals, approximately 1–2% of the patients get nosocomial pneumonia, related to the degree of emergency and intensive activity, surgical procedures, isolation conditions, seasonal outbreaks, endemic and epidemic conditions in the community, etc. [4–15]

Respiratory infections are common in the population [1–3, 39]. Lower respiratory tract infection is mostly preceded by upper respiratory infection, short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly subjects.

Pneumonia outside healthcare, CAP. In the United States, approximately 915,000 people, usually older than 65 years of age, get pneumonia every year. And the CAP together with influenza constitutes the seventh leading cause of death in the United States [2, 39, 40]. Vaccination against influenza and pneumococci is highly recommended for certain age groups and categories of patients in the United States [39]. Occurrence in Norway is unknown due to a lack of registration.

Nosocomial lower respiratory infection affects 15–20 per 1000 hospitalized patients, and 20–45% dies from infection.

Nosocomial pneumonia increases hospital stay for the patient 7–14 days and represents an additional cost of approximately 25,000 USD per patient [23, 34, 41]. Incidence in the United States is estimated to 5–15 cases per 1000 hospitalizations and 5–15% of ICU (intensive care unit) patients [34, 36]. It is dominant in the ICU and the cause of more than 50% of consumption of antibacterial agents in the unit [34]. Mortality is estimated at 30–70% (crude mortality) in 2005 [34].

In Norway, nosocomial lower respiratory infection accounts for approximately 25% of hospital infections [8, 11, 15].

27.5.4 Microbes: Respiratory Infections

Many types of microbes cause lower respiratory tract infection. Aetiological agents are often difficult to detect, and in severe cases it can be a polymicrobial flora [34]. Sampling is required; blood culture, cultivation of sputum, quick tests for influenza and other viruses, legionella and pneumococcal, urine antigen tests, fungal cultures, tuberculosis and atypical mycobacteria in bronchial aspirate, etc. [39] Invasive sampling gives usually no more than a good quality sputum [42]. One gram preparation of sputum may be useful [43].

In cases of pneumonia occurring outside the hospital, aetiological agent is detected in only about 25% [44]. Bacteria associated with respiratory tract infections, like pneumococci, are still sensitive to common antibiotics in Norway [45, 46]. However, patients from abroad are often colonized with more resistant microbes, including penicillin-resistant pneumococci.

The oral cavity has a rich arsenal of 100 different aerobic and anaerobic bacteria, including pneumococcus and *Haemophilus influenzae* which could be more pathogenic if introduced into the sterile area below the vocal cords. This may occur by aspiration, intubation, lack of cough reflexes and poor oral hygiene. In the frontal third of the nose mucosa, there is often a rich growth of staphylococci and gram-negative bacteria, while in the back part (nasopharynx) of the nose, the mucosa is almost sterile. Upper respiratory infection with rhinovirus and other respiratory viruses may quickly spread to the lower respiratory tract with secondary bacterial invasion.

27.5.5 Hospital Flora

One day after hospitalization, the patient may have “new flora” in the upper respiratory tract, gastrointestinal tract, skin and mucosa, transferred from the hospital’s food, environment, water, equipment, hands, etc. Hospital flora is promoted by antibiotics that remove protective normal flora and can cause severe lower respiratory tract infection.

27.5.6 Epidemics: Respiratory

Epidemics in society may affect infections in the hospital. Outbreaks of influenza usually increase the rate of hospitalization and thus the risk of nosocomial infection. This was observed during the pandemic influenza in 2009. Epidemics in the society may influence hospital admittance and infection control:

- *Mycoplasma pneumoniae*—ca. each fourth year.
- *Chlamydia pneumoniae*—annually.
- Influenza—annually +10–50–100-year larger outbreaks.
- *Legionella*—local epidemics (water, aerosol).
- RSV—annually (children’s section and nursing homes).
- *Metapneumovirus*—annually.

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Suction of Respiratory Tract Secretions

28

Abstract

Suction of respiratory tract secretion involves the removal of mucus and fluids from the lower respiratory tract with a thin plastic catheter through the tracheal cannula or the endotracheal tube in intubated patients. The procedure takes place via open or closed suction system. Avoid damage of airway epithelium in patients with tracheal tube. The trachea is a sterile, semi-critical area and should be treated as such. All equipment and fluids introduced, passing the patient's vocal cords, should be sterile to prevent lower respiratory tract infection.

Keywords

Respiratory infections · Suctioning respiratory tract · Mechanically ventilation · Infection prevention · Pneumonia · Sterile procedures

28.1 Purpose

To prevent the development of nosocomial pneumonia (NP) and other respiratory infections in patients treated at the hospital [1–21].

28.2 Comprise

All patients that are on respirators, ventilators and need suction of airways because of accumulation of secrete in the respiratory tract. All health care personnel that are working with patients on ventilators and with similar problems in the airways [21].

28.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

28.4 Practical Measures

Suctioning respiratory secretions involves the removal of mucus and fluids from the lower respiratory tract via open or closed suction systems. All equipment introduced, passing the patient's vocal cords, should be sterile to prevent lower respiratory tract infection [3, 23].

28.4.1 Suction

Suction of airways is considered for patients on ventilators, with pharynx paresis, with lack of coughing reflex, etc. Accumulation of fluid and mucus in the lower respiratory tract should be removed, but this is evaluated by a doctor. Place patient in a semi-recumbent position, i.e. 30–40° head elevation.

Conditions where the suction considered:

- Slime sounds from the patient during inspiration or expiration.
- Coughing when on a respirator.
- Decrease in oxygen saturation in the blood—sp. O₂.
- Descending cardiac output (BiPAP/pressure-controlled ventilator setting).
- Increasing airway pressure (IPPV/volume-controlled ventilator setting).

Risk when suctioning with tracheal catheter:

- Contamination with upper respiratory flora or environmental flora and development of pneumonia.
- Damage of airway epithelium in the trachea, especially through the use of dry suction catheters.

- Atelectasis.
- Damage to lung tissue and pneumothorax by careless use of the suction catheters.
- Patient discomfort if not sedated.
- Sucking more than two consecutive times; easier for contamination.
- Pollution from bag (spray aerosols) and hands – this is a serious problem!
- Patients with respiratory infections may transmit infections to other patients, personnel and the environment especially by open tracheal suction.

28.4.2 Oxygenation of the Patient: Before Suction

To increase concentration of oxygen in blood to protect against low level during the suction process

- Respirator-controlled preoxygenation with 100% O₂ for 2–3 min. Most commonly today for ventilator patients, pressing the button for 100% O₂.
- Respirator-controlled/increased ventilation pressure—individually for each patient. Follow advice from specialist.
- Bagging is manual ventilation of the patient. This may be used during physiotherapy, at extubation, during transition from respirator, during transport in ambulances and other situations where use of respirator is difficult.

28.4.3 Suction Catheters

- Sterile single-use catheters—open to the environment and may be exposed to contamination during the process.
- Closed system—sterile catheters, changed every sixth hour. The patient is not disconnected from the ventilator during the suction process. This is used particularly for respiratory-unstable patients or infectious patients.
- Suction catheter's diameter should be less than half of the tube diameter = tube number minus 2 times 2. For instance, tube no. 8: (8-2) × 2 = 12 in diameter. Suction catheter must therefore have a diameter of <6.

28.4.4 Suction with Disposable, Sterile Catheter

All openings/connections are treated sterile during the entire process.

Equipment: sterile, disposable suction catheter, surgical mask, cap, sterile gloves, clean gown, clean bag with reservoir (bag and filter change any time between each use, eventually sterile single-use equipment)

1. The patient is oriented and placed in correct position. Sterile single-use catheters—open to the environment.

2. Wash or disinfect your hands.
3. Disinfect the table with 70% alcohol.
4. Place the equipment on the disinfected table.
5. Put on surgical mask, cap and gown and disinfect your hands.
6. Prepare the catheter. The suction is turned on with the suction force from 13 to 20 kpa with the suction clamped.
7. Note—mouthpiece of the suction system may be heavily contaminated!
8. Oxygenate the patient using a ventilator for 2–3 min or bagging (see below).
9. Disinfect your hands.
10. The patient-related respiratory section is opened at the Y-piece and treated sterile, -placed on sterile paper, while the procedure is taking place. The respirator opening must not be contaminated with new microbes!
11. The patient is bagged if not oxygenated by the respirator (physiotherapy, etc.). By bagging can respiratory secretions from the patient be drawn into the bag where proliferation of present bacteria may occur in a “sea” of secretes, during the next 6–12 h.
12. Bag with reservoir should preferably be replaced by a clean, disinfected one between each use to prevent infected secrete from the bag to be reintroduced into the airway. This is a risk procedure. In cases of reuse, the bag’s exterior is disinfected between uses. There should be a sterile glove placed over the opening after use, and the bag must be kept in clean disposable plastic bag. The bag is sterilized after use in patients with infection.
13. Disinfect your hands after bagging.
14. Sterile glove holding the sterile suction catheter. Avoid contact with the tracheal cannula/the tube edge.
15. The suction catheter is inserted into the tube with quick but gentle motion—not connected suction—reduce speed when 3/4 down the tracheal tube—and stop when the catheter meets resistance.
16. Pull the catheter up with medium speed, while it is rolled between the fingers. Hold the tube at rest. Throw the suction catheter after use.
17. Take off the sterile glove and disinfect your hands.
18. Connect the respirator/bag, etc. without contaminating openings, and ventilate/bag the patient for about 2 min after suction.
19. Disinfect your hands.
20. Ventilator inspiration pressure is returned to its original position if it has been changed.
21. If mucus comes into the bag opening, change the equipment to prevent reflux during the next treatment.
22. Equipment used in the respiratory tract is treated as infected by the patient’s respiratory flora.
23. The procedure ends with cleaning, handwashing, gown hung up and surgical mask and cap removed.
24. Protect gowns against infection from the patient, the environment and other patients if reused, and prefer a single-use gown.

25. Disinfect your hands.
26. Emergency procedures when needed for rapid suction situations may make it necessary to deviate from this procedure.

28.4.5 Cleaning and Care of the Inner Tracheal Cannula

- Daily cleaning.
- The cannula is removed aseptically and cleaned in the instrument washing machine at 85° C.
- Then it is treated aseptically in sterile gauze and is not affected by non-sterile equipment or hands. Use sterile gloves when inserting the cannula.

28.4.6 Control and Responsibility

The *physician* is responsible for the indication for use of suction, oxygenation methods and monitoring of suction of the airways and responsible for solving/advising on issues that may occur during use. The physician has the medical professional responsibility to follow up the patient and obtain advice and guidance for complications, accidents or deviations. The *nurse* is responsible for the implementation and control of the procedure and to immediately report to the doctor responsible problems with the suction procedure, oxygenation or suspected complications.

28.5 Background Information

Lower respiratory tract infection “is cough, fever and purulent sputum, irrespective of the result of expectorate culture and/or pulmonary radiographs. If purulent sputum does not occur, but lung X-rays show typical infection image, is the diagnosis still reported as infection” [3–5]. This definition is originally from the CDC and is modified to Norwegian conditions by the Norwegian public health [4–14, 16–19]. More recent definitions from the CDC are also used by some hospitals in Norway [15, 20].

Patients may be admitted *because* of a respiratory infection or *because* of another disease like infarct, having in addition a respiratory tract infection. Both cases are potential sources of infection in the hospital environment.

28.5.1 Definitions

- CAP is community-associated pneumonia caused *outside the healthcare*.
- HCAP (HAP) is healthcare-associated pneumonia that occurs in hospitals, nursing homes, homecare, dialysis, etc.; nosocomial infection [21, 24–32]. Nosocomial respiratory tract infections occur up to 30–90 days after admission to hospital or other health institution. Pneumonia may occur in patients, person-

nel, visitors, service personnel and others who handle material, equipment and textiles from healthcare institutions. It is often older patients or young children who get nosocomial pneumonia and who need hospital treatment [24–32].

- *Respiratory tract infection*: acute inflammation of the respiratory tract caused by microbes.
- *Upper respiratory tract (URT) infection*: the nose, sinuses, ears, pharynx and larynx (rhinitis, sinusitis, otitis, pharyngitis, laryngitis), relatively rarely occurring in hospitals, except outbreaks of sore throat.
- *Lower respiratory tract (LRT) infections*: trachea, bronchi and lung tissue (tracheitis, bronchitis, pneumonia). Lower respiratory tract is a sterile, semi-critical area. All technical equipment introduced, passing the patient's vocal cord, is a risk to the patient. Surgical patients and patients on assisted ventilation are therefore very susceptible to lower respiratory tract infection.
- *Nosocomial pneumonia (NP)* might be difficult to distinguish from other lower respiratory tract symptoms occurred during or after hospitalization. Typically, NP occurs 2 days or more after admission and is not in the incubation period at admission.
- *Ventilator-associated pneumonia (VAP)* develops usually after more than 2 days after endotracheal intubation. The risk of VAP is found to increase by 3% per day for the first 5 days, 2% per day from days 5 to 10 and then 1% per day [30, 33].
- *Ventilator-associated complications (VAC) and ventilator-associated events (VAE)* are more advanced methods that may detect deterioration of a ventilated patient [23, 34–36].
- *Nosocomial lower respiratory tract infection*: there are a number of recent definitions that include bronchitis and various stages of chronic obstructive pulmonary disease, not further discussed here [37].
- *Carrier of pathogenic microbes*: individual with bacterial colonization of the upper airways without signs of infection. The bacteria can cause individual infections and may be the source of infection to others.

28.5.2 Criteria for Nosocomial Pneumonia: CDC 1988 [16]

The criteria are often difficult to clarify, but include the following:

1. Auscultation of the chest—not normal + one of the following findings:
 - (a) Recent purulent expectorate or increased secretion.
 - (b) Changed nature of sputum.
 - (c) Microbes isolated from blood culture.
 - (d) Pathogenic microbe isolated by trans-trachea aspiration, bronchial test or biopsy.
 - (e) Isolation of virus or virus antigens in the respiratory tract.
 - (f) Detected specific IgM or four times IgG titre increase in pairs.
 - (g) Histopathological findings.

2. X-ray result: new infiltrate or progression, densification, caverns or pleural liquid + one of the following: see (a)–(g) as above.
3. The patient has two of the following symptoms: apnoea, tachypnoea, bradycardia, wheezing respiration, rhonchi or cough + one of the following: see (a)–(g) as above [16].

28.5.3 Prevalence

Hospital infections occur in 3–21% (mean 8.7%) of all cases, and 0.5–11% may get nosocomial lower respiratory tract infection [1–3]. In Norwegian hospitals, approximately 1–2% of the patients get nosocomial pneumonia, related to the degree of emergency and intensive activity, surgical procedures, isolation conditions, seasonal outbreaks, endemic and epidemic conditions in the community, etc. [4–15]

Respiratory infections are common in the population [1–3, 38]. Lower respiratory tract infection is mostly preceded by upper respiratory infection, short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly subjects.

Pneumonia outside healthcare, CAP. In the United States, approximately 915,000 people, usually older than 65 years of age, get pneumonia every year. And the CAP together with influenza constitutes the seventh leading cause of death in the United States [2, 38, 39]. Vaccination against influenza and pneumococci is highly recommended for certain age groups and categories of patients in the United States [38]. Occurrence in Norway is unknown due to a lack of registration.

Nosocomial lower respiratory infection affects 15–20 per 1000 hospitalized patients, and 20–45% dies from infection.

Nosocomial pneumonia increases hospital stay for the patient 7–14 days and represents an additional cost of approximately 25,000 USD per patient [23, 33, 40]. Incidence in the United States is estimated to 5–15 cases per 1000 hospitalizations and 5–15% of ICU (intensive care unit) patients [33, 35]. It is dominant in the ICU and the cause of more than 50% of consumption of antibacterial agents in the unit [33]. Mortality is estimated at 30–70% (crude mortality) in 2005 [33].

In Norway, nosocomial lower respiratory infection accounts for approximately 25% of hospital infections [8, 11, 15].

28.5.4 Microbes: Respiratory Infections

Many types of microbes cause lower respiratory tract infection. Aetiological agents are often difficult to detect, and in severe cases it can be a polymicrobial flora [33]. Sampling is required; blood culture, cultivation of sputum, quick tests for influenza and other viruses, legionella and pneumococcal, urine antigen tests, fungal cultures, tuberculosis and atypical mycobacteria in bronchial aspirate, etc. [38] Invasive sampling gives usually no more than a good quality sputum [41]. One gram preparation of sputum may be useful [42].

In cases of pneumonia occurring outside the hospital, aetiological agent is detected in only about 25% [43]. Bacteria associated with respiratory tract infections, like pneumococci, are still sensitive to common antibiotics in Norway [44, 45]. However, patients from abroad are often colonized with more resistant microbes, including penicillin-resistant pneumococci.

The oral cavity has a rich arsenal of 100 different aerobic and anaerobic bacteria, including pneumococcus and *Haemophilus influenzae* which could be more pathogenic if introduced into the sterile area below the vocal cords. This may occur by aspiration, intubation, lack of cough reflexes and poor oral hygiene. In the frontal third of the nose mucosa, there is often a rich growth of staphylococci and gram-negative bacteria, while in the back part (nasopharynx) of the nose, the mucosa is almost sterile. Upper respiratory infection with rhinovirus and other respiratory viruses may quickly spread to the lower respiratory tract with secondary bacterial invasion.

28.5.5 Hospital Flora

One day after hospitalization, the patient may have “new flora” in the upper respiratory tract, gastrointestinal tract, skin and mucosa, transferred from the hospital’s food, environment, water, equipment, hands, etc. Hospital flora is promoted by antibiotics that remove protective normal flora and can cause severe lower respiratory tract infection.

28.5.6 Epidemics: Respiratory

Epidemics in society may affect infections in the hospital. Outbreaks of influenza usually increase the rate of hospitalization and thus the risk of nosocomial infection. This was observed during the pandemic influenza in 2009. Epidemics in the society may influence hospital admittance and infection control:

- *Mycoplasma pneumoniae*—ca. each fourth year.
- *Chlamydia pneumoniae*—annually.
- Influenza—annually +10–50–100-year larger outbreaks.
- *Legionella*—local epidemics (water, aerosol).
- RSV—annually (children’s section and nursing homes).
- *Metapneumovirus*—annually.

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Care of the Ventilator Patient and Equipment

29

Abstract

Patients on respirator treatment are in a special situation where infection control is extremely important to prevent serious ventilator-associated lower tract infections. The trachea is a sterile, semi-critical area and should be treated as such. All equipment and fluids introduced, passing the patient's vocal cords, should therefore be sterile to prevent lower respiratory tract infection. The bedridden, often unconscious patient is in a high-risk situation and needs a continuous care and surveillance of sterility and disinfection of the equipment and procedures during the change of ventilation circuit, personal hygiene and other treatments.

Keywords

Respiratory infections · Mechanical ventilation · Infection prevention · Pneumonia · Sterile procedures · Personal hygiene · Care of the patient · Change of ventilation circuit

29.1 Purpose

To prevent the development of lung infections in patients on respirator treatment [1–35]. To prevent spread of microbial agents from patients on respirators.

29.2 Comprise

Patients on respirator treatment [1–3, 18, 19, 21, 23, 33, 35]. Special trained personnel that takes care of patients on ventilators. Personnel that handle equipment associated with treatment of respiratory tract problems.

29.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

29.4 Practical Measures

Always consider whether intubation and mechanical ventilation are needed. If the patient needs respirator treatment, reduce intubation time as much as possible [3, 23].

29.4.1 General

- *Sterile conditions.* Openings to the lower respiratory tract must be treated sterile! Avoid making tracheal tube "non-sterile," i.e. colonized with other than the patient's own throat flora! Avoid adding new microbes to the tracheal tube/system!
- *Control of disinfection/autoclave.* Washing machines for respirator equipment should be routinely checked and temperature documented every week. Written routines!
- *Storage of clean* ventilator equipment should have low bacterial counts (<100 CFU—colony-forming units—per m² air) and should not be used for other activities. Floors are cleaned daily. Outer cartons are avoided to prevent microbes and particles. Follow procedures for sterile stock (see separate chapter).
- *Ventilation disposable tube sets* must be sterile, wrapped individually and handled aseptically when connected to the patient. Reusable tube set should, after wash and disinfection, be pre-mounted, packaged and autoclaved for each shift.
- *Used ventilation sets* with accessories must be treated as infected both by transport and when handling in the disinfection room.
- *Reusing decontaminated equipment* that is not packed correctly and sterilized causes at least two undesirable conditions:
 - Increased infection burden with increased risk for nosocomial pneumonia.
 - Increased workload and infectious load and time for the staff in the form of inefficient treatment of respiratory equipment.

- *Wetting* of respiration air is carried out with disposable, sterile, closed system.
- *Ventilation tubes* can be replaced once every week, except for infection, high humidity and particular problems.
- *Gloves may have holes and the glove box is easily contaminated.* Therefore, sterile gloves are required when working with openings into the airway.
- *Bag* is a source of infection for the patient and the environment with aerosol which is blown into the patient's lungs. The opening is treated aseptically and provided with filters. A new, sterile bag is recommended for each time the patient needs bagging or other similar solutions.

29.4.2 Regular Washing and Care of the Patient on a Respirator

1. Hand hygiene, gown with long sleeves and cuffs and gloves as needed and type of care.
2. Handle carefully the ventilator tube when the patient is turned from side to side so that no liquid from the circle flows into the lungs of the patient.
3. Avoid reflux of condensed water to the trachea by care/handling. This is important!
4. Secure connection to the tracheal tube and Y-piece before care and washing the patient! The connection should be treated sterile if it is loose (have spare set ready).
5. Handwash between procedures and after care.
6. Hang care gown in place in distance preferably >2 m from the patient and replace every shift and when soiled. Specific routines are followed if infected (see isolation routines).

29.4.3 Change of Respirator Equipment

Two experienced staff persons are participating. The equipment is changed once a week or more often if wet, infected, etc. Before shift, thoroughly suction and have chest physiotherapy if the patient has gurgling sounds.

1. Handwash, gown with long sleeves and cuff, surgical mask, cap (risk of splashing) and gloves.
2. Always use sterile gloves when connecting the ventilation circle to prevent new microbes to enter the lower airways of the patient.
3. Sterile sheets on the patient's upper half, around the cannula, or made ready beside the patient.
4. Sterile ventilator system is pre-mounted and ready, and the package is opened carefully.
5. Sterile wet system is pre-mounted and ready, and the package is opened (if used).
6. Sterile bag system is opened, ready for "bagging".

7. Used system is disconnected; the cannula opening is wiped gently with sterile saline before fast connection to the new set. Connection is performed by using sterile gloves.
8. Used system is installed directly in a container for further processing.
9. Do not reuse thermometer in the ventilator circle—it is a risk of infection.
10. The band around the neck is changed daily or more often. Wash around the cannula with sterile saline × 2 daily and more often if needed. Sterile compresses are then placed around the cannula. Conducted aseptically.
11. Heater for air humidifier is washed with soap and water two times/day and more often if needed.
12. Sterile water to the humidifier is changed at least two times/day because of risk of bacterial growth after ca. 6 h.
13. The outside of the respirator is cleaned with soap and water and is checked at least once a day. In addition, wipe over with alcohol each duty (see cleaning procedures).
14. Used ventilator set—reusable—is transported and further processed as infected in container. If handling the equipment before disinfection, use gloves, gown and mask/cap. NB! Opens *from* you because of risk of splashing. The set is sent to central control for packing and autoclaving.
15. The procedure ends with cleanup and handwash. Care gown is treated as described previously.

29.4.4 If a Sterile Respirator Set is Not Available (Caution, in Case of Need!)

Treatment of not sterile, but decontaminated, machine washed (85 °C), equipment:

1. When handling disinfected respiratory equipment: Hand wash, clean gown, sterile gloves.
2. After washing and disinfection in washing machine, put the equipment into a clean locker for drying (NB. cleaning routines for the locker!). Avoid touching the openings and connections and place equipment on a sterile/disinfected base/cloth for drying.
3. Dry thoroughly due to bacterial growth in wet areas.
4. Connect the ventilation set on a sterile textile in a clean room using sterile gloves. Pack it into this textile, and store it in well-cleaned lockers.
5. Humidifiers (reusable) are treated in the same manner as respirator set and are packed separately.

29.4.5 Water Trap (If Used)

1. Treat as other respiratory equipment.
2. Condense capture is part of an initially sterile system and should be treated as sterile.

3. The content should be treated as infectious. Bacterial growth may start in a matter of few hours.
4. Use gloves, and handwash before and after emptying water traps. Do not make the opening/connection unsterile!

29.4.6 Cleaning and Care Of Inner Cannula

1. Daily cleaning.
2. Take out aseptically, and wash it in instrument washer (85 °C).
3. Afterwards put it aseptically in sterile gauze into a clean plastic bag.

29.4.7 CPAP

1. CPAP equipment must have the same sterility requirements as usual respirator equipment.
2. CPAP must have the same cleaning and disinfection status as other respiratory equipment if coupled into ventilator circle.
3. Hand hygiene before and after, and use sterile gloves for sterile connections and openings.

29.4.8 Humidifier Systems for Patient off the Ventilator

1. If applied to mask without direct access to the airways, disposable moisture system can be used. It may only be used on a patient in 6–8 h.
2. Hand hygiene before and after use/connection with the use of sterile gloves.

29.4.9 Puritan Humidifier Nebulizer

1. Bottle with sterile water is to be used only for one single patient and changed at least two times a day due to bacterial growth.
2. If connected to ventilation circle, apply the same cleaning status as of the latter.
3. Hand hygiene before and after care/connection with the use of sterile gloves.

29.4.10 PEP (Positive Expiratory Pressure) Bottle

Because of the risk of growth of bacteria in the tap water, sterile water is used for PEP therapy. Bottles of sterile water are present on most departments. Excess water is poured out to the desired height (in cm H₂O). The patient blows through a tube into the water. Because of the growth of bacteria, it is important to change the PEP bottle at least two times/day. The use of PEP mask or flute to avoid water systems is recommended.

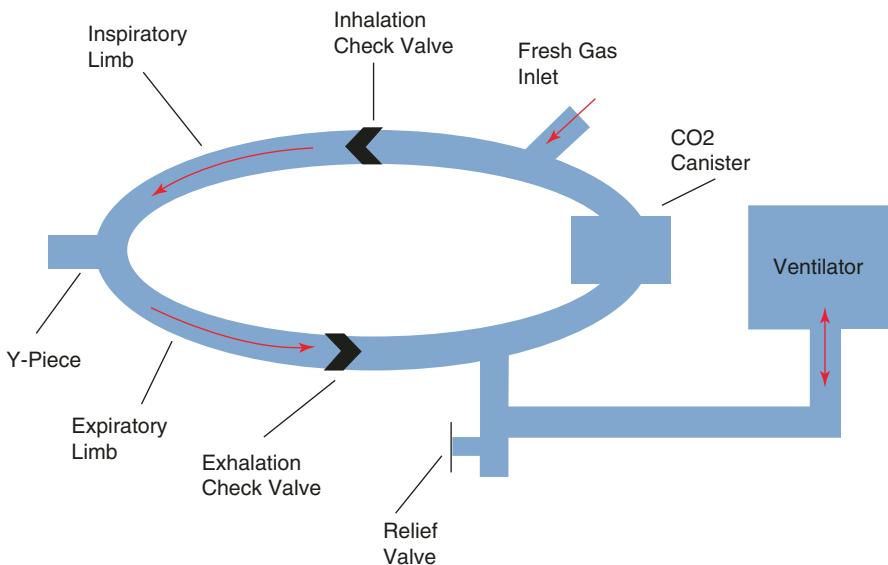


Fig. 29.1 The respirator patient—with the ventilation circuit—is especially exposed to infections in the respiratory tract (VAP ventilator-associated pneumonia). Source: www.biogearsengine.com

29.4.11 Hand Hygiene

1. Handwash and hand disinfection have a significant infection-preventing effect both from personnel to patient and vice versa and for other patients, equipment, etc.
2. Hand hygiene must be included in the routine before and after procedures in connection with respirator equipment and patient on a respirator.
3. Use hand disinfectant in routine work when the hands are visibly clean.

29.5 Background Information

Ventilator circuit with inspiratory and expiratory limbs, Y-piece and ventilator is schematically shown in Figure 29.1. *Lower respiratory tract infection* “is cough, fever and purulent sputum, irrespective of the result of expectorate culture and/or pulmonary radiographs. If purulent sputum does not occur, but lung X-rays show typical infection image, is the diagnosis still reported as infection” [3–5]. This definition is originally from the CDC and is modified to Norwegian conditions by the Norwegian public health [4–14, 16–19]. More recent definitions from the CDC are also used by some hospitals in Norway [15, 20].

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- *Upper respiratory tract (URT) infection*: the nose, sinuses, ears, pharynx and larynx (rhinitis, sinusitis, otitis, pharyngitis, laryngitis), relatively rarely occurring in hospitals, except outbreaks of sore throat.
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29.5.2 Criteria for Nosocomial Pneumonia: CDC 1988 [16]

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1. Auscultation of the chest—not normal + one of the following findings:
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 - (b) Changed nature of sputum.
 - (c) Microbes isolated from blood culture.

- (d) Pathogenic microbe isolated by trans-trachea aspiration, bronchial test or biopsy.
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2. X-ray result: new infiltrate or progression, densification, caverns or pleural liquid + one of the following: see (a)–(g) as above.
 3. The patient has two of the following symptoms: apnoea, tachypnoea, bradycardia, wheezing respiration, rhonchi or cough + one of the following: see (a)–(g) as above [16].

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Hospital infections occur in 3–21% (mean 8.7%) of all cases, and 0.5–11% may get nosocomial lower respiratory tract infection [1–3]. In Norwegian hospitals, approximately 1–2% of the patients get nosocomial pneumonia, related to the degree of emergency and intensive activity, surgical procedures, isolation conditions, seasonal outbreaks, endemic and epidemic conditions in the community, etc. [4–15]

Respiratory infections are common in the population [1–3, 38]. Lower respiratory tract infection is mostly preceded by upper respiratory infection, short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly subjects.

Pneumonia outside healthcare, CAP. In the United States, approximately 915,000 people, usually older than 65 years of age, get pneumonia every year. And the CAP together with influenza constitutes the seventh leading cause of death in the United States [2, 38, 39]. Vaccination against influenza and pneumococci is highly recommended for certain age groups and categories of patients in the United States [38]. Occurrence in Norway is unknown due to a lack of registration.

Nosocomial lower respiratory infection affects 15–20 per 1000 hospitalized patients, and 20–45% dies from infection.

Nosocomial pneumonia increases hospital stay for the patient 7–14 days and represents an additional cost of approximately 25,000 USD per patient [23, 33, 40]. Incidence in the United States is estimated to 5–15 cases per 1000 hospitalizations and 5–15% of ICU (intensive care unit) patients [33, 35]. It is dominant in the ICU and the cause of more than 50% of consumption of antibacterial agents in the unit [33]. Mortality is estimated at 30–70% (crude mortality) in 2005 [33].

In Norway, nosocomial lower respiratory infection accounts for approximately 25% of hospital infections [8, 11, 15].

29.5.4 Microbes: Respiratory Infections

Many types of microbes cause lower respiratory tract infection. Aetiological agents are often difficult to detect, and in severe cases it can be a polymicrobial flora [33].

Sampling is required; blood culture, cultivation of sputum, quick tests for influenza and other viruses, legionella and pneumococcal, urine antigen tests, fungal cultures, tuberculosis and atypical mycobacteria in bronchial aspirate, etc. [38] Invasive sampling gives usually no more than a good quality sputum [41]. One gram preparation of sputum may be useful [42].

In cases of pneumonia occurring outside the hospital, aetiological agent is detected in only about 25% [43]. Bacteria associated with respiratory tract infections, like pneumococci, are still sensitive to common antibiotics in Norway [44, 45]. However, patients from abroad are often colonized with more resistant microbes, including penicillin-resistant pneumococci.

The oral cavity has a rich arsenal of 100 different aerobic and anaerobic bacteria, including pneumococcus and *Haemophilus influenzae* which could be more pathogenic if introduced into the sterile area below the vocal cords. This may occur by aspiration, intubation, lack of cough reflexes and poor oral hygiene. In the frontal third of the nose mucosa, there is often a rich growth of staphylococci and gram-negative bacteria, while in the back part (nasopharynx) of the nose, the mucosa is almost sterile. Upper respiratory infection with rhinovirus and other respiratory viruses may quickly spread to the lower respiratory tract with secondary bacterial invasion.

29.5.5 Hospital Flora

One day after hospitalization, the patient may have “new flora” in the upper respiratory tract, gastrointestinal tract, skin and mucosa, transferred from the hospital’s food, environment, water, equipment, hands, etc. Hospital flora is promoted by antibiotics that remove protective normal flora and can cause severe lower respiratory tract infection.

29.5.6 Epidemics: Respiratory

Epidemics in society may affect infections in the hospital. Outbreaks of influenza usually increase the rate of hospitalization and thus the risk of nosocomial infection. This was observed during the pandemic influenza in 2009. Epidemics in the society may influence hospital admittance and infection control:

- *Mycoplasma pneumoniae*—ca. each fourth year.
- *Chlamydia pneumoniae*—annually.
- Influenza—annually +10–50–100-year larger outbreaks.
- *Legionella*—local epidemics (water, aerosol).
- RSV—annually (children’s section and nursing homes).
- *Metapneumovirus*—annually.

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Respirator and Anaesthesia Equipment

30

Abstract

Patients on respirator treatment (respirator, ventilator, anaesthesia machines) are in a special situation where infection control is extremely important to prevent serious lower tract infections. The trachea is a sterile, semi-critical area and should be treated as such. All equipment and fluids introduced, passing the patient's vocal cords, should therefore be sterilized to prevent lower respiratory tract infection. New respirator systems are launched each year, technically improving, but often more and more complicated concerning hygiene and infection control. Hygienic principles described in this chapter should be followed with regard to cleaning, disinfecting and sterilizing all types of respiratory equipment.

Keywords

Respirator · Ventilator · Mechanical ventilation · Anaesthesia machines · Respiratory infections · Infection prevention · Pneumonia · Sterile procedures · Hygiene · Infection control

30.1 Purpose

- To prevent nosocomial pneumonia (NP) in health care institutions [1–28].
- To protect respirator patients from airway infections from contaminated respiratory tract-associated equipment [1–3, 19, 21, 23–28].
- To clean, disinfect, sterilize and handle airway-associated equipment in a proper manner to protect patients against nosocomial infections.
- To handle used respiratory equipment in a safe way so as not to expose personnel and other patients to infectious agents.

30.2 Comprise

All patients on respirator treatment or other treatment of respiratory tract.

All personnel that handle (clean, disinfect, sterilize and store) airway-associated equipment.

All waste and infected materials from respirator patients.

30.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

30.4 Practical Measures

All airway-associated equipments (respirator, ventilator, anaesthesia machine) should be updated in relation to modern respiratory therapy [3, 23]. When planning to purchase new respiratory equipment, it is necessary to involve experienced personnel working with anaesthesia, intensive medicine, medical equipment and infection control, to ensure proper cleaning procedures. Hygienic principles for servo-ventilator are described in this chapter and should be followed with regard to cleaning and disinfecting all types of respiratory equipment.

30.4.1 Servo- and Other Ventilators/Respirators

This equipment is used in intensive and postoperative care and in other monitoring wards.

For each patient without infection that is treated on a respirator over time:

- Ventilator exterior knobs and wires are washed with soap and water every day (if used beyond 24 h).
- Replace sterile wrapped, disposable ventilator circle (tube set) or autoclaved reusable set about every 7th day or earlier, depending on the condition of the patient - or formation of secretions etc.
- For prolonged treatment and in respiratory tract infections with secretions:
 - Surface, knobs and wires are cleaned with soap and water every 24 h.

- Sterile disposable sets or autoclaved disposable set can be changed every 24th hour, if needed.
- When the treatment is finished, the surface of the ventilator, knobs and wires are cleaned with soap and water.
- Tube set and test lung—disposable—are discarded. Reusable equipment is washed in a decontaminator at 85 °C (special washing machine), dried, packaged and autoclaved.
- Inner parts of the machine, like inner tubes and sensor areas where the patient's air is passing, are cleaned, disinfected, autoclaved or treated with gas disinfection prior to use for the next patient [24].

For patient with suspected infection treated on respirator:

Machine surface, knobs and wires are disinfected before it is sent to the sterile central for disinfection of internal parts. Used equipment should be packaged on site and treated as infectious during transport. Further treatment needs written information about the type of infection, and the equipment should be marked “infectious”.

- Tube set and test lung—disposable—are discarded as infectious materials. Reusable equipment is washed in a decontaminator at 85 °C (special washing machine), dried, packaged and autoclaved.
- Ventilator's exterior knobs and wires are disinfected with chloramine 5% (or bleach) in 1 h and then washed over with soapy water. Peracetic acid can also be used.
- Inner parts can be removed and disinfected chemically or autoclaved—depending on what the equipment can tolerate—and then washed over with soap and water.
- For adequate disinfection of the ventilator's inner parts and other machines that are being air-cooled with air from the patient's room, gas disinfection with dry hydrogen peroxide gas is used according to the described procedures [24].
- After treatment for pulmonary tuberculosis or other mycobacteria, the ventilator should be discarded because of no adequate disinfection methods in gas form for mycobacteria (the inner technical part of the machines) [25].

30.4.2 Cleaning of Servo-Ventilators and Corresponding Machines

Servo-ventilators have the advantage that most of the interior parts of the machines can be removed and disinfected/autoclaved. They are to be replaced with new systems, but the principles apply as for servo and are described for this system optimally. The cleaning and control are often done in a special “sterile-central” with competent personnel.

No infection:

- The surface of the ventilator, knobs and wires is cleaned with soap and water.
- Replace with sterile, disposable tubing sets or autoclaved disposable sets. Tubing set and test lung (if reusable) are washed in decontaminator at 85 °C (special washer), dried, packaged and autoclaved at 120 °C.

- Transducers, two pieces, are placed in 70% alcohol for a minimum of 1 min.
- Expiration and inspiration parts are washable in decontaminator at 85 °C (special washer).
- Expiration and inspiration portions and transducers are autoclaved at 120 °C and are then directly put into servo-ventilator. Use sterile gloves during assembly.
- Timecard and register system are checked for any 1000 h' control.
- Ventilator should be readied for a new patient.
- Cover with clean disposable plastic before use.

Suspicion of infection:

(Example: disinfection used for servo-ventilator 900, 900B, 900C and 300)

- Ventilator's exterior knobs and wires are disinfected with chloramine 5% (or bleach) in 1 h and then washed over with soap and water.
- Disposable tubing sets and test lung should be discarded.
- Reusable equipment is washed in a decontaminator at 85 °C (special washing machine), dried, packaged and autoclaved at 120 °C.
- Transducers, two pieces, are placed in 70% alcohol for at least 10 min and autoclaved at 120 °C.
- Expiration and inspiration portions are washed in decontaminator at 85 °C (special washer) and autoclaved at 120 °C.
- When mounting the expiration and inspiration parts and transducers, use sterile gloves.
- Timecard and register system are checked for any 1000 h' control.
- Ventilator should be readied for a new patient.
- Cover with clean disposable plastic before use.

30.4.3 Surgery Department: Anaesthesia

Between each patient:

- Ventilator's exterior knobs and wires are washed with soap and water.
- New sterile tubing sets and test lung are sterile packed.
- Tubing set and test lung—if reusable—are washed in a decontaminator at 85 °C (special washer), dried, packaged and autoclaved.
- Timecard and register system are checked for any 1000 h' control.
- Ventilator should be readied for a new patient.
- Cover with clean disposable plastic before use.

Suspected infection:

Equipment that is to be taken out of the operating room, prior to disinfection, is packaged and treated as infectious and labelled as infection. With confirmed pulmonary mycobacterium infection, the machine should be discarded if the inner parts cannot be disinfected in an appropriate manner [25].

- Ventilator's exterior knobs and wires are disinfected with chloramine 5% (bleach) in 1 h and washed over with soap and water. Peracetic acid can also be used.
- Tubing set and test lung—if disposable—are discarded.
- Reusable equipment is washed in a decontaminator at 85 °C (special washing machine), dried, packaged and autoclaved at 120 °C.
- Transducers, two pieces, are placed in 70% alcohol for at least 10 min, dried, packaged and autoclaved at 120 °C.
- Expiration and inspiration portions are washed in a decontaminator at 85 °C (special washing machine), dried, packaged and autoclaved at 120 °C.
- When connecting the expiration and inspiration parts and transducers, use sterile gloves.
- Timecard and register system are checked for any 1000 h control.
- Ventilator should be readied for a new patient.
- Cover with clean disposable plastic before use.

30.5 Background Information

Respirator-treated patients have 6–21 times greater risk of nosocomial pneumonia than patients who are not treated with respirator. The risk is estimated to be about 1% increase per day [19, 26]. The risk is associated with the mouth flora when intubated, general condition of the patient, biofilm formation, technic and hygiene during secrete suction, leakage around the endotracheal cuff, personnel's hand hygiene, humidifier systems and contamination of the ventilator equipment [3, 23].

All technical equipment used in the respiratory tract is potentially an infectious reservoir or vehicle for infection-causing agents. Aerosol-producing equipment is an important source of infection. Also viruses may be transferred by contamination of equipment [26].

Disinfection, cleaning and sterilization of the reusable equipment are important for reducing nosocomial lung infections. The processing of equipment must lead to a complete *dry* equipment where bacterial growth will not occur and not further transmitted to the next patient.

30.5.1 Mechanical Ventilator (Servo-Ventilator)

Internal respirator part is not appreciated as a serious source of infection [19, 26]. Filter between the machine and inspiration tube can eliminate contamination from inspiration gas and prevent to a certain degree retrograde infection from patient to the machine. Filter or condensate trap on the expiratory side can prevent the infection from patient to surroundings, but filter use is controversial.

30.5.2 Respirator Circle, Humidifiers, etc.

Humidifiers that are not making *aerosols* and/or are producing heated steam are preferred, less risk of nosocomial pneumonia [19, 26]. Humidifiers are using sterile water due to the risk of gram-negative bacteria and *Legionella* in non-sterile tap water. Condensates in the respirator system are colonized very fast by bacteria, particularly in temperature differences. Thirty-three percent of the inspiration part is colonized by the patient's upper airway flora within 2 h and 80% after 24 h of use.

The condensate that overflows to the patient's lower airways (manipulation, sucking, wrong angle, etc.) is causing pneumonia. *Training* of regularly emptying and careful manipulation of such system are important. Contaminated condensate should not be transmitted via the hands/equipment or on uniform to other patients or environments.

Replacement of respiration tubes with accessories for a patient can be postponed to every 2–7 days using special humidifier [19, 26–29]. An “artificial nose” (HME) is recycling heat and moisture from the patient's exhalation and eliminates humidifier equipment. Filter associated with HME is not adequately documented.

30.5.3 Small-Volume Medicine Nebulizer

In the ventilation system, these may constitute the risk of contamination. They should be avoided and in any case treated sterile [19, 26].

30.5.4 Large-Volume Nebuliser

Large-volume, > 500 cc, reservoirs include those used by intermittent positive-pressure respiration (IPPB) and ultrasonic or “spinning disc” humidifiers. They are the greatest risk of pneumonia development in the patient because of aerosol formation. In such reservoirs, large quantities of bacteria may be propagated within 2–24 h. They are not recommended, except for IPPB. If this type is used, it must be sterilized/disinfected thoroughly afterwards.

30.5.5 Manual Small-Volume Medicine Nebulizer

Small-volume nebulizer may produce bacterial aerosol and is associated with nosocomial pneumonia and should therefore be avoided. However, if necessary, use only newly opened, sterile processed vials and sterile water.

30.5.6 Suction Catheter, Bags, Oxygen Analyser, Spirometer, etc.

Tracheal suction: Disposal open-catheter system or multi-use closed system. Until now they have not shown any differences regarding prevention of lung infection, but closed systems may save the environment for contamination [19, 26].

Bag (lærdalsbag) can be cleaned/autoclaved after use. While in use, the patient secretions may be sprayed back into the patient's lungs as aerosols. Contamination of the hands happens frequently when disconnection. Change bag frequently, and avoid external contamination.

Oxygen analyser/spirometer: Associated with outbreak of infections from patient to patient or via staff hands. It is cleaned and sterilized between patients or single use. *Training and knowledge* are needed.

30.5.7 Anaesthesia Equipment

Anaesthesia apparatus: Internal parts are not estimated as significant risk of infection [5, 6]. However, this may change because of the development of newer, more robust and resistant microbes.

Patient system (unidirectional and circular equipment, tubes with equipment + tube) will become contaminated with upper respiratory tract flora. Components that are directly or indirectly in contact with the patient's mucous membranes are single use or should be autoclaved if reused for each patient.

The use of high-performance filters at V/Y part, or at inspiration/exhalation part, may decrease the burden of bacteria in the tubing system, but it is uncertain whether it prevents nosocomial pneumonia [30]. If using a filter at the Y portion in patient system, one-way system or circle system, the filter is changed. Mask, bag and 2 litre bag are cleaned in decontaminator, dried and autoclaved. Reusable parts of the patient system can be autoclaved. Disposable items are discarded between each patient. Carbon dioxide chambers are disposables.

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Respirator in Intensive Treatment

31

Abstract

New types of respiratory equipment are launched each year, technically improving but often more and more complicated concerning hygiene and infection control. Hygienic principles described in this chapter should be followed with regard to cleaning, disinfecting and sterilization of all types of respiratory equipment used in intensive wards. Intensive care units are high-risk areas with a high number of critically ill patients, a high use of antimicrobial agents and a high environmental burden of microbes, skin cells, dust from paper, aerosols and other airborne particles. For patients on respirator, infection control is extremely important to prevent serious lower tract infections. All equipment's inner parts, connected directly or indirectly to airways, should therefore be sterile to prevent lower respiratory tract infection. A respirator will always be an “extended lung” when connected to the patient’s airways.

Keywords

Intensive treatment · Respirator · Ventilator · Mechanical ventilation · Respiratory infections · Pneumonia · Infection prevention · Sterile procedures · Hygiene · Infection control

31.1 Purpose

To prevent nosocomial pneumonia (NP) in health care institutions [1–21]. To protect respirator patients from airway infections from contaminated respiratory tract-associated equipment. To clean, disinfect, sterilize and handle airway-associated reusable equipment in a proper manner to protect patients against nosocomial infections. To handle used respiratory equipment in a safe way for not to expose personnel and other patients for infectious agents.

31.2 Comprise

All patients on respirator treatment or other treatment of respiratory tract. All personnel that handles (clean, disinfect sterilize and store) airway- associated equipment. All routines and processes to clean and sterilize reusable respiratory equipment. All waste and infected materials from respirator patients [21].

31.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

31.4 Practical Measures

Note: All equipment with inner parts in direct access to the lower respiratory tract should be kept sterile as an "extended outer lung." The reason is that it is normally sterile conditions in the lower respiratory tract and the patient's infection defence is reduced during intubation.

31.4.1 Respirator-Ventilator

- Ventilator should be cleaned and finished in a suitable room, with ample room for soiled and clean zone for the machine, to prevent the formation of aerosols.
- A clean respirator, ready to use for the next patient, is covered with clean plastic, and completion date is set, and the equipment is placed in a clean storage room if it is not used immediately.
- Avoid using machines which are difficult to clean internally to patients with known infections. Be critical when purchasing new equipment, especially in view of resistant microbes.

31.4.2 Inner Respirator Part

A number of recent ventilators have internal respirator parts that cannot be cleaned. This is due to advanced electronics that do not tolerate chemical disinfectants or moisture. Only specially trained technical personnel from the company may open inner technical parts (control approximately once/year). In Norway there are public medical-technical centres associated to hospitals for treatment of all risks—equipment, also inner parts—between patients.

There are a number of openings to the interior of a ventilator. Both the inspiration air and some of the expiratory air enter and pass through the inner parts. The interior of respirators is not generally estimated as a serious source of infection. However, when used in a patient with respiratory tract infection, the most robust and surviving microbes may remain in the inner parts in weeks to months to years.

In technical centres, the equipment is opened and rinsed, and some parts are taken out for heat disinfection in special washing machines at 85 °C. The electric and machine system is disinfected by dry hydrogen peroxide gas 5%—three cycles—controlled by spore test, and this is carried out for the entire machine [23]. In cases of tuberculosis or other mycobacteria, the ventilator is discarded. This is recommended since there is no effect of hydrogen peroxide gas (and no other known gas) on mycobacteria [23].

31.4.3 Ventilator Connection Point for Inspiration

Inspiration air will pass from the wall outlet (O_2 , air) which is mixed internally through the ventilator electronic system and lead to the connection point of inspiration on the ventilator's front.

- Filter between the machine and inspiration tube can eliminate contamination from inspiration gas and prevent retrograde infection from the patient to the machine. Use new filter for each patient.
- Avoid using moisture systems that can promote retrograde bacterial growth.
- Connection point—outer and inner parts—is washed with soap and water, dried and then wiped with chlorhexidine alcohol 70%, between patients.
- If suspected infection, use 5% chloramine or peracetic acid at the same areas in 1 h, followed by ordinary washing with soap and water, and in addition gas disinfection with dry hydrogen peroxide gas [23].

31.4.4 Ventilator Connection Point for Exhalation

The expiratory air passes through the “knee” connected to the machine where most of the expiratory air—via a Spirolog sensor (flow sensor)—is sent out to the room.

Some of the patient's expiratory air runs continuously in—through two holes—to internal electronic measurement and adaptation of activity.

- “Knee” link is washed and sterilized satisfactory.
- Spirolog sensor may be damaged during cleaning in water or fluids. It should be singly used between patients and washed and disinfected with 70% chlorhexidine-alcohol.
- The area of contact—including holes for expiratory air—is cleaned with soap and water, thoroughly dried and treated with chlorhexidine-alcohol 70%.
- If infection is suspected, use 5% chloramine or peracetic acid in 1 h, followed by ordinary washing with soap and water. In addition, use gas disinfection with dry hydrogen peroxide gas [23].

31.4.5 Nebulizer System

This is a thin tube that is connected to a small external opening on the front of the ventilator. Atomized air comes from the same system as the inlet air and then sent via the tube to the atomizer system. The tubing is wiped over the exterior. It is very thin and can therefore be difficult to clean internally.

- Air outlet for nebulizer is washed with soap and water before disinfected with chlorhexidine-alcohol 70%.
 - If infection is suspected, use 5% chloramine or peracetic acid at the same areas in 1 h, followed by ordinary washing with soap and water, and in addition gas disinfection with dry hydrogen peroxide gas [23].
 - The nebulizer tube is changed between each patient.
-

31.5 Background Information

Lower respiratory tract infection “is cough, fever and purulent sputum, irrespective of the result of expectorate culture and/or pulmonary radiographs. If purulent sputum does not occur, but lung X-rays show typical infection image, is the diagnosis still reported as infection” [3–5]. This definition is originally from the CDC and is modified to Norwegian conditions by the Norwegian public health [4–14, 16–19]. More recent definitions from the CDC are also used by some hospitals in Norway [15, 20].

Patients may be admitted *because* of a respiratory infection or *because* of another disease like infarct, having in addition a respiratory tract infection. Both cases are potential sources of infection in the hospital environment.

31.5.1 Definitions

- CAP is community-associated pneumonia caused *outside the healthcare*.
- HCAP (HAP) is healthcare-associated pneumonia that occurs in hospitals, nursing homes, homecare, dialysis, etc.; nosocomial infection [21, 24–33].

Nosocomial respiratory tract infections occur up to 30–90 days after admission to hospital or other health institution. Pneumonia may occur in patients, personnel, visitors, service personnel and others who handle material, equipment and textiles from healthcare institutions. It is often older patients or young children who get nosocomial pneumonia and who need hospital treatment [25–33].

- *Respiratory tract infection*: acute inflammation of the respiratory tract caused by microbes.
- *Upper respiratory tract (URT) infection*: the nose, sinuses, ears, pharynx and larynx (rhinitis, sinusitis, otitis, pharyngitis, laryngitis), relatively rarely occurring in hospitals, except outbreaks of sore throat.
- *Lower respiratory tract (LRT) infections*: trachea, bronchi and lung tissue (tracheitis, bronchitis, pneumonia). Lower respiratory tract is a sterile, semi-critical area. All technical equipment introduced, passing the patient's vocal cord, is a risk to the patient. Surgical patients and patients on assisted ventilation are therefore very susceptible to lower respiratory tract infection.
- *Nosocomial pneumonia (NP)* might be difficult to distinguish from other lower respiratory tract symptoms occurred during or after hospitalization. Typically, NP occurs 2 days or more after admission and is not in the incubation period at admission.
- *Ventilator-associated pneumonia (VAP)* develops usually after more than 2 days after endotracheal intubation. The risk of VAP is found to increase by 3% per day for the first 5 days, 2% per day from days 5 to 10 and then 1% per day [31, 34].
- *Ventilator-associated complications (VAC) and ventilator-associated events (VAE)* are more advanced methods that may detect deterioration of a ventilated patient [35–38].
- *Nosocomial lower respiratory tract infection*: there are a number of recent definitions that include bronchitis and various stages of chronic obstructive pulmonary disease, not further discussed here [39].
- *Carrier of pathogenic microbes*: individual with bacterial colonization of the upper airways without signs of infection. The bacteria can cause individual infections and may be the source of infection to others.

31.5.2 Criteria for Nosocomial Pneumonia: CDC 1988 [16]

The criteria are often difficult to clarify, but include the following:

1. Auscultation of the chest – not normal + *one* of the following findings:
 - (a) Recent purulent expectorate or increased secretion.
 - (b) Changed nature of sputum.
 - (c) Microbes isolated from blood culture.
 - (d) Pathogenic microbe isolated by trans-trachea aspiration, bronchial test or biopsy.
 - (e) Isolation of virus or virus antigens in the respiratory tract.
 - (f) Detected specific IgM or four times IgG titre increase in pairs.
 - (g) Histopathological findings.

2. X-ray result: new infiltrate or progression, densification, caverns or pleural liquid + *one* of the following: see (a)–(g) as above.
3. The patient has two of the following symptoms: apnoea, tachypnoea, bradycardia, wheezing respiration, rhonchi or cough + *one* of the following: see (a)–(g) as above [16].

31.5.3 Prevalence

Hospital infections occur in 3–21% (mean 8.7%) of all cases, and 0.5–11% may get nosocomial lower respiratory tract infection [1–3]. In Norwegian hospitals, approximately 1–2% of the patients get nosocomial pneumonia, related to the degree of emergency and intensive activity, surgical procedures, isolation conditions, seasonal outbreaks, endemic and epidemic conditions in the community, etc. [4–15].

Respiratory infections are common in the population [1–3, 40]. Lower respiratory tract infection is mostly preceded by upper respiratory infection, short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly subjects.

Pneumonia outside healthcare, CAP. In the United States, approximately 915,000 people, usually older than 65 years of age, get pneumonia every year. And the CAP together with influenza constitutes the seventh leading cause of death in the United States [2, 40, 41]. Vaccination against influenza and pneumococci is highly recommended for certain age groups and categories of patients in the United States [40]. Occurrence in Norway is unknown due to a lack of registration.

Nosocomial lower respiratory infection affects 15–20 per 1000 hospitalized patients, and 20–45% dies from infection.

Nosocomial pneumonia increases hospital stay for the patient 7–14 days and represents an additional cost of approximately 25,000 USD per patient [34, 35, 42]. Incidence in the United States is estimated to 5–15 cases per 1000 hospitalizations and 5–15% of ICU (intensive care unit) patients [34, 37]. It is dominant in the ICU and the cause of more than 50% of consumption of antibacterial agents in the unit [34]. Mortality is estimated at 30–70% (crude mortality) in 2005 [34].

In Norway, nosocomial lower respiratory infection accounts for approximately 25% of hospital infections [8, 11, 15].

31.5.4 Microbes: Respiratory Infections

Many types of microbes cause lower respiratory tract infection. Aetiological agents are often difficult to detect, and in severe cases it can be a polymicrobial flora [34]. Sampling is required; blood culture, cultivation of sputum, quick tests for influenza and other viruses, legionella and pneumococcal, urine antigen tests, fungal cultures, tuberculosis and atypical mycobacteria in bronchial aspirate, etc. [40]. Invasive sampling gives usually no more than a good quality sputum [43]. One gram preparation of sputum may be useful [44].

In cases of pneumonia occurring outside the hospital, aetiological agent is detected in only about 25% [45]. Bacteria associated with respiratory tract infections, like pneumococci, are still sensitive to common antibiotics in Norway [46, 47]. However, patients from abroad are often colonized with more resistant microbes, including penicillin-resistant pneumococci.

The oral cavity has a rich arsenal of 100 different aerobic and anaerobic bacteria, including pneumococcus and *Haemophilus influenzae* which could be more pathogenic if introduced into the sterile area below the vocal cords. This may occur by aspiration, intubation, lack of cough reflexes and poor oral hygiene. In the frontal third of the nose mucosa, there is often a rich growth of staphylococci and gram-negative bacteria, while in the back part (nasopharynx) of the nose, the mucosa is almost sterile. Upper respiratory infection with rhinovirus and other respiratory viruses may quickly spread to the lower respiratory tract with secondary bacterial invasion.

31.5.5 Hospital Flora

One day after hospitalization, the patient may have “new flora” in the upper respiratory tract, gastrointestinal tract, skin and mucosa, transferred from the hospital’s food, environment, water, equipment, hands, etc. Hospital flora is promoted by antibiotics that remove protective normal flora and can cause severe lower respiratory tract infection.

31.5.6 Epidemics: Respiratory

Epidemics in society may affect infections in the hospital. Outbreaks of influenza usually increase the rate of hospitalization and thus the risk of nosocomial infection. This was observed during the pandemic influenza in 2009. Epidemics in the society may influence hospital admittance and infection control:

- *Mycoplasma pneumoniae*—ca. each fourth year.
- *Chlamydia pneumoniae*—annually.
- Influenza—annually +10–50–100-year larger outbreaks.
- *Legionella*—local epidemics (water, aerosol).
- RSV—annually (children’s section and nursing homes).
- Metapneumovirus—annually.

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External CPAP: Cleaning Procedures

32

Abstract

For patients on respirator, infection control is extremely important to prevent serious lower tract infections. All equipment's inner parts, connected directly or indirectly to airways, should be sterile to prevent lower respiratory tract infection. A CPAP (Continuous positive airway pressure) will always be an “extended lung” when connected to the patient’s airways. The inner parts of CPAP may be strongly contaminated during use by patients. There may be a huge growth of bacteria and fungi in biofilms and secrets in wet areas in the inner part of the CPAP.

Keywords

CPAP · Continuous positive airway pressure · Intensive treatment · Respiratory infections · Pneumonia · Infection prevention · Sterile procedures · Hygiene · Infection control

32.1 Purpose

To prevent nosocomial pneumonia (NP) in health care institutions [1–24]. To protect patients from airway infections from contaminated respiratory tract-associated equipment, like CPAP. To clean, disinfect, sterilize and handle external CPAP equipment in a proper manner to protect patients against transmission of nosocomial infections. To handle used CPAP in a safe way for not to expose personnel and other patients for infectious agents.

32.2 Comprise

All patients on external CPAP treatment or other treatment of respiratory tract. All personnel that handles (clean, disinfect sterilize and store) CPAP and other airway-associated equipment. All routines and processes to clean and sterilize inner parts of external, reusable CPAP and other similar equipment. All waste and infected materials from CPAP and other respiratory equipment.

32.3 Responsibility

The hospital management should ensure a general prevention of nosocomial respiratory infections in the hospital by written routines, isolates for airborne infections, stock of personal protective equipment (PPE), disinfectants, etc.

The department's management must organize infection prevention measures, like training in hand hygiene, use of PPE and isolation treatment. Responsibility includes information to the Director concerning the lack of resources regarding the prevention of respiratory infections.

The staff should ensure that patients and visitors are protected from airborne infection. Staff most often meet the patient first ("frontline") and should therefore be especially protected from airborne infections [22].

Visitors should have access to information, hand hygiene, cough hygiene and actual protective measures such as PPE when visiting a patient with airborne infection.

32.4 Practical Measures

The inner parts of CPAP may be strongly contaminated during use (Fig. 32.1). There may be a huge growth of bacteria and fungi in biofilms and secrets lining the wet areas in the inner part of the CPAP [23].

32.4.1 External CPAP as a Whole

- CPAP should be cleaned and finished in a suitable room, with ample room for soiled and clean zone for the machine, to prevent the formation of aerosols.
- A clean CPAP, ready to use for the next patient, is covered with clean plastic, and completion date is set, and the equipment is placed in a clean storage room if it is not used immediately.
- Avoid using CPAP machines which are difficult to clean internally to patients with known infections. Be critical when purchasing new equipment, especially in view of resistant microbes.
- CPAP used for pulmonary tuberculosis should be discarded [23].
- Avoid shared use between several departments because of the risk of disease transmission.
- If infection is suspected, disinfect all equipment with dry hydrogen peroxide gas [23].

Fig. 32.1 CPAP like other equipment that is drawing air from rooms and patients can be very contaminated inside and need to be cleaned and disinfected both inside and outside before use for the next patient. Source: Andersen et al. [23]



32.4.2 Inner Parts of the CPAP

The internal part “bag” cannot be cleaned at all because of advanced electronics that do not tolerate disinfectants or moisture. There are several openings for air to the inner part. Inspiration air enters and passes through the inner parts of the CPAP. For heavily contaminated and unusual infectious agent, the inner parts should be cleaned and disinfected by specific procedures at medical-technical centres [23].

32.4.3 CPAP: Connection Point for Inspiration

Inspiration air passes from the wall outlet (O_2 , air) which is mixed internally through CPAP’s mechanical system and leads to the connection point for inspiration on the front of the CPAP.

- Filter between the machine and inspiration tube can eliminate contamination from inspiration gas and prevent retrograde infection from the patient to the machine. Use new filter for each patient.

- Avoid using moisture systems that can promote retrograde bacterial growth.
- Connection points—outer and inner parts—are washed over with soap and water, dried and then wiped over with chlorhexidine alcohol 70%, between patients.
- If infection is suspected, use 5% chloramine or peracetic acid at the same areas in 1 h, followed by ordinary washing with soap and water, and in addition gas disinfection with dry hydrogen peroxide gas [23].

32.5 Background Information

Lower respiratory tract infection “is cough, fever and purulent sputum, irrespective of the result of expectorate culture and/or pulmonary radiographs. If purulent sputum does not occur, but lung X-rays show typical infection image, is the diagnosis still reported as infection” [3–5]. This definition is originally from the CDC and is modified to Norwegian conditions by the Norwegian public health [4–14, 16–19]. More recent definitions from the CDC are also used by some hospitals in Norway [15, 20].

Patients may be admitted *because* of a respiratory infection or *because* of another disease like infarct, having in addition a respiratory tract infection. Both cases are potential sources of infection in the hospital environment.

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32.5.2 Criteria for Nosocomial Pneumonia: CDC 1988 [16]

The criteria are often difficult to clarify, but include the following:

1. Auscultation of the chest – not normal + *one* of the following findings:
 - (a) Recent purulent expectorate or increased secretion.
 - (b) Changed nature of sputum.
 - (c) Microbes isolated from blood culture.
 - (d) Pathogenic microbe isolated by trans-trachea aspiration, bronchial test or biopsy.
 - (e) Isolation of virus or virus antigens in the respiratory tract.
 - (f) Detected specific IgM or four times IgG titre increase in pairs.
 - (g) Histopathological findings.
2. X-ray result: new infiltrate or progression, densification, caverns or pleural liquid + *one* of the following: see (a)–(g) as above.
3. The patient has two of the following symptoms: apnoea, tachypnoea, bradycardia, wheezing respiration, rhonchi or cough + *one* of the following: see (a)–(g) as above [16].

32.5.3 Prevalence

Hospital infections occur in 3–21% (mean 8.7%) of all cases, and 0.5–11% may get nosocomial lower respiratory tract infection [1–3]. In Norwegian hospitals, approximately 1–2% of the patients get nosocomial pneumonia, related to the degree of emergency and intensive activity, surgical procedures, isolation conditions, seasonal outbreaks, endemic and epidemic conditions in the community, etc. [4–15].

Respiratory infections are common in the population [1–3, 40]. Lower respiratory tract infection is mostly preceded by upper respiratory infection, short incubation time and a rapid spread of infection. Pneumonia is severe in both young and elderly subjects.

Pneumonia outside healthcare, CAP. In the United States, approximately 915,000 people, usually older than 65 years of age, get pneumonia every year. And the CAP together with influenza constitutes the seventh leading cause of death in the United States [2, 40, 41]. Vaccination against influenza and pneumococci is highly recommended for certain age groups and categories of patients in the United States [40]. Occurrence in Norway is unknown due to a lack of registration.

Nosocomial lower respiratory infection affects 15–20 per 1000 hospitalized patients, and 20–45% dies from infection.

Nosocomial pneumonia increases hospital stay for the patient 7–14 days and represents an additional cost of approximately 25,000 USD per patient [34, 35, 42]. Incidence in the United States is estimated to 5–15 cases per 1000 hospitalizations and 5–15% of ICU (intensive care unit) patients [34, 37]. It is dominant in the ICU and the cause of more than 50% of consumption of antibacterial agents in the unit [34]. Mortality is estimated at 30–70% (crude mortality) in 2005 [34].

In Norway, nosocomial lower respiratory infection accounts for approximately 25% of hospital infections [8, 11, 15].

32.5.4 Microbes: Respiratory Infections

Many types of microbes cause lower respiratory tract infection. Aetiological agents are often difficult to detect, and in severe cases it can be a polymicrobial flora [34]. Sampling is required; blood culture, cultivation of sputum, quick tests for influenza and other viruses, legionella and pneumococcal, urine antigen tests, fungal cultures, tuberculosis and atypical mycobacteria in bronchial aspirate, etc. [40]. Invasive sampling gives usually no more than a good quality sputum [43]. One gram preparation of sputum may be useful [44].

In cases of pneumonia occurring outside the hospital, aetiological agent is detected in only about 25% [45]. Bacteria associated with respiratory tract infections, like pneumococci, are still sensitive to common antibiotics in Norway [46, 47]. However, patients from abroad are often colonized with more resistant microbes, including penicillin-resistant pneumococci.

The oral cavity has a rich arsenal of 100 different aerobic and anaerobic bacteria, including pneumococcus and *Haemophilus influenzae* which could be more pathogenic if introduced into the sterile area below the vocal cords. This may occur by aspiration, intubation, lack of cough reflexes and poor oral hygiene. In the frontal third of the nose mucosa, there is often a rich growth of staphylococci and gram-negative bacteria, while in the back part (nasopharynx) of the nose, the mucosa is almost sterile. Upper respiratory infection with rhinovirus and other respiratory viruses may quickly spread to the lower respiratory tract with secondary bacterial invasion.

32.5.5 Hospital Flora

One day after hospitalization, the patient may have “new flora” in the upper respiratory tract, gastrointestinal tract, skin and mucosa, transferred from the hospital’s food, environment, water, equipment, hands, etc. Hospital flora is promoted by

antibiotics that remove protective normal flora and can cause severe lower respiratory tract infection.

32.5.6 Epidemics: Respiratory

Epidemics in society may affect infections in the hospital. Outbreaks of influenza usually increase the rate of hospitalization and thus the risk of nosocomial infection. This was observed during the pandemic influenza in 2009. Epidemics in the population may influence hospital admittances of infectious patients and thereby the infection control work:

- *Mycoplasma pneumoniae*—ca. each fourth year.
- *Chlamydia pneumoniae*—annually.
- Influenza—annually +10–50–100-year larger outbreaks.
- *Legionella*—local epidemics (water, aerosol).
- RSV—annually (children's section and nursing homes).
- Metapneumovirus—annually.

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Part VI

Surgery



Prevention of Postoperative Wound Infections

33

Abstract

Surgery creates most hospital infections, injuries, accidents, invalidity and death in the global healthcare system. The number of surgically treated patients per year is high and increasing.

Surgical site infection (SSI) is dependent on type of operation and may occur in 5–20% after surgery, triggers 7–11 extra postoperative days in hospitals and results in 2–11 times higher risk of death than comparable, noninfected patients. Up to 60% of SSI can be prevented. Prevention of postoperative wound infection is done by good general hygiene, operative sterility and effective barriers against transmission of infections, before, during and after surgery. A basic support by hospital leaders, knowledge and skill of the surgical teams, enough resources, excellent treatment of the complete patient admission and monitoring patients after discharge may lead to significant reduction of SSIs, lower death rates and a less expensive health system.

Keywords

Surgical site infections · SSI · Postoperative wound infections · Prevalence · Death rate · Costs · Instruments · Technique · Ventilation · Cleaning and disinfection · Attire · Surgery on infected patient · Anaesthesia · Infection control · Airborne contamination · Sterile procedures · Infection prevention

33.1 Purpose

- To reduce the incidence and severity of postoperative wound infections (surgical site infections—SSI).
- To prevent spread of wound infections to other patients, staff, visitors and the environment [1–13].

33.2 Comprise

- All surgical patients, before, during and after surgery.
 - Personnel, equipment and environment associated with operating treatment, before, during and after surgery [14].
-

33.3 Responsibility

Hospital management has the responsibility for providing:

- Hygienic and safe conditions for the patient at surgical wards, in the operation department and during the postoperative phase.
- Enough personnel, expertise and resources for professional and proper surgical treatment.
- A modern, sterile centre with knowledge and good storage conditions for sterile, surgical equipment
- A system for deviation and risk notification, for example, unnecessary removal of patients from planned operating programmes and lack of personnel, equipment, capacity or expertise that may expose patients to risk of hospital infection.

Department management has the responsibility for:

- Written and implemented surgical, hygienic and other procedures to prevent SSI
- A system for control, action and notification to the director in case of deviation concerning problems with sterile equipment, anaesthesia, capacity, risk of infection or any other risk to life and health of patients and personnel, such as over-crowded and understaffed wards, poor hygiene, etc.

Intensive-postoperative and anaesthesia departments have corresponding responsibilities, especially in pre- and postoperative phase. Deviations are reported to the head of the department where the patient is located.

The personnel follow procedures with respect to prevention of SSI and report deviations, problems, risk of poor hygiene and infection, to the department's management.

The surgeons inform and follow up their patients in pre- and postoperative phases. Deviations concerning hygiene, risk of infection and other risks are reported to the head of the department where the patient is located.

33.4 Practical Measures

Documentation and recommendations [1–13].

Grading of recommendations (1A, 1B, 1C, II) is often used according to CDC/HICPAC's supervisors where 1A is the strongest recommendation (see background information) [1, 8, 12, 13].

33.4.1 Information to the Patient: Before and After Surgery

- Inform about contact with healthcare abroad. Inform recent illness, stomach ache with vomiting, urinary tract infections, other infections or having received antibiotics.
- Good body wash, including the hair, and change to clean clothes—from the inside to the outside –before hospitalization.
- If diabetes, ask for a good control before, during and after surgery, to heal the wound quickly and not to be infected (1B).
- Quit smoking at least 1 month before elective surgery—especially orthopaedic surgery. Smoking increases the risk of infection and reduces bone healing (1B).
- Do not shave the area to be operated on before surgery (1A).
- No unnecessary hospital stays before surgery to avoid contact with more resistant hospital bacteria. Preferably admission the day before—or the same day as the operation. To remove the patient from a planned operating programme should be an exception!
- Notify the manager if poor hygiene and cleaning in the patient room.
- Perform good hand hygiene throughout your stay. If bedridden, ask for wipes for hand disinfection. Ask visitors to carry out hand hygiene on arrival and when they leave the hospital.
- Ask health professionals to carry out hand hygiene if this fails—before and after your examination.
- Good body wash before surgery, including hair. Use a disinfecting soap—Hibiscrub—containing chlorhexidine the night before and in the morning. This reduces the amount of bacteria on the skin (1B). Used especially in elective operations—when inserting prostheses and other foreign bodies.
- Learn good breathing exercises that are used after surgery.
- You should not be placed together with patients with infections—either before or after surgery, because of risk of infection. You should not be placed on the corridor or other places not intended for patients, since you there is more at risk for infections.
- Do not touch the wound or the bandages. Bacteria must not come to the wound while it is healing. Do not let the bandage get wet because bacteria can then grow more easily through.
- All who are going to take off the bandage and treat the wound should have clean hands and sterile gloves and use sterile equipment when removing stitches, doing wound care, etc.
- If itching, pain or leakage through the bandage, contact a doctor or nurse.
- Physiotherapist will help you with breathing so you get well soon after surgery.
- Be placed a little high up with your upper body in bed after surgery, it reduces problems with respiratory infections.

33.4.2 Central Checkpoints for Each Patient To Be Operated: Department and Operation Team

- Well-prepared patient; informed about the operation and infection prevention measures and has no ongoing infections (1A).
- Good surgical handwashing is carried out (1B).
- The operation team uses approved sterile operating clothing (1B).
- Good and proper skin disinfection and aseptic sterility are carried out (1B).
- Puncture of operating gloves avoided; good routines for change of gloves exist.
- The number of airborne bacteria that might contaminate the surgical wound during the operation is below the threshold level ($<100 \text{ CFU}/\text{m}^3$ at normal surgery, $<10 \text{ CFU}/\text{m}^3$ at ultraclean surgery—prostheses and other foreign bodies).
- The operating room has positive air pressure with a defined HEPA (high-efficiency particulate air)—filter that removes at least 99.97% of airborne particles that have a size of $0.3 \mu\text{m}$ —for air intake (1B).
- The surgical technique is good, the equipment is controlled and the operating team is experienced.
- Procedures for antibacterial prophylaxis are followed (1A) [13].
- Postoperative phase is protected for risk of infection—with skilled personnel.

33.4.2.1 Registration: Prevalence or Incidence

- In Norway, point prevalence of SSI is monitored 3–4 times a year as a part of all nosocomial infections in hospitals [14–18]. Incidence is followed continuously for certain types of SSI. Results are openly available [14–18].
- Registering and return of results to the clinics and surgical departments may increase the awareness of SSI and of the efficacy or lack of infection control measures (1B) [1, 4, 8].
- Registering usually reduces SSI; it is a tool in itself [1, 2, 4, 19–24].
- Registering may use a local “threshold” for infection control reaction, for instance, local upper threshold of more than [25, 26]:
 - 2–3% for postoperative deep wound infection after arthro-prosthesis surgery
 - 1% for bypass ACB (aorto-coronary bypass) surgery
 - 1.5% for elective neurosurgery [26]
 - 1.25% for prostheses in larger blood vessels
 - 1% for uncomplicated gallstones
 - 3% for uncomplicated appendicitis
 - 7% for colon surgery
 - 13% for active appendicitis [25].

33.4.2.2 Preoperatively Check for the Patient

1. Careful preoperative assessment, preparation and good outpatient clarification. Written information before admission. Well-planned surgery and well-prepared patient.

2. Ask if the patient has recently been ill; had fever, stomach ache with vomiting, urinary tract infections, other infections and received antibiotics; or had been exposed to norovirus prior to admission.
3. Eradicate infections. Ensure the eradication of infections, urinary tract infections, skin infections and other local infections prior to admission. Check the dental status, especially before larger elective interventions with implants and the like. Postpone surgery, if possible, until the infection is cleared (1A) [4, 8].
4. Resistant bacteria. Check if the patient has been in contact with the healthcare abroad for the past 12 months, has been exposed to MRSA (methicillin-resistant *Staphylococcus aureus*) or has previously been MRSA infected/carrier.
 - (a) *If yes* for exposure or infection, this is tested in advance (preferably before admission) by taking samples for detection of MRSA, VRE (vancomycin-resistant enterococci), ESBL (extended-spectrum beta-lactamase-producing) gram-negative bacteria, CRE (carbapenem-resistant *Enterobacteriaceae*) and other current or epidemic, resistant bacteria.
 - (b) *If not checked* negative in advance and have been exposed to or infected by resistant bacteria, postpone elective operations until this is clear.
 - (c) NB! In acute disease state, necessary surgery should not be postponed but performed as an air contamination surgery.
5. Short preoperative stay, less than 1–2 days.
6. Intestinal surgery. Bacterial volume in the intestine should be reduced, but the effect of mechanical drainage alone is controversial. Estimated as important in the case of impaired immune defence. The most important is the systemic antibacterial prophylaxis as a single dose (usually) at the onset of anaesthesia.
7. Hair removal. It must be considered whether hair removal is necessary (1B). If done, it should be performed as close to the operation as possible, but not in the operating room. Remove loose hairs!
8. Glucose control perioperatively for all patients; use blood control target levels less than 200 mg/dl in patients with and without diabetes (1A) [13]. Monitor at regular measurements at least during the first postoperative day (1B).

33.4.2.3 Operational Department Requirements

1. Separated from general traffic and airflow through the hospital.
2. Do not mix with day surgery.
3. Increasing cleanliness and air quality in work zones—from the entrance to the operating rooms.
4. Movement between clean areas should be possible without needing to pass through “unclean” areas.
5. Remove unclean material from the operating room without passing through clean areas.
6. Airflow should pass from clean to more unclean areas. Positive air pressure on operating rooms and defined “clean rooms” (1B). Positive air pressure on the entire operation department relative to other departments and outdoor air (1B).

7. Heating and ventilation to ensure comfortable conditions for the patient and staff [4].
8. *Structural quality.* Dense, robust and easily washable walls, firm and complete ceilings and a solid floor that can withstand disinfectants. Do not use tiles that can be difficult to clean and replace. Do not use wood that attach bacteria more easily. No swing doors that produce piston power on air currents. No sliding doors that are impossible to wash and not doors with “brush material” or other edge material that collects dust and dirt.
9. *Good sluice conditions for patients:* Patients without infections or carrier state are sluiced into a clean bedroom waiting hall, “green area,” for preoperative treatment.
10. *Good sluice conditions for personnel:* There is good place for changing clothes, spacious wardrobe, with a separate storage for clean clothes, bathroom and good daily cleaning.
11. *Storage* of clean or sterile equipment in separate rooms (14–20 m²): sterile equipment, prostheses, intravenous fluids, major medical equipment, sterile cover materials, operation tops, bandages, etc. Storage rooms are not offices, due to large amounts of bacteria-bearing skin cells and particles released from the skin and deposited around from persons present. A clean room has <100 CFU/m³ air and a low particle load.
12. *Throughput lockers for equipment to operating rooms* should be avoided due to uncertain pressure conditions and risk of contamination of stored equipment and the operating room.
13. *Surgical specialties* should have their own custom-made equipment rooms for special materials. Reduces the need for intermediate storage in cabinets inside the operating room.
14. *Corridor* is not storage for any equipment that is used in operation rooms.
15. *Separate washing units* for operating tables, etc. and for shoe cleaning and drying.
16. *Separate anaesthetic unit* with plenty of space for cleaning and disinfection of equipment. A separate room for intravenous fluids.
17. *Sterilization central.* A separate, nearby located sterilization centre for cleaning, control, packing, sterilization of instruments and clean storage rooms and clean transport routes to the operating department.
18. *One operating room (surgery)* per 5–15 surgical beds. At least 42 m² area (6 × 7 m) for ample space for equipment, place around the operation table for the operating team and anaesthesia and for assistants, students, etc. that are not getting too close to the clean zone. Operation robots often need more space.
19. *Operations on infectious patients* are preferably carried out at the end of the day, if possible, and are well planned.
20. *Operation room, specific in use for most infectious agents* (resistant bacteria - MRSA, VRE, ESBL, CRE, and *Clostridium difficile*; mycobacteria, intestinal-pathogenic bacteria, etc, and virus like norovirus, influenza virus), can be established by switching off the positive-pressure ventilation, closing for air intake/air out and not using operating rooms with LAF (laminar airflow) filter.

The room should be large, stripped of unnecessary equipment and close to the entrance of the operating department. It is immediately disinfected after use with chemical liquids and dry hydrogen peroxide gas, according to defined arrangements, but notice that there is no documented effect of hydrogen peroxide gas on tuberculosis or other mycobacteria.

21. *Operation room, specific for high-risk, serious infectious agents* (multiresistant tuberculosis, other highly resistant bacteria and respiratory tract viruses such as SARS, MERS, Ebola and other haemorrhagic fever viruses, highly pathogenic avian influenza virus, etc.) that may cause airborne infection during the surgery. The entire operation unit (including rooms with openings directly into this high-risk area) must be on a negative pressure—25 Pa or lower with separate ventilation—not shared with other rooms or buildings. Air in and air out must be disinfected and filtered (HEPA filter) [4]. Air out, including filters, should be treated with chemical gases and or UVC. The unit should have designated disinfection room with instrument washer and autoclave, storage room, good sluice functions and direct, sheltered outside access. All waste and fluid from the unit should be disinfected as required (autoclaving, heat disinfection, chemical disinfection).
22. *Surgical hand disinfection* room should not be storage for equipment and not a “coffee-break” room because of generation of aerosols during the washing process and risk for growth of bacteria. Choose a washstand that does not sprinkle outwards. As a wet room, it may have a lower air pressure in relation to the operating room, with air direction from the operation room to the hand disinfection room.
23. *Disinfection room for equipment and instruments* is not used as storage for equipment or used for packing of cleaned instruments. It is a process room—wet room—for disinfection and has a lower air pressure in relation to the operating room with air direction from the operation room to the disinfection room.
24. *Disinfected instruments* are packed in a separate, clean, packing room and autoclaved in a separate autoclave room with steam exhaust.
25. *Anaesthesia initiating room* is a clean room with storage in glass cabinets of equipment for preoperative treatment, but no office or warehouse at large.
26. *Break rooms, meeting rooms*; with plenty of space, easy to clean, and furniture that is cleaned and washed weekly—fabric furniture must not be used.
27. *Office space and expedition*. Enough areas for operating descriptions, journals, dictation, etc. Offices for the personnel should be outside the operating department to reduce the microbial and particle burden on the operating environment.

33.4.2.4 Air Quality: Requirements for Bacterial Number in Air, Airflows and Temperature

- *Incoming air* is directly from outside; it is HEPA-filtered and tempered before coming into the operating room. The air comes in from the ceiling or high up on the wall and goes out at the floor level—ca 15 cm above the floor area (1B) [4, 8]. There should be no heating-cooling systems in the operating room because of

accumulation of dust, skin cells, particles, bacteria and fungi. This may result in growth and spread of microbes to the air, as well as unsafe air currents.

- *Air filter on incoming air.* Two filter layers (HEPA) must be passed through before the air is entering the operating room (1B) [4]. EU filter with minimum 9 for intake of air at normal operating theatres and EU filter minimum 13 on LAF theatres. Filter quality is checked by DOP test (smoke/particle test), at least once a year.
- *Positive air pressure* in operating theatres should be 10–15 Pa, in relation to nearby rooms and corridor.
- *Daily control* of ventilation, temperature and humidity in the operating room.
- *Bacterial number in the air;* colony-forming units (CFU) per m³ air:
 - Standard surgery room <100 CFU/m³ air.
 - Ultraclean surgery room: <10 CFU/m³ which applies to infection-sensitive surgery like implantation of foreign bodies, cardiovascular surgery and patients with impaired immune defence. An effective LAF system may often reduce bacteria in the air to 0–5 CFU/m³, 30–50 cm above the incision site, throughout the operation.
 - Vertical LAF air with at least 500 air changes/h gives <2 CFU/m³ when using conventional clothing with cotton textiles.
 - Horizontal LAF air may increase the CFU/m³ >10 times.
 - By reducing the operation room to a “tent” and using very tight operation suits, <1 CFU/m³ may be obtained by vertical air supply.
 - *Clean storage for sterile equipment* <100 CFU/m³.
 - *Control and measurement of CFU in air (sterile covered measuring instrument!)*
 - 30–50 cm from incision
 - Close to the instrument table.
 - Central and peripheral in the operating room.
 - When the room is empty, when preparing, when opening wounds and when tidying up.
 - Analysis of samples: growth after 2–7 days, number of colonies, bacteria and fungi per m³.
 - *Control of CFU in air—how often/when?*
 - 1–2 times each year
 - After newbuilding, rebuilding, filter changes (afterwards, all channels are vacuum cleaned, maximum ventilation for 24 h, then two 0 measurements of an empty room).
 - At high incidence of SSIs.
 - *Air changes.*
 - *Standard surgery:* 17–20 fresh air changes/h; minimum 15 air exchanges with HEPA-filtered air per hour, of which 3 with fresh outdoor air (1B) [4].
 - *Ultraclean:* >>200 air changes/h (recycled): orthopaedics, cardiac surgery, implantation of foreign bodies, etc.
 - Lower number of air changes on other rooms like storage rooms and rooms for anaesthetic and surgical hand disinfection rooms and lowest at the entrance area, wardrobes, etc.

- *The airflow* in the operating room is of great importance. Everything “unclean” that comes between clean airflow in the direction of the operating area and the wound poses a risk of contamination of the wound. Any unclean thing that comes between airflow and uncovered instrument tables poses a risk of contamination of instruments. The use of tight operating suits and phantom hood that covers the neck, hair, ears and cheeks protects the wound and environment against release of skin cells and bacterial contamination.
- *Opening doors* lead to increased bacterial amount in the operating room from corridors, etc. The doors should be kept closed (1B).
- *Diathermia* releases large amounts of particles—diathermia smoke—partly with protein residues. This is a major burden on air quality. Protein residues on the diathermia needle may be difficult to remove. Check cleaning routines and reduce, if possible, use of diathermia.
- *Largest microbial load of the operating room* is registered when preparing the patient and when tidying up upon completion of surgery.
- *The number of persons present* is strongly associated with bacterial and particle numbers in air. Preferably, it should not be more than six to eight people present.

33.4.2.5 Contact Infection: Measures to Reduce Contact Transmission

Everyone who enters the operating department/operation room follows routines:

- Good hand hygiene at the entrance and exit of the surgical department.
- Follow routines for the use of uniform, shoes, cap and surgical mask.
- Change to green operation scrub suit and use the department's shoes.
- Put on the cap in the wardrobe, covering hair and ears.
- Private clothing—except for underwear—should not be used.
- Green-coloured uniform only in the surgical department; not used outside the department. In case of acute response elsewhere, change to new green laundry before returning the operating department. Exceptions are when following the surgical patient to postoperative treatment. Then white coat is taken over and shoes are changed.
- Jewellery, rings, piercing, wrist watches, etc. are not allowed, nor covered with bandages or clothes.
- Nail polish, fake nails, fake eyelashes, etc. are not allowed. Do not bring private equipment into the department and disinfect glasses and watch-phone.
- Beard is unsuitable in the operation department since it is not good enough covered by surgical mask.

33.4.2.6 Equipment: Preparing and Storage

- The operating room should be clean and empty—no storage space for sterile or other equipment. Storages with, for example, sutures in operation rooms may be loaded with large amounts of skin particles, microscopic blood and tissue particles, dust and bacteria and pose risk through air and contact transmission.

- Sterile equipment storage has restricted access, closed doors and daily cleaning of surfaces and weekly of cabinets and has <100 CFU/m³ air. Store rooms should be so large that personnel can move freely in the room.
- Equipment is stored in tight cabinets and boxes.
- Avoid throughput cabinets to the operating room due to the risk of imbalance in air pressure and ventilation. A locked cabinet can be used if it is airtight.
- The array of sterile instruments should be performed sterile in a clean and empty operating room—under the LAF ceiling, if it is a LAF operating room. This is because sterile instruments should be protected from dust, skin particles and microbes deposited.
- Sterile instruments with table are then covered—before the patient and the anaesthetic personnel come in and the preparation begins. More people and more activity increase particles and microbes in the air.
- All sterile equipment is best covered during the entire operation.
- Cotton textiles may emit particles that may become “locus minoris” for subsequent infection in wounds.
- Compressors should not emit particles (“locus minoris”) and have a good suction effect.
- Place sterile instruments in clean airflows. Non-sterile items (arm, head, hair, etc.) may not come over sterile instruments or between sterile airflow and instruments.
- The instruments are thoroughly cleaned immediately after the operation in instrument machine washers, etc., to prevent drying of tissue, blood and protein on the instrument. This is a good general preventive against prions.
- Regular temperature and wash controls of decontaminators, instrument washing machines, autoclaves, etc.

33.4.2.7 Personnel

- Fewest possible present in the operating room during surgery (<6–8 persons) and reduced movements that may cause unfavourable air currents. The increasing number of people present has direct effect on the amount of particles and the number of bacteria (CFU/m³) in the air, especially in the case of uncovered skin.
- Personnel with infection or eczema of the hands with *Staphylococcus aureus* or group A streptococci should not be present in the operating department, as this may cause SSI (1B).
- Personnel with streptococcus or active tuberculosis should not stay in the operating department. It is recommended sick leave of employee having upper and lower respiratory tract infections, influenza, norovirus, other diarrheal infections, blood-borne virus infection (active or chronic hepatitis or HIV, etc.) and a number of other infections.

33.4.2.8 Attire: Uniform

Everyone Who Enters the Operating Room

- Always wear surgical masks and cap in operating theatres and follow procedures for hand hygiene and dressing (1B), even for short-term “visits” (IB).

- Bacterial tight operation uniform reduces airborne wound contamination.
- Trousers should be tight by the ankles so that skin particles and bacteria do not “flow out” and burden the environment in the operating room.
- *Cotton fabric/textiles* should be avoided; they may be permeable and release relatively large amounts of particles, including bacteria-bearing skin particles.
- Avoid getting wet on cotton clothes if this is still being used; moisture increases the growth of bacteria from the skin.

Surgical Team

- Check proper attire, cover of hair and ears and absence of jewellery before entering the department.
- Follow the hospital’s procedures for surgical handwash and hand hygiene (1B).
- *Sterile operating gowns*; tight, pressure-tolerant, durable and wet-resistant are recommended (1B). The gown should be close around the neck, have long sleeves with long cuffs and provide enough room for free movements.
- *In humid or wet operations*, use surgical gowns with liquid-tight sleeve and front (1B).
- *Caps* covering all hair and ears. Ears may release considerable amounts of bacteria.
- *Phantom hood* protects against bacteria and particles from the neck, head, ears and cheeks running down into the operating wound. In LAF operating room with vertical ventilation, phantom hood should be used, on the outside of a cap and surgical mask. This applies to the operation team.
- *Operation helmet* designed to prevent “fallout” from the head/hair can be used instead of other organized measures that provide the same protection.
- Wear *tight surgical masks* which cover the nose and mouth and is stuck and at rest (1B). If too much movement of a loose-sitting face mask, the release of microbes and particles increases—from the face to the air. It is not avoidable that some skin particles and microbes may “run out” from the underside of the mask.
- *Beard* cannot be fully covered by surgical mask and may cause release of microbes into the air. Remove beard if you are going to work in an operating department.
- *Protecting against blood and tissues*. Surgical mask protects against large amounts of invisible blood and tissue drops that come from surgery, especially diathermy, suction, etc. Most of the blood drops and spills around the operation team are invisible. Respirator (P3 mask) protects best against diathermy smoke. Visor or goggles may protect the eye mucosa against risk of blood-borne microbes, since hepatitis virus and HIV can invade the eye mucosa.
- *Disciplined clothing* must be followed by all personnel working in the operating area. Be particularly careful with “fallout” of skin cells and particles from the head and neck when working under LAF roofs; also applies to anaesthesia.
- Sterile dressing kits are opened by an assistant immediately before taking on in the operating room.
- Check that sterile gown is large enough, is suitable for current surgery (e.g. a lot of blood-fluid spills), has good cuffs and is comfortable around the neck.

- Learn careful dressing of sterile operating equipment.
 - It is easy to contaminate sleeves and cuffs when putting on sterile gloves. Learn the safest method to put on gloves—with the help of an assistant.
 - Use sterile strong gloves with long cuff covering the entire cuff on the gown. After surgery, punctures are often detected in the gloves. Therefore, it is particularly important with good hand disinfection before surgery. If puncture is detected during the operation, turn away from the operating table, remove the gloves, disinfect hands and put on new sterile gloves.
 - Preferably use *double gloves*, possibly with colour indicator for holes, especially at the risk of puncture. Double gloves should be used in orthopaedics and other infection-sensitive surgeries, for procedures where the glove easily gets rifles and always for possible blood-borne infection (hepatitis, HIV, etc.).
 - Change gloves and disinfect hands—from an unclean operating area to a cleaner.
 - Change gloves and disinfect hands—if there is a very large amount of biologic material on the gloves or if suspected contamination.

33.4.2.9 Surgical Technique

- A well-trained surgical “team” has normally fewer SSIs than others that are new in the department, and this team is also working more efficiently and faster.
- Operating volume has a certain effect on the infection rate, but large volume does not mean lower infection rate.
- Before starting the operation, make peace in the room for a few minutes so that swirled dust/bacteria “settle,” keep the doors closed and provide fewest possible major movements and fewest people present. This applies during the surgery until the wound is sewn and covered with bandages.
- Use least possible amount of foreign materials, thin suture thread, preferably synthetic (minimum reaction), and check that it is stored sterile.
- Monofilic sutures may imply less infection risk than twisted wire of the same material.
- If possible, choose synthetic, resorbable suture material, and use the least possible variants in the standard scheme.
- Avoid tissue damage with poor blood supply (less with sharp cuts than with diathermy) (1B).
- Avoid drying, strong pressure against tissue and local constringent medicaments.
- Avoid haematoma and seroma (blood fluid) that give growth conditions for bacteria.
- Instruments and equipment must be sterile—throughout the operation—and must therefore be covered (1A).
- Avoid sedimentation of bacteria and particles on an open instrument tables that can further be transferred to surgical wound.
- Avoid direct touch with gloves on foreign materials (screws, prostheses, sutures) that are to be inserted into tissues for a long period; use sterile forceps, etc.

- NB. The tip of operating suction system is easily contaminated! Change if suspected to be contaminated. For interventions on different places during an operation, use different suction systems. Also separate use of other equipment between several operating sites during the same operation.
- Use closed drainage when pus is collected (1B).
- Avoid prophylactic drainage, or use closed drainage that is treated sterile.
- Check compressed air and compressed air equipment, preferably battery-powered equipment since compressed air from the wall can contain some bacteria (coagulase-negative staphylococci and others).

33.4.2.10 Antibacterial Prophylaxis

- Correct antibacterial agent adapted to specific surgery type (1A).
- Avoid resistant-driving agents like cephalosporins (third generation), quinolones, clindamycin, etc., and avoid using “commonly” used and important agents.
- Avoid using vancomycin as a prophylaxis (1B).
- The prophylaxis should only cover the current operating time and start at the beginning of anaesthesia (1A).
- The prophylaxis should reach high enough tissue doses before incision (1A). Short half-life preparations (e.g. cefalotin) must be followed up with a new dose if prolonged operating time.
- Note: antibiotic prophylaxis when elective colorectal surgery (1A).
- Note: antibiotic prophylaxis at high-risk caesarean section (1A).
- Note: antibiotic prophylaxis to defined patient groups (foreign bodies, endocarditis, multiple, contaminated trauma, drowning, CNS leakage, frostbite, aspiration, etc.).

33.5 Background Information

Surgery creates most hospital infections, injuries, invalidity and death in the health-care system [1–13].

The basis for preventive actions lies in major US materials from 1964 with wound classification (clean-dirty), later on Cruse and Foord's 10-year observation of 63,000 operations (1980), Olson's 5-year studies of 20,200 surgical wounds (1984) and CDC's studies of 84,700 operations (1990) [1, 27–29].

Charnley's [30] and Lidwell's [31] air contamination studies laid the foundation for infection control in modern surgery. Antibacterial prophylaxis was effective but weakened the importance of other infection control measures [32]. Long-term problems with antibiotic resistance were not considered at that time [32, 33].

The first Norwegian studies came in the 1960s from Haukeland Hospital, Aker Hospital, Rikshospitalet and Lillehammer County Hospital [34–38]. CDC's guidelines for prevention of SSI was translated by the Hygiene Group for Eastern Norway in 1985 [38–40].

33.5.1 Knowledge, Evidence and Recommendations

Skilled knowledge in infection control may be low, often not well studied or well documented. High surgical activity in hospitals often results in a high rate of complications like SSIs which leads to serious consequences for patients, healthcare and society. Still, infection control is lacking or rated too low in healthcare. The prevention of SSI is dependent on enough resources, interest, studies, surveys, organization and responsibility. One in three patients in Norwegian hospitals is operated, and 10–20% is complicated by hospital infections that often are preventable! [15–17, 41].

Knowledge is based on studies, experience, attitude and evaluation [4–12, 39, 40]. Requirements for strict evidence may allow most studies to fall through. And “evidence” may often be based on personal understanding and attitude and governed by limited economic resources (Table 33.1).

An easier method of rating may be “grading of the quality of evidence”; GRADE (grades of recommendation, assessment, development, and evaluation) *freely summed up from reference* [11]:

- Level I—high level—many studies that show essentially the same.
- Level II—moderate level—fewer studies, limited but showing about the same, not controversial.
- Level III—low level—low-quality studies, varied, differentiating results or no rigorous studies, only expert consensus [11].

“Evidence-based medicine” is often used incorrectly, for example, in case of missing studies. During the SARS epidemic in 2003, the WHO reported that

Table 33.1 Levels of evidence for Intervention Studies, According to Research, Theory, Etc. [6]

<i>Level and source of evidence</i>	
1++	High-quality meta-analyses, systematic reviews of randomized, controlled trials (RCTs) or RCTs with a very low risk of bias (failure)
1+	Well-conducted meta-analyses (review of others' studies), systematic reviews of RCTs or RCTs with a low risk of bias
1-	Meta-analyses, systematic reviews of RCTs or RCTs with a high risk of bias
2++	High-quality systematic review of case-control or cohort studies; high-quality case-control or cohort studies with a very low risk of confounding, bias or chance, and a high probability that the relationship is causal
2+	Well-conducted case-control or cohort studies with a low risk of confounding, bias or chance, and a moderate probability that the relationship is causal
2-	Case-control or cohort studies with a high risk of confounding, bias or chance, and a significant risk that the relationship is not causal
3	Non-analytical studies (e.g. case reports, case series)
4	Expert opinion, formal consensus

Nation Coll Center Wom Child Health 2008. Surgical site infection [6]

Table 33.2 Recommendation categories for infection protection: divided into categories from the CDC/HICPAC system

<i>According to research, theory, feasibility and if possible economic solution</i>	
Category IA	A strong recommendation supported by high- to moderate-quality evidence suggesting net clinical benefits or harms
Category IB	A strong recommendation supported by low-quality evidence suggesting net clinical benefits or harms or an accepted practice (e.g. aseptic technique), supported by low- to very low-quality evidence
Category IC	A strong recommendation required by state or federal regulation
Category II	A weak recommendation supported by any quality evidence suggesting a trade-off between clinical benefits and harms
No recommendation/unsolved issue	An issue for which there is low- to very low-quality evidence with uncertain trade-offs between the benefits and harms or no published evidence on outcomes deemed critical to weighing the risk and benefits of a given intervention

Refs. 2–4, 12, 13, 39, 40, 44

“there was no evidence of” SARS transmission in airplanes, which led to greater spread of infection among air passengers where SARS patients had been passengers [42]. During the Ebola epidemic in 2014–2015, WHO said that there was “no evidence of airborne transmission,” which resulted in only contact isolation (contact and droplets, rate 1 m from the patient) and lack of infection protection equipment for healthcare professionals and assistants. Several hundreds were infected and died before personal protective equipment for airborne transmission came into place [43].

Many key infection control studies are *ethically* not feasible for evidence-based medicine. It is never documented that using sterile gloves leads to fewer SSIs than the use of non-sterile gloves or no gloves at all. It has never been studied whether disinfection of the operating area has any effect. Therefore, “recommendations” are often used: 1A, 1B, 1C, II and unclear (see Table 33.2), which is easier to acquire [2, 4, 12, 13, 39, 40, 44].

Practical learning and experience determine the outcome. Degree of implementation of preventive measures and written procedures depends on management, knowledge and responsibility.

33.5.2 Definitions, Diagnosis and Registration

Surgical site infection may occur up to 30 days after surgery and up to 1 year of implanted prosthesis and other foreign matters [2–4, 7, 8–13]. Definitions and methods of registration change constantly [2–13, 18]. Daily observation and registration is the gold standard [11].

33.5.2.1 Wound Classification

In 1964, the National Academy of Sciences-Research Council classified surgical wounds [27]:

1. Clean wound—sterile tissue.
2. Clean-contaminated wounds—through mucous membranes—controlled measures may be taken.
3. Contaminated wounds—open trauma or contamination from the intestinal tract or major break of sterility.
4. Heavily contaminated or infected surgical wound—pus, perforated intestines, etc. [27].

The Research Council's wound classification system resulted in prevalence of SSI in 3.3%, 7.4%, 16.4% and 28.6% in classes 1–4, respectively [27]. The highest rate of SSI was found among patients with heavily contaminated surgical wound, class 4 [27]. In Cruse and Foord's surveys were classes 1–4 consistent with the development of SSI in 1.5%, 7.7%, 15.2% and 40%, respectively, and in the CDC's large material, 2.1%, 3.3%, 6.4% and 7.1%, respectively [1, 29]. The definitions are further developed by CDC [7, 18].

Special Diagnosis: SSI (CDC) [3]

Superficial Wound Infection

Occurring within 30 days after operation + involving the skin, subcutaneous tissue or musculature over fasciae + one of the following:

- Pus from the wound or the drain.
- Microorganism isolated from sore fluid prior to primary suture.
- The wound is opened/drained.
- Medical doctor's diagnosis.

Deep Wound Infection

Inflammation/pus in deeper tissues (the fascia, intra-abdominal, intramuscular, osteitis, arthritis, mediastinitis, mm.)—occurring within 30 days postoperatively or up to 1 year after implant (foreign) prosthesis, metal wire (sternum, etc.) + one of the following:

- Infection is related to operative treatment.
- Involves tissue at or under fascia.
- + one of the following:
 - Pus from the wound or the drain.
 - Wound opens spontaneously with pus production and/or is opened by a surgeon when the patient has a fever ($>38^{\circ}\text{C}$) and/or localized pain or tenderness.
 - Abscess occurs.
 - Medical doctor's diagnosis.

More recent definitions divide postoperative deep wound infections into deep infections and deep infections in organs/cavities (organ/space) [7, 18].

33.5.2.2 Quality of Registration Is Discussed

Definitions of SSI are often perceived as varied, partly unclear and different [45, 46]. In a study from 156 hospitals in the United Kingdom, definitions for SSI were not used (15%), superficial wound infections not reported (10%), postoperative period not followed up (8%) or not according to routines, and a large number of hospitals delivered non-compliant data [47]. Similar problems are detected in Norway. The patient is often not informed—even when serious SSI [48]. Partly this may be due to lack of consensus and/or the wish for good results [48].

Since 1970, many national registration systems for hospital infections have been developed. However, they are not completely comparable. There are separate systems for the United States (NHSN), Spain (INCLIMECC), France (RAISIN), Hungary (NNSR), Germany (KISS), Finland (SIRO), the Netherlands (PREZIES), Scotland (SSHAIP) and the United Kingdom (NINSS) and for Europe (HELICS) [49, 50]. In all systems, registration generally leads to lower infection rates [49].

Registering the Operations Team's Competence

There is a lack of methods for monitoring surgical skills and competence of the operation team; some surgeons may have a too high share of SSI compared to others [1]. In one study, four factors were significantly associated with SSI: patient age, preoperative hospital stay, preoperative shaving and the surgeon [51]. Recently graduated surgeons may have a some higher rate of SSI than experienced surgeons without having more risk patients, but because of longer operating time. With more experience, operating time and SSI rate may decrease [52].

Sherlaw et al. [53] observed SSI in 11.9% of 2146 cardiac surgery patients in London. Accumulation of SSI was seen in some surgeons, so called bad run, which was corrected when detected [53]. In the United States, the prevalence of SSI may be connected to the individual surgeon as the basis for evaluation and further employment contracts.

The operation team must have good competence in infection control and should follow established routines [54].

Syndrome Monitoring and Registration

Algorithms, with data from the patient administration system, can be used with relatively high sensitivity and specificity regarding SSI, which in one study was 6.6% of all operated patients [55].

33.5.2.3 Surgical Quality: Volume and Number of Beds

Medicare patient complaints are used in the United States for the ranking of hospitals with high or low rate of infection after hip arthroplasty [56]. Among 524, 900

patients hip-operated at 3300 US hospitals in the period 2005–2007, 7.8% had SSI [56]. The best hospital (“best-performing”) had an infection rate of 4.3% against 14.9% among the worst (worst-performing). Patients in the “worst hospitals” had a 2.9-fold chance of getting SSI. Most infections, 90–97%, were detected after discharge from the hospitals (stay in hospital ca 5 days), after 16.5 days for superficial SSI and 30 days for deep and organ/cavity SSI (21–59 days) [56]. One in five deep infections were detected more than 3 months after surgery. In all, 90% of the “best” hospitals and 74% of the “worst” hospitals performed less than 20 hip prostheses surgery each year on Medicare patients. The annual operating volume per hospital was often very low [56].

A prospective study of surgical volume and SSI was conducted at 18 hospitals between 2004 and 2005 [57]. Hospitals were divided into small volumes (<1500 procedures), medium volumes (1500–4000 operations) and large volumes (\geq 4000 operations). The smallest and largest hospitals had almost two times the risk of SSI, compared to medium-sized hospitals [57].

A health network study (NHSN) from the United States, detected SSI in 1.9% of 849,659 surgery patients at 847 hospitals in 43 states from 2006 to 2009 [58]. A total of 39 types of surgery were studied and only deep/body cavity infections were recorded. Only hospitalized and readmitted patients were examined [58]. Several types of surgery had an increased risk of SSI associated with larger hospitals than hospitals with fewer beds. In hip arthroplasty, there was a significantly greater risk of SSI in hospitals with $>$ 200 beds versus \leq 200 beds ($p < 0.0001$, multivariate analysis). Similar findings were shown for knee replacement surgery, open surgery on long tubular fractures, colon surgery, rectum surgery, appendectomy, hernia surgery, small intestine surgery, exploratory abdominal laparotomy, thoracic surgery, amputation, cholecystectomy, laminectomy and craniotomy. Between 201 and 500 beds (versus $<$ 200/ $>$ 500) were associated with fewer SSIs for ventricular shunt, chest surgery and coronary artery bypass graft. Fewer SSIs after surgery on the biliary tract, liver and pancreas were associated with $<$ 200 beds or $>$ 500 beds (versus 200–500), and fewer SSIs were reported after hysterectomy and renal transplantation in hospitals with more than 500 beds (versus $<$ 500) [58].

In some cases, large hospitals may be an advantage, while most surgical procedures provide significant best results with regard to SSI in smaller hospitals, \leq 200 or 200–500 beds; see Table 33.3 [58].

33.5.3 Occurrence and Mortality

- In Europe, 1.5–20% of operations may result in SSI, depending on type of surgery and wound classification [20–22, 49, 50]. Patients with SSI are being up to 60% more frequent intensive patients, five times more frequently readmitted to hospital, and have 2–3 times greater risk of dying than corresponding patients without SSI.

Table 33.3 Deep or organ/cavity SSIs detected during admission/readmission at the same hospital; National Healthcare Safety Network, 2006–2008

Type of operation	Operations	Number of beds «bed size»	OR	p-value	Statistics analysis	Lowest SSI at larger hospitals Or smaller hospitals?
					Ref mu	
Appendectomy	5889	>500 vs <500	2.6	0.0013	Multivariate	Less than 500
Craniotomy	9918	>500 vs <500	1.8	0.0013	Multivariate	Less than 500
Laminectomy	40,513	>500 vs <500	1.8	0.0003	Multivariate	Less than 500
Rectum Surgery	1215	>500 vs <500	3.5	0.006	Multivariate	Less than 500
Small intestine surgery	4200	>500 vs ≤200	1.8	0.0001	Multivariate	Less than 200
Cholecystectomy	14,726	>200 vs ≤200	2.6	0.0022	Multivariate	Less than 200
Colon Surgery	62,782	>200 vs ≤200	1.2	0.0004	Multivariate	Less than 200
Caesarean Section	30,645	>200 vs ≤200	2.3	<0.0001	Multivariate	Less than 200
Open op. fracture long bones	10,646	>200 vs ≤200	1.7	0.0064	Multivariate	Less than 200
Hernia operation	7487	>200 vs ≤200	2.3	0.0035	Multivariate	Less than 200
Hip arthroplasty	131,823	>200 vs ≤200	1.4	<0.0001	Multivariate	Less than 200
		>500 vs ≤500	1.2	0.0004	Univariate	Less than 500
Knee arthroplasty	172,055	>200 vs ≤200	1.2	0.01	Multivariate	Less than 200
		>200 vs ≤200	1.12	0.039	Univariate	Less than 200
Hysterectomy	54,877	≤500 vs >500	1.4	0.0137	Multivariate	Greater than 500
Kidney transplant	1625	≤500 vs >500	3.7	<0.0001	Univariate	Greater than 500
Breast surgery	3167	≤200/>500 vs 201–500	4.5	0.0422	Multivariate	200–500 beds
Ventricular shunt	5379	≤200/>500 vs 201–500	5.9	<0.0001	Multivariate	200–500 beds

Source: Mu et al. [58]

- In the United States, it is calculated that 2–5% of surgical patients may develop SSI. This generates 7–11 extra days in hospital and leads to 2–11 times as high mortality where 77% of deaths are directly related to the infection [4, 11].
- After general surgery, the risk of death may be 7.5% with one postoperative infection, and if there are more hospital infections in the patient at the same time, the risk of death may increase to 17.1% [59]. Organ-associated postoperative infection shows very high “in-hospital” mortality [59].
- Elderly patients (70 years or more) with SSI caused by *S. aureus* have approximately three times greater risk of death than the same age group without infection [60]. If more virulent bacteria, like MRSA, the death rate may increase up to 74% [8, 61].
- A survey of 114,677 patients in the period 2009–2011 showed that among surgical patients with hospital infection, 14.4% died, against 3.7% of non-operated with the same type of hospital infection [62]. If all complications were merged, mortality was 73% among surgical patients, versus 37% of non-operated with the same proportion of complications [62].

33.5.3.1 Smaller Hospital: Fewer Infections and Lower Mortality?

In Pennsylvania State, 4.1% of patients with SSI died in 2007 [24]. Mortality rate was twice as large at hospitals with the greatest surgical activity, compared with small hospitals with only half of the surgical activity; see Table 33.4.

33.5.4 All Types of Operations

- In a national study based on hospital data (NIS) from 723,500 operations in the United States in 2009, only 1% had SSI; extra stay in hospital was 9.7 days and extra expenses approximately 20,850 USD per patient [63]. Lowest infection rates were in obstetrics/gynaecology, 0.06%, and highest for small intestine resection (6.24%) [63].
- Health network study from the United States in 2011 detected SSI in 1.9% of 849, 659 operated patients [58]. A total of 39 surgery types were investigated; only deep/organ-cavity infections were recorded, and only admitted and readmitted patients were examined [58]. Increased risk for SSI was related to higher risk

Table 33.3 Infections and death in large and small hospitals—Pennsylvania 2005 PHC4 [24]

Type of hospital (patients)	Surgical activity	HAI	Died with HAI	Died without HAI
Group 1 hospital (636998)	36%	1.40%	14.2%	2.2%
Group 2 hospital (352047)	31%	1.18%	14.4%	2.4%
Group 3 hospital (426984)	22%	0.93%	11.5%	2.4%
Group 4 hospitals (104189)	16%	0.57%	10.5%	2.6%

Source: Pennsylvania Healthcare C42005. HAI hospital-associated infection [24]

score (ASA score), contaminated-strongly contaminated surgeries, long operating time and at larger hospitals compared to smaller hospitals [58].

- In France it was 38% reduction of SSI after surgery in 964,128 patients, from 2.0% in 1999 to 1.26% in 2006 ($p < 0.001$) [21]. Risk factors were age (≥ 65 years), ASA score 3–5, wound classes 3 and 4, operation duration over the 75 percentile, emergency operation, many procedures on the same patient and admitted for 48 h or more preoperatively. Gastrointestinal and gynaecological surgery had the highest infection rate, 2.81% and 1.72%, respectively [21].
- A multicentre study from four continents found that 2.9% of 261,000 surgical patients had SSI [64].
- In Australia, 183,625 operations were monitored in the period 2002–2013. In all, 2.8% had SSI [19]. Infection rate fell by an annual reduction of 11% for superficial infections, 9% for deep and 5% for organ/cavity infections [19]. But in the same period, the SSI with antibiotic-resistant bacteria increased [19].

33.5.4.1 Norway

- Investigations from the 1960s showed incidence of SSI in 13.1% of the cases at Haukeland Hospital, Bergen (1968–1969); 2.3% at Aker Hospital, Oslo (1975–1976); 8% at Rikshospitalet, Oslo (1975–1976); and 2.2% at Lillehammer County Hospital, Oppland (1976–1977) [34–38]. Variations may have been related to registration methods. In 1981, the prevalence of SSI registered nationwide was 4% [65]. Over the past 20 years, SSI has varied between 5% and 12%, and up to 15–20% of patients have been followed up after discharge [15–17, 41]. The number of patients with SSI is relatively large in Norway, since one out of three admitted to hospitals is operated [17].
- At Ullevål University Hospital, 57,300 patients were followed with prevalence studies during the period 1995–2007 [17]. In all, 13.4% of 12,430 operated patients had postoperative HAI compared to 5% among non-operated, which documented surgery as a risk area in medicine [17]. SSI was detected in 6.2%, with an annual variation from 3.9% to 7.2% and with the lowest rate in 2002. There was a significant reduction of SSI from 1995 to 2002. Establishment of healthcare enterprises in 2002, according to “new public management” with a focus on efficiency and profit, resulted in increased prevalence of SSI and other hospital infections [17]. The general workload with patients increased, while cleaning and maintenance of the hospital fell into decay. This may have led to increase in hospital infections, including SSI [17].
- Most SSIs are deep infections in Norway. In 2011, SSI was proven nationwide in 7.8% (6.8–8.8) of surgical patients at hospitals, and 80% of these were deep or cavity infections. At the same time, 12.7% (9.5–16.0) of recently operated patients in Norwegian nursing homes had SSI, and half of these had serious, deep infections (National Public Health). Mortality of SSI is not recorded in Norway.

33.5.5 Special Types of Operations

33.5.5.1 Prosthesis Operations

- Prosthetic surgery in the hip and knee is increasing and is a source of severe SSIs [49]. Registration in Europe and the United States shows a similar rate of infection, 1–3%; total hip joint arthroplasty, 1.3–2.91%; and total knee joint arthroplasty, 0.67–3.7% [49].
- In 2004, 49,500 hip operations were examined in 14 European countries; 2.2% had SSI, total prosthesis 1.6% and partial 4% [50].
- Simultaneous arthroplasty for the knee joint and hips showed no difference with regard to SSI between unilateral and bilateral operations. An exception was for antibiotic prophylaxis that could be prolonged by bilateral surgery [66].
- In the United States, SSIs after hip surgery are monitored by insurance companies such as Medicare at 3300 hospitals [56]. During the period 2005–2007, 7.8% of 524,892 operated patients had SSI [56]. By a ranking of hospitals, the best had a prevalence of approximately 1.5% SSIs and the worst 2.5–3%. The worst of all hospitals, with SSIs of 5–8.8%, were represented by only 0.2% of all hospitals [56].
- In France, there was 36% reduction of SSI after hip prosthesis, from 1.1% in 1999 to 0.7% in 2006 ($p = 0.002$ for linear trend) [21].
- In Sweden, deep infections following total hip prosthesis were followed up for 2 years. In all, 0.9% had deep SSIs, and 405 of 443 were reoperated one or more times. The most common microbes isolated were *S. aureus* and white staphylococci [67].
- Norway established a hip register in 1987 with extension to register for other prosthesis surgeries in 1994 [68, 69]. Ca. 2% of 854 total prostheses of the knee were reoperated because of infection in 1994 [68]. During the period 1987–2011, there were ca. 11,000 surgeries with hip prosthesis every year, having an SSI rate of 3%; and 1% were reoperated [70]. The SSI rate was for total prosthesis 2.6% and for hemiprosthesis 7.7%. Risk factors were hemiprosthesis, man, high age, other concomitant diseases, too short or long operating time, immediate help operations, uncemented prosthesis and NNIS risk index of >0. The reasons why—despite many preventive measures—there is now more than a threefold risk of reoperation due to prosthetic infection, compared to earlier, are discussed [70].
- Uckay et al. [10] refer to the risk of SSI according to different SSIs—registers for primary hip—and knee operations, such as 0.8% (Norwegian register, 73,000 arthroplastics), 0.9% (Finnish register, 4628 arthroplastics) and 0.9% (Geneva register, 6101 arthroplastics), and recommend active follow-up of the patient after discharge (1A), multimodal intervention (1A) and adequate antibiotic prophylaxis (1A).
- Deep/organ-cavity infections were detected in 0.7% of 131,879 hip-operated patients in a US healthcare study in 2011. Only inpatient and recruited patients were investigated [58]. Multivariate analysis showed increased risk of SSI in older patients, higher ASA scores, longer operating time, type of surgery (total, partial, reoperated) and larger hospitals, >200 beds versus ≤ 200 beds [58].

33.5.5.2 Hernia Operations

- In France it was 70% reduction of SSI, from 1.0% in 1999 to 0.3% in 2006 ($p < 0.0001$) [21].
- Among 120,000 hernia operations, the following anatomical site was associated with risk of SSI, 0.45% for inguinal/femoral, 1.16% for umbilical and 4.11% for ventral hernia surgery [71]. SSI was higher at open surgery than endoscopic surgery by bowel obstruction/necrosis [71].

33.5.5.3 Caesarean Sections

- Among 1605 patients with lower-segment caesarean sections in the United States, 5% had SSI [72].
- In France there were 56% reduction of SSI after caesarean section, from 3.6% in 1999 to 1.6% in 2006 ($p < 0.0001$) [21].
- Deep/organ-cavity infections were detected at 1.9% of 30,645 caesarean surgery patients in the United States, 2011 [58]. Multivariate analysis showed increased risk of SSI in obesity, older pregnant women, higher-risk scores, contaminated/highly contaminated surgery and major hospitals, >200 beds versus ≤ 200 beds [58].
- In England (2008), after 5563 caesarean sections, 13.6% reported wound problems, hence 84% after discharge, while 8.9% (2.9–17.9%) had defined SSIs [73]. In all, five risk factors for SSI were detected: obesity, age, blood loss, wound closure method and haste operation [73].
- In four hospitals in the United Kingdom, 9.8% out of 4107 caesarean patients developed SSI; median time of detection was 10 days [74]. Sixty-six percent of the cases were detected by healthcare professionals and 34% of the patient herself [74]. Follow-up time was 30 days but might vary.
- In Norway, SSI rate was 5.2% in 6855 caesarean sections during the period 2009–2011 with a large variation between the different hospitals [75]. The smaller hospitals had no more SSI than the large university hospitals. Ullevål University Hospital with the largest number of patients had a very low postoperative wound infection rate, 2.9% [75]. In 2014 the national incidence was 4.9%, thereof deep 1.2%, with significant variation between hospitals.

33.5.5.4 Hysterectomy

- In Finland, a study among 516 patients with abdominal hysterectomy (benign conditions) showed a SSI rate of 4.7% [76].

33.5.5.5 Kidney Transplants

- Among 441 kidney transplant patients in the period 2010–2011, 15% had SSI, of which over half were deep or cavity infections [77]. The most vulnerable were obese patients ($BMI > 30$) or former drug addicts.

33.5.5.6 Coronary Artery Bypass Graft (CABG) and Other Cardiac Surgeries

- SSI after cardiac surgery varies, 6.2% or more. Among 1000 CABG patients, 5.6% had SSI [78]. Over 60% were detected after discharge. Diabetic patients

had a longer incubation time for SSI—more than 17 days postoperatively, than others. In order to make SSI a more reliable indicator, it is recommended that the patient should be followed up for more than 6 weeks [78].

- CDC reported 7.8% SSIs in 2576 patients, largely bypass operated, in 2000 [79]. Patients with SSIs had significantly longer operation time and time on cardiopulmonary bypass, than patients without infection [79].
- A total of 4.5% SSIs among 2620 bypass-operated patients in 2012 resulted in reoperation in 7.7% of the cases [80]. There was SSI in the sternal wound in 3.6% and in the donor wound in 1.2% of the cases. SSI prolonged hospital stay from 14.5 to 42.2 days, $p < 0.001$, and quadrupled time in intensive units, from 4 days to 15 days, $p < 0.001$.
- A high infection rate, 11.9%, detected among 2146 heart-operated patients in London, was associated with age over 70 years, number of surgical procedures, CABG and flap operated combined, kidney disease and 3 or more days between admission and surgery [53].
- The number of major heart surgery (MHS) operations among 13 countries in Europe was in 2006 estimated to be 25,570; 26.8% had postoperative infections, and 2.2% had SSIs [81].
- Sternal infections were studied among 18,460 patients in the period 2005–2012 in Turkey [82]. In all, 2.6% got SSI caused by white staphylococcus (36%) or *S. aureus* (31%) [82].
- Surgical site infections caused by environmental flora and by contamination of sterile procedures (ice water cardioplegic) are well known, especially of multiresistant *Enterobacter cloacae* [83–86].
- From 1987 to 1988, nine patients had postoperative infections with multidrug-resistant *E. cloacae* after cardiovascular surgery [83, 84]. All survived the infection that was transmitted via contaminated sterile fluids (cardioplegic fluids—for cooling the heart) [83, 84].
- *Postoperative mediastinitis* caused by MRSA is more serious than MSSA (methicillin-sensitive *S. aureus*), in that patients with MRSA have significantly shorter survival time than patients with MSSA [87]. After 1 month, 1 year and 3 years, the survival rate was 60%, 52.5% and 26.3% for MRSA patients, respectively, compared to 84.6%, 79% and 79% for MSSA patients, respectively. There was a significantly greater treatment failure in MRSA patients than MSSA patients with medianistitis [87].
- Sternal wound infections occur three times more frequently in men than women, and smoking, use of internal mammary artery for grafting and age over 70 years are associated with sternal wound infection [88].
- Among 12,315 patients with median sternotomy in the period 1987–1998, 3.3% became reoperated due to postoperative bleeding [89]. Of these, 14% died postoperatively by noninfectious complications. Early reoperation reduced wound infections, sepsis and respiratory treatment. Late reoperation resulted in more than 20 days of extra hospital stay [89].

- Bitkover et al. [90] examined sternal wound infections caused by coagulase-negative staphylococci (kns) and found that in an ultraclean environment, the bacteria come into the wound during surgery from the patient's skin and from the operation team.
- Tegnell et al. [91] compared sternal wound infection caused by kns with uninfected matched controls and found that the risk of infection was associated with the number of preoperative days in the hospital, total surgery length and early reoperation for other reasons. A long exposure to the hospital environment is a risk factor and the treatment may be difficult because of more resistant bacteria [91].
- De Feo et al. [92] studied the prognosis of deep postoperative sternal infection among 13,420 operated and found that 0.8% had deep infection; hence 16.9% died in hospitals. Early and aggressive treatment reduced morbidity and mortality [92].
- Among 133,488 patients with CABG, SSI was detected in 2.2% of the sternal wounds and in 1.2% of deep/organ-cavity wounds [58]. Only hospitalized and rehospitalized patients were recorded [58]. Small hospitals ≤ 200 or large hospitals > 500 beds were significantly associated with the occurrence of deep, serious SSIs, $p = 0.0001$, than mid-sized hospitals [58].
- At Ullevål University Hospital, Norway, in all 1237 CABG-ACB patients were monitored in the period 2005–2009 [93]. SSI was detected in the sternal wound, drainage site and/or donor site in 17.8% of the patients. In all, 14.3% of SSIs were detected within 30 days and 3.5% between 30 and 60 days. Infection in sternal wound occurred in 5.7% (superficial 4.7% and deep 1.1%), leg wound (donor site) in 7.3% and drainage site in 1.3%. *S. aureus* was the most frequently detected bacterium (23.2%) and MRSA in one patient (0.6%) [93].
- Risk factors are obesity, diabetes, age over 70 years, nasal carrier state of *S. aureus* in the patient (occasionally also in the operation team), preoperative long retention (48 h or more), high-risk score (ASA score, etc.) and long operating time (over 75 percentile).

33.5.5.7 Colorectal Surgery: Elective

- In a study of 99 patients at Lillehammer County Hospital, SSI was detected in 8%, seven in the abdominal wound and one in the perineum after rectum amputation [94].
- SSI was detected in 20.7% of 13,661 patients with elective colorectal surgery in Spain in 2007–2011, one in five after discharge, and these were most often operated by laparoscopy [95].
- Antibiotic-resistant gram-negative rod bacteria increase strongly and pose a particular risk at intestinal surgery, also concerning the selection of antibiotic prophylaxis [96].

33.5.5.8 Cholecystectomy

- In France there were 55% reduction of SSI after cholecystectomy, from 0.9% in 1999 to 0.4% in 2006 ($p = 0.01$ for linear trend) [21].
- In the United States, among national materials of 14,726 patients, 0.4% had deep/organ-cavity infection after surgery [58]. Age over 52 years, ASA score >2 and the duration of the operation were significantly related to SSI ($p = 0.013$, $p = 0.38$ and $p < 0.0001$). Hospitals with beds over 200 were significantly associated with increased incidence of deep, serious hospital infection, $p = 0.002$ [58].

33.5.5.9 Neurosurgery: External Ventricular Drainage

- Risk of ventriculitis after neurosurgery is significantly associated with the drain placed under unsterile conditions and with the number of samples taken from the drain [97]. In a retrospective study of 410 patients during 2005–2010, 10.2% of the patients had postoperative ventriculitis [97]. It is assumed that 5–20% of these patients may develop postoperative ventriculitis, mostly by *S. aureus* and *S. epidermidis*.
- In the United States, 5% of 5373 patients operated with a ventricular shunt developed a deep/organ-cavity infection [58]. Small hospitals with fewer beds ≤ 200 or large hospitals with >500 beds were significantly associated with an increased incidence of deep, serious hospital infection, $p = 0.0001$, than medium-sized hospital with 201–500 patient beds [58].

33.5.5.10 Robot-Assisted Surgery

- Increased incidence of SSI has been demonstrated for certain types of robot-assisted surgery compared with national data for open surgery in the United States [98]. This can be related to “learning curve” by use of the robot [98]. After 273 robot-assisted procedures, 5.9% developed SSIs [98]. Operating time was mean 333.6 min (>5.5 h), and those with the longest operating time had significantly more infections than those with shorter time ($p < 0.001$) [98]. Robot-assisted and open surgery showed a difference in incidence of SSI, especially in prostate, gynaecological, colon and hernia surgery [98].

33.5.6 Norway

In 2014, the incidence of registered SSI was 4.5%, for bypass operations, 4.1%; for caesarean section, 4.9%; for hip prosthesis total, 1.8%; for hip prosthesis hemi, 3.1%; for open cholecystectomy, 14.2%; for laparoscopic cholecystectomy, 4.1%; and for colon surgery, 11.8% (Table 33.5) [99].

Table 33.4 Postoperative wound infection—surgical site infections: international and Norwegian results

Reference	Operation type	Year publ.	Total operated	Total %	Hip prosthesis total	Hip prosthesis partiell	CAGB sterum and donor	Colon surgery	Cholesystectomy	Comments
Rosenthal et al.; INICC	More types	2013	261,000	2,9			4,5	0,7	9,4	4 Continents
CDC-NHSN data, Edwards	More types	2009					2,9	1,8	5,6	USA
Lissovy	More types	2009	723,490	1				0	4,1	USA 2005
Mu, USA ^a	Many types	2011	849,659	1,9	1,4		2,2	1,9	5,8	USA National ^a
Wilson 2007	More types	2007	111,360	1,6	4		3,7	2,7	8,9	Europe 2004; HELICS
Worth 2015	More types	2015	183,625	2,8			4,9	2	8,7	Australia
Sherlaw-Johnson	CAGB	2007	2146				11,9			England
King	CAGB	2014	303				6,6			London
Wilson	Cesarean	2013	4107					9,8		UK
Calderwood	Hip prosthesis	2013	524,892				7,8			Medicare, USA
Lindgren	Hip prosthesis	2014	45,531				0,9			Sweden
Norway										
Ullevål (Andersen)	All	2009	12,430	6,2						Prevalence Ullevål

(continued)

Table 33.4 (continued)

Reference	Operation type	Year publ.	Total operated	Total %	Hip prosthesis total	Hip prosthesis partiell	CAGB sternum and donor	Colon surgery Cesarean section	Cholesystectomy	Comments
National prevalence (FHI)	All	2014	?	7						National Public Health
Flatmark	Colon surgery	2000	100						8	Lillehammer FSH
Dale H (1987-2011)	Hip prosthesis	2011	11,000	2,6	7,7					Norwegian register
Norway FHI—6 op. types	6 types	2011	6469	3,1	5,1	6,7	6,9	15,9	7,1	Incidence 2011
Norway FHI—6 op. types	6 types	2013	29,016	2,2	3,9	3,6	4,2	13,5	4,5	Incidence 2013

CAGB, coronary artery bypass graft; ACB, artery coronary bypass. Ref. 100

^aPrimary wound, only detected in hospital + readmitted same hospital

33.5.7 Monitoring and Readmissions for SSIs

Over 60% of postoperative surgical site infections may be detected after discharge from hospital, mostly due to the short length of stay [11]. The SSI was detected after discharge in one of four patients in a study of 1103 patients, of which 9.4% had SSI [100]. The same was found in 13,661 uncomplicated elective, colorectal operations, of which 20.7% had SSI; one of four patients with SSIs were detected after discharge [95]. More than half of them were readmitted. The SSI was related to younger age, women and endoscopic surgery [95].

SSIs are often deep and severe infections that most often may lead to rehospitalization and additional surgery [14–17, 47, 48]. In Norway, about 0.5% of all patients in hospitals are readmitted, mainly because of surgical site infections [14–17].

Most SSIs occur within 30 days, but for prosthesis and other foreign materials, a significant proportion may occur later on (Fig. 33.1) [101]. The time from surgery to deep/organ SSI after total knee replacement (TKR) surgery can often be up to 1 year, and the same may apply to mastectomy with prosthetic implant, while infections after total hip prosthesis (THR) and coronary artery bypass grafting (CABG) seem to occur some earlier, within 60–90 days (see Figure 33.1) [101].

A short follow-up after surgery may often fail [47, 48, 101–106].

- A study of 50,128 procedures (most with implants) over 10 years showed that most SSIs were detected within a month (75–92%) after operation, 93% after 3 months, 97% after 6 months and 100% after 12 months [103]. Surgical procedures examined were heart, orthopaedic, neuro, spinal, thorax and vascular operations, a total of 888 infections, 1.7% [103].

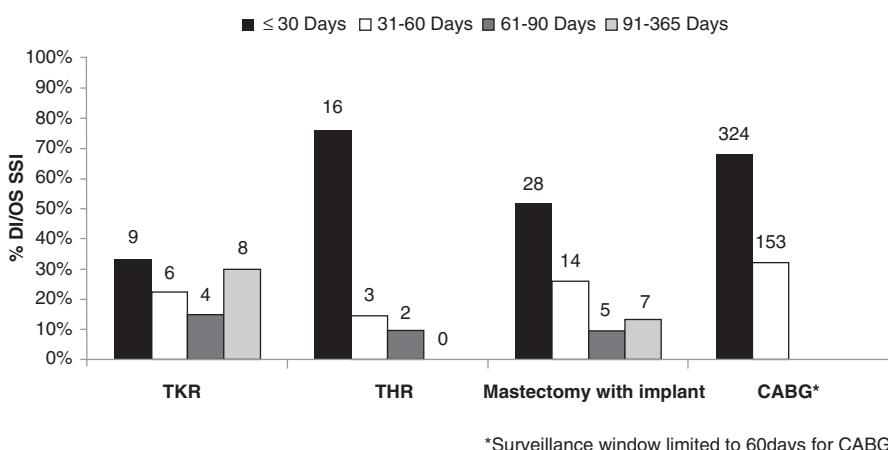


Fig. 33.1 Time from surgery to deep/organ SSI after total knee replacement surgery (TKR), mastectomy with prosthetic implant, total hip prosthesis (THR) and coronary artery bypass grafting (CABG). Source: Julie D Lankiewicz, ICHE 2012 [101]

- In a study of Norwegian SSI after coronary bypass surgery of 1237 patients at Ullevål University Hospital in Norway, SSIs occurred in 12% of the patients, 3.5% after 30 days [93].
- Among Swedish ACB-operated patients, SSIs were found in totally 30.5% [104]. Most sternal infections came within 30 days postoperatively, while 27% of leg infections (harvesting site) came 30–60 days postoperatively [104]. Similar findings have been made by Sharma et al. [105].
- In a large study from the United States of 723,490 surgical procedures from seven specialties (neuro, cardio, colorectal, skin/chest, gastrointestinal, ortho, obstr-gyn), only 1% had defined SSI, but ca. 2.5% of the patients (ca. 18,300) were readmitted one or more times because of SSI! [63].

Registration of SSI is still a major challenge [47, 48, 78, 106].

33.5.7.1 Long-Lasting SSIs

Monitoring shows long-term sick leave, out of work, early retirement, large consumption of home care, many subsequent readmissions and prolonged hospital stay, transfer to nursing homes, etc. because of SSIs [48]. So the final cost for the patient and for society at large is probably great.

The Norwegian System of Patient Injury Compensation (NPE) (Norsk Pasienteskade Erstatning) treated in the period 2001–2012 137 cases concerning equipment left behind in the patient during surgery. Out of these, 83 were approved and 54 rejected. Forgotten compresses and tampons dominated, but it was also abandoned metal equipment [107].

33.5.7.2 Short Postoperative Hospital Stay Is Associated with Increased Mortality

Studies from Sweden show that short postoperative hospital stay, <10 days after hip fracture, results in significantly increased mortality [108]. A total of 116,100 hip surgery patients were in the period 2006–2012 examined for death within 30 days [108]. Increased mortality rate may be the result of savings, shorter hospital stays, fewer beds and sicker patients, treated by a less competent and deficient health level outside hospitals. A good system for registering mortality rate according to hospital infections and other injuries should be established in all countries, including Norway.

33.5.7.3 Healthcare Personnel May Be Infected and Be a Source of Infection

The staff can become infected from patients, resulting in long-term sick leave, residual damage and disability benefits. Among 389 healthcare professionals with work-related infection in Germany, only 17 complaints were accepted, the rest rejected [109]. Outbreaks of infections among surgery patients may be related to infection or carrier state in the surgical personnel or the personnel handling the patients in the pre- or postoperative phases [110–112].

33.5.8 Expenses Related to SSIs

Hospital infections may cost extra, depending on the severity and on each country's basic costs and contribution for patients in hospital [11, 60, 83, 113–119]. SSI means often 6–14 days extra stay in hospital, reduced capacity and resources and delayed treatment of other patients.

- Additional costs for SSIs were in 2008, from 3000 to 29,000 USD per patient with SSI in the United States [11].
- After SSIs in hip replacement (Sweden) or heart surgery (France) were the direct costs for many years ago approximately 35,700 USD per patient.
- In Norway, the extra expense of three heart surgery patients with SSIs during an outbreak was about 142,860 USD [83].
- Elderly patients with SSIs caused by *S. aureus* compared to those in the same age group without infection have longer hospital stays (13 days compared to 9 days) and are almost doubling the direct expenses for the hospital (85,600 USD against 45,700 USD, $p < 0.001$) [60]. They have about three times greater risk of death than the same age group without infection [60].
- SSI in 12.4% of patients after breast surgery implant costed “crude medial” 16,900 USD for the patient with SSI compared to 6100 USD without infection [113].
- SSI after orthopaedic surgery prolongs length of stay in hospital of about 2 weeks, doubles rehospitalization rate and increases healthcare costs to >300%, compared with noninfected patients [116]. In addition, SSI patients have often a marked limited physical activity and a significant reduction of health-related quality of life.
- In the Netherlands (2009), the cost of a patient with SSI tended to double the cost of a patient without SSI [119].
- After discharge, there are often large extra costs of the SSIs [116–118]. A study (2003) found that cost for the first 8 weeks during the postoperative period was about 5100 USD with SSI, compared to 1800 USD without SSI ($p < 0.001$) [117].

33.5.9 Microbes and Transmission Routes

Peroperative and particularly *intraoperative* bacterial contamination of the wound is of greatest importance. Up to 98% of bacteria in orthopaedic wounds are arising from operational environment. They come from the environment, equipment and persons *exogenously* or from the patients themselves (skin, intestine, the mucosa), *endogenously*. Endogenous flora may change 1–2 days after admission to “hospital flora,” often with more resistant bacteria. Therefore, patients should be operated within 1 day after admission.

33.5.9.1 Microbes and Particle Load in the Wound

During surgery, at least five to seven people are present in the operating room. They are continuously liberating skin cells and particles with and without bacteria to air and surfaces. Each person liberates 30,000–60,000 skin cells per minute as dust, 600,000 to one million or more, per hour. Dead skin cells are laying as traces in the room and ca 10% of loose skin particles are carrying bacteria. Therefore, good personal hygiene, use of clean operation textiles and cleaning between each operation are important.

The skin is protected as long as it is intact. Normal skin flora represents coagulase-negative staphylococci, dominated by *Staphylococcus epidermidis*, 10^{3-4} per cm^2 . Diphtheroides, anaerobic bacteria (*Propionibacterium acnes*), gram-negative rods, *Candida* (yeast) and mites (*Demodex*) are common findings and also *Staphylococcus aureus*. New microbes are continuously deposited on the skin, usually transient and loose. Greatest amount is found on the forehead (half million per cm^2), around the ears, the head (6.1 million per cm^2), axillae and nose opening (10.1 million per cm^2), the upper back (10,000–100,000 per cm^2) and palmar side of the hands, arms, chest (1000–10,000 per cm^2), etc., with variation between gender [120]. Hair and beard may contain large amounts of microbes.

The heavy skin flora and liberation of skin particles from bare skin must be considered when working with sterile procedures, with infection-susceptible patients, surgical activity, wound care and care of drains and intravascular equipment [120].

33.5.9.2 Bacteria Types Causing SSIs

SSI is most frequently caused by *S. aureus*. Coagulase-negative staphylococci as *S. epidermidis* is the most common cause of infections in implant surgery. Others are *Escherichia coli*, *Klebsiella* sp., *Enterobacter cloacae*, *Pseudomonas* species, etc. and enterococci and anaerobic bacteria. *Candida* can be significant with prolonged antibacterial therapy. *S. aureus* is an increasing problem and especially resistant *S. aureus* as MRSA.

Group B streptococci, unusual gram-negative bacteria and anaerobic bacteria increase [121]. More resistant and super-resistant gram-negative rods (ESBL, carbapenem resistant, etc.) and VRE can be linked to “medical tourism,” patients who undergo surgery or dental treatment abroad. These patients should be tested and isolated as for MRSA until known result.

MRSA is the worst of all bacteria and in the United States the dominant cause of fatal nosocomial infections. A total of 3.5–6.5/100,000 population in the United States dies each year from MRSA [122, 123]. SSIs caused by MRSA led—in one study from the United States—to 16 extra days in hospital, 13.5% increase in discharge to long-term institutions, about 70% more frequent readmissions and 14% higher mortality rate than in surgical patients without SSIs [124]. The additional cost was about 40,000 USD per MRSA patient [124]. In Europe, the risk of unknown MRSA in patients hospitalized in surgical wards is estimated to about 4% [125].

33.5.9.3 Transmission Routes

About 25% of *S. aureus* in surgical wounds comes from operating personnel, 25% from the patient and the rest from environment, pre-, per- or postoperatively. *S. epidermidis* is related to airborne transmission. Surgery with ultraclean air reduces airborne infection if staff is properly dressed [30–32, 126, 127]. SSI may also occur via infected urinary catheters, intravascular accesses or intubation and mechanical ventilation before surgery.

S. aureus is normally present in the nose of 10–20% of healthy individuals and 5–15% in the perineum and can periodically be on hands/wrists and other skin areas, especially if eczema and other skin infections [128].

Endogenous wound infection. Presence of *S. aureus* in the nose of the patient may be an independent risk factor for endogenous SSI. Surgery on patients with infections may always be a risk of SSI [1]. Gram-negative rods present in the airway preoperatively may dispose for postoperative infections, including wound infections [129].

Exogenous wound infection. Large numbers of bacteria present on the staff's skin, especially on the head and neck areas, around the ears and upper back, is a challenge concerning SSI, because of the bent work situation over instruments and wounds [120].

33.5.9.4 Conventional and Ultraclean Conditions: Airborne Microbes and Particles

The amount of air contamination is dependent on free particles and microbes generated by activities, air currents, personnel, equipment, environment and dust from furniture, equipment, floors, etc.

Air quality is important—especially in the area around the wound—and is the main cause of wound contamination [130–132]. In conventional ventilation, after total joint prosthesis, SSI was 3.4%, by ultraclean air 1.7%, with addition of exhaust suits 0.75% and with addition of antibacterial prophylaxis 0.2% [131]. Friberg et al. [132] conducted many studies concerning ultraclean conditions and the effect of dressing concerning wound contamination.

Ultraclean operating rooms with vertical laminar airflow (LAF) have <10 CFU/m³ air during the entire operating period, even by up to 12 people present, while conventional operating rooms may reach over the maximum limit >100 CFU/m³, even when there are few persons present [126]. Particles in air reach high values, in particular by diathermy [126]. LAF and conventional operating rooms have a low bacterial count on the floor before operational activity which remains low on effective LAF operation rooms throughout the day [126]. In contrary, the conventional operation rooms have a rise of the floor contamination to 100–120 bacteria per 20 cm² before day's last end cleaning. This may occur despite good routines of washing the floors between all operations [126]. The LAF system has effects both on the bacterial load in the air and on the amount deposited on surfaces in the room [126]. Hambreas et al. [133] described already in 1978 floor contamination as a source of airborne bacteria.

There is still a discussion concerning the effect of ultraclean laminar flow [134]. Surgeons observe that LAF conditions may lead to “false security” with reduced operating room discipline, lack of use of masks, increased traffic under the surgical phase, etc. [134]. LAF system is still recommended by the CDC by ultraclean surgery with insertion of foreign objects, provided good discipline.

Healthy individuals may release varied amounts of bacteria and skin particles into the air and the environment, as shown in a Swedish study [135]. Many infectious outbreaks may start from “heavy dispersers” and people with eczema. Upper respiratory tract infections may increase the release of *S. aureus* and other microbes from the nose to the air. Males emit more bacteria than women and shower increases the release of bacteria for 1–2 h afterwards. High temperature and humidity increase bacterial growth, and bacterial and particle count increases with the number of people and activities in the operating room. Ears, forehead and eyebrows in surgical personnel who are bent over surgical and instrument tables pose the risk of shedding particles and bacteria in the wound, and therefore good covering of hair and ears is recommended [136].

Small particles and microbial contaminants floating in the air increase with surgical time, mostly because of use of diathermy [126, 137]. If the door of the operating room is opened several times, the small dust particles from the air are reduced, while the bacteria count rises from unfiltered corridor air [137].

Patients with infected wounds constitute an additional load, in particular by pus, leakages, punctures and care of dressings. A fast removal of the dressing may release more bacteria from the wound up in the air [138].

33.5.9.5 Contaminated Ventilation System and Control

Ducts, filters and other equipment that are not controlled, cleaned and replaced can result in serious infections. In a 4-year period, 47 patients were infected by *Penicillium* species, due to the growth of *Penicillium* and *Aspergillus* in ventilation ducts and fibre glass filter in a surgical department [139]. Filters were replaced and ventilation ducts were disinfected with chlorine solution in gaseous form. This had an effect, but 7 months later the problem reiterated [139]. It is important to control the ventilation and the operating room for both bacteria and fungi. Ventilation systems and operating rooms may also sometimes be invaded by flies and other insects [140].

The Norwegian Board of Health Supervision has defined microbiological control of operating rooms (IK-2/97): “Ventilation for operating rooms should ensure: 1. The supplied air is sufficiently free of microbes, 2. The microbe particles generated in the operating room is removed, 3. That the air in the operation area to a minimum degree streams from people against the wound, 4. That there is not a negative pressure in the operating room so that the microbes may be supplied from the neighbouring rooms.”

Ventilation can be regulated down during rest but must be set up again at least 30 min before the next operation [141].

33.5.9.6 Routine Errors, Accidents and Failures

Surgical staff who do not follow procedures for personal hygiene, dressing, hand hygiene or use of jewellery pose a risk for development of SSI.

- *Nocardia farcinica* caused sternal infection in five patients undergoing heart surgery [112]. Case-control studies showed that the patients had been exposed to an anaesthesiologist A having identical ribotype profile of *Nocardia* on the hands, in own home, including the house cat. The outbreak stopped after intensive cleaning, hand hygiene, use of personal infection control equipment and cleaning the anaesthesiologist A's home [112].
- Mediastinitis caused by MRSA among five cardiac surgery patients was tracked to a surgeon who had identical genotype in the nose [110]. After elimination of the carrier state, the outbreak stopped [110].
- Major outbreaks of group A streptococci have been traced to the surgical staff with chronic carrier state [111].
- Prostate abscess with bilateral orchietomy and flushing the incisional wound proved to be active tuberculosis, *Mycobacterium tuberculosis* [142]. In all, 128 HCW were exposed to infection, including 12 (13%) who became tuberculin positive, including 1 of 12 in the surgical team [142].
- *Rhodococcus (Gordona) bronchialis* in sternal wound in seven patients after open heart surgery was associated with surgical nurse A. The bacterium was detected on the hands, head and other skin areas of nurse A, in the environment and in the air around A, in A's home and in A's dogs [143]. Attempts to remove the bacteria from nurse A were unsuccessful [143].
- Nasal carrier state—with large amounts of *S. aureus*—increases risk of SSIs. When the surgeon is a nose carrier of *S. aureus*, the risk is highest [144].
- During 1 month, seven heart surgery patients in California had SSI with *Serratia marcescens*, and one died [145]. The infection was traced to an operation-nurse A, who used artificial nails and in a cream tube in A's home. The outbreak stopped after removing the cause.
- During 1 year, 15 neurosurgical patients in the Netherlands got SSIs with *Serratia marcescens* [146]. Environmental samples were negative. Nurse A, 1 of 100 in contact with the actual patients, had identical bacteria on the hands [146]. Nurse A that had been most in contact with the infected patients had psoriasis on hands. Nurse A was on sick leave for 3 months with persistent positive samples, while the outbreak stopped in the department. One year later there was a new outbreak of three patients related to nurse A which again was infected and who had not got rid of the bacteria because of the psoriasis [146].
- In a cardiac surgical unit in England, four patients got deep surgical infections and pneumonia with MRSA during 1 year (epidemic strain MRSA-15) [147]. Employees were then tested with the discovery of a nurse who was nasal carrier and without symptoms. After clearance, the outbreak stopped. It was recommended screening of personnel for MRSA [147].

- A highly resistant—*Pseudomonas aeruginosa*—strain was transferred to four patients via contaminated gastroscope during a few months in 2013 [148]. The reason was deviations in cleaning, disinfecting and drying the scope. After removal of the gastroscope and establishment of safe practices, the outbreak stopped [148].
- *Serratia marcescens* caused increased number of patients with postoperative empyema at a thoracic-surgical intensive care unit in March 2013 in Turkey [149]. The common source of infection was a portable suction machine. After full disinfection, sterilization and control of the equipment, the outbreak stopped.
- Ear cleaning instruments may be too poor disinfected, as shown by subsequent transmission of *Pseudomonas aeruginosa* to 17 patients with severe external otitis [150].
- Contaminated tap water in surgical wound has caused outbreaks of *Legionella* SSIs [151].
- Water may often contain mycobacteria which are not detectable by conventional bacteriological tests and are resistant to chemical disinfectants and to some extent also to heat.
- *Mycobacterium fortuitum* endocarditis was detected in three heart-operated children in Serbia in 2013 [152]. Bovine pericardial patches were used for correction of ventricular septal defect. Parts of the same pieces of tissue had been used for several operations, and this was not compatible with a good routine. Estimated infection cause was contamination by thawing and freezing. All three children survived after antimicrobial therapy [152].
- Contaminated equipment brought into the operating theatre is linked to repeated outbreaks of infections.

33.5.10 Risk Factors for Development of Surgical Site Infections

There are many well-documented risk factors for SSIs; however, they may often be mixed, combined, transient, not recorded and difficult to trace [1, 4, 8, 11, 20, 21, 24, 29, 56–58, 144, 153–164].

Risk is primarily associated to wound pathogenic types of bacteria introduced during surgery or afterwards. Development is dependent on four factors: (1) the amount of bacteria in the wound at the end of operation, (2) the bacterial virulence (invasion properties), (3) the patient's immune defence and general condition and (4) the condition of the surgical site at the end of surgery (tissue necrosis, loss of vascularization, foreign bodies, poor surgical technique, etc.) [4, 8, 159].

The risk of SSI increases at 10^5 bacteria per gram of tissue but low bacterial levels; 10–20 bacteria can start infection if present close to sutures and other foreign matters [4, 8].

SSIs registered in Canada, 2002–2008, were detected in 13.5% of 622,683 patients followed up postoperatively for 30 days [160]. Over half (7.8%) of SSIs

occurred after discharge. The reason for detection of SSIs after discharge was related to shorter surgical time, shorter hospitalization, “rural residence,” alcoholism, diabetes, obesity, increased risk of readmission, reoperation and urgent hospitalization [160]. DeBoer et al. found that for orthopaedic patients the increased risk of SSIs was related to increasing age from 45 years, preoperative stay in hospital in more than 4 days, more than one surgery, more hospital infections at the same time in the patient, the use of antibiotic prophylaxis, emergency surgery, contaminated wounds and surgery duration of 2 h or more [155].

33.5.10.1 Patient-Related Risk [4, 8, 153]

Documented

- General condition and underlying disease.
- High or low age (elderly, infants) [20, 160].
- Overweight - obs increased dosage of prophylactic antibiotics [20, 160].
- ASA score >2 [20, 160].
- Infections in the patient—before surgery—especially hospital infections (skin, airways, teeth, urinary tract) [1].
- Carrier state of *S. aureus* in the nose [110, 144].
- Preoperative stay in hospital >1–2 days [20].
- Preoperative shaving.
- Short postoperative hospital stay [108, 160].

Likely

- Diabetes and hyperglycaemia—recommended well regulated [160–162].
- Malnutrition and low albumin.
- Steroids (high dose).
- Age >70 years is frequently associated with deep infections by ACB operations [105].
- Smoking; recommended to stop 30 days prior to surgery.

Possible

- Alcohol consumption [160].

33.5.10.2 Procedure-Related Risk

Documented

- Urgent surgery [20, 160].
- Contaminated wounds; wound class >2. Classification of wounds, 1–4 (clean, clean-contaminated, contaminated, heavily polluted), transplantation and implantation [20].
- Preoperative shaving of hair.
- Failure in preoperative preparation.

- Surgical type.
- Surgical technique and complications—bad run [53].
- Treatment and control of sterile equipment and prosthesis.
- Microbial contamination of the wound at the end of the operation. About 70% of wounds may be contaminated during surgery.
- Antibacterial prophylaxis.
- Surgical time >2 h.
- Too short or too long surgical time, over 75 and under 25 percentile [20, 70, 160].

Likely

- Multiple procedures.
- Trauma to tissues, necrosis, bleeding.
- Foreign materials.
- Blood transfusion.
- Intensive treatment—ASA score.
- Disinfection of skin and covering surgical site.
- Ventilation system and CFU/m³ air.
- Drainage.

Possible

- Lack of preoperative shower with disinfectant (Hibiscrub).
- Urgent surgery.
- Hypothermia.
- Low oxygen saturation of tissues.

33.5.11 Preoperative Phase

33.5.11.1 Patient Assessment and Protection Against Infection

All patients should undergo a careful preoperative assessment and preparation with clearance of infections of the skin, urinary tract, tooth, etc. Dental status should be checked before elective surgery with foreign materials like prosthesis. The risk of surgical wound infection is high in patients that have ongoing infections (18.4% with other infections and 6.7% without) [1]. In 55% of the cases in one study, the same microbes were found in the wound as in primary infection [1].

Glucose level should be controlled in all patients and patients with diabetes should be specially followed up. The shortest possible preoperative length of stay, <2 days, is well documented to avoid transmission of hospital microorganisms [1, 8]. Cancellation of operations and readmissions is not compatible with infection control.

Shielding against infection is important. In England, MRSA testing was done at home, before arthroplasty [165]. MRSA-positive cases were cleared for carrier state before surgery. MRSA-negative patients were physically separated in a unit with

restricted admission for healthcare personnel and relatives. This measure provided significant reduction of SSIs, $p < 0.001$, and increased the surgical capacity by 17% [165].

33.5.11.2 Shaving, Clipping and Shampoo

Shaving may cause SSI by making many small wounds in the skin which are gateways for microbes [1, 166–168]. Among 406 patients, 5.6% had postoperative wound infection after shaving, 0.6% after cutting and 0.6% after the hair was not removed [168]. That all mothers in Toronto, Canada, were asked not to remove hair on the stomach and below, last month before birth, resulted in a halving of the SSIs [168]. Ten heart-operated male patients had during 3 months SSIs, osteomyelitis and sepsis with *Serratia marcescens* [169]. Common to all ten patients was shaving by a barber that had the same bacteria on hands and equipment. Similar outbreaks are described in a neurosurgical department [170]. Fourteen neurosurgical patients developed SSIs with *Serratia marcescens* within a 6-month period at a hospital in China [171]. This infection was traced back to two barbers and their shaving equipment; they had performed wet shaving of the patients preoperatively [171].

It has been detected a rich flora of resistant gram-negative bacilli in different types of shampoo and cream tubes and boxes [145, 172]. Outbreak with *Serratia marcescens* among 14 newborns in Saudi Arabia was traced back to a contaminated baby shampoo [173]. Sepsis and other serious infections were recorded and one child died.

33.5.11.3 Body Wash with Chlorhexidine, Etc.

Cruse and Foord found that by clean surgery, 2.3% had SSIs without shower before the operation, 2.1% after shower with soap and only 1.3% after shower with hexachlorophene soap [1]. In one study, Hibiscrub body wash led to a reduction of bacteria from 900 to 50 colonies per plate [174]. Whole body wash, including hair, is recommended the night before surgery, possibly also in the morning (sweat, using the toilet, etc.). The final wash must be completed at least 2 h prior to surgery due to the release of skin particles. Still, there is insufficient evidence for this action (Cochrane) [175].

The use of disinfectant wipes from dispensers and open packages may cause infection since many of the most resistant bacteria can survive and multiply in the presence of various disinfectants [176].

33.5.11.4 Internal Check of Personnel

Procedures for internal check of surgical staff should be present in the department, like the following: not active infections; access control works; staff change clothes; uses hand hygiene and does not use jewellery; uses green operation clothes; shoes that are machine washable; hair and ears covered with hoods; surgical face mask taken on before entering the operating room and removed

afterwards; especially clothing protection by vertical laminar flow airstream; surgical handwashing/disinfection performed as a routine; sterile dressing opened immediately before dressing; and sterile gloves should be double, with indicator, and strong with long cuff.

33.5.11.5 Cleaning, Disinfection and Environmental Treatment of Floors and Surfaces

Operations may generate large amounts of visible and even more invisible biological material in the environment of the operating room [126, 127]. Cleaning is performed between each operation after defined methods, often with varying quality [126, 127]. Dry mopping should not be used due to poor effect on biological, dried materials, biofilms and dust that may swirled up [177–179]. Terminal cleaning each day and disinfection of inventory in the morning before operational activity are recommended [179]. Closets and drawers for instruments, bandages and other equipment are cleaned each week, and all storage rooms are cleaned daily. A major cleaning of walls and ceiling and inventory of all rooms in the operation department twice a year is recommended [179].

After operations with “pus” and infections, disinfection is carried out with 5% chloramine or PeraSafe and/or hydrogen peroxide gas, before the ordinary cleaning [179, 180]. The disinfection includes all technical equipment in the room, including inner parts of medical technical equipment, which are otherwise difficult to reach [180, 181]. Start the machine and let it draw hydrogen peroxide gas through the inner parts during the room disinfection [181]. Note that gas disinfection does not kill *Mycobacterium tuberculosis* [182, 183]. UV light has not been proven beneficial in this situation [184]. Newer disinfectants and methods must be checked thoroughly for effect (spore test, etc.), and the disinfectant does not harm equipment and people or develop resistance. Ineffective disinfection can lead to the spread of more resistant, environmental microbes [185].

Quality of the cleanliness is monitored and controlled by the detection of biological material (ATP—adenosine triphosphate test), bacterial counts and other methods. ATP methods provide quick answers used properly [178, 186]. Regular cleaning with soap and water reduces the amount of bacteria significantly and the organic material is also removed [126, 127, 178, 179, 187]. Environmental contamination of blood and tissue particles in an operating room is considerable, both through the air and as debris [188].

33.5.11.6 Uncleaned Equipment

The surgical department should not be a “sterile central” for other departments. All equipment, including drugs, medical equipment, paper and records, beds and stretchers, fluids, cloth, shoes, mobile phones, pens, stethoscopes, etc., which enters the surgical department, should be clean.

Mobile phones, tourniquet, stethoscope, PC board, blood pressure gauge, etc. carry large amounts of bacteria [189–191]. Among 90 surgeons, anaesthesia

personnel and medical students, 53% were carrying their mobile phones, etc. into the operating room. About 15% had two or more phones, and most of them (85–96%) were never cleaned by the owner. Nearly all were contaminated (90%), and more than 11% were colonized with *S. aureus*, *Pseudomonas aeruginosa*, *Acinetobacter* and *Stenotrophomonas maltophilia*, microbes that may cause severe wound infections [191].

Paper and journals. Bacteria and virus survive on dry paper and journals for days to months and should therefore be handled with care and not brought into rooms where there may be infections [192].

Outer packaging of goods to the surgical department should be unpacked in a separate room outside the department because of possible contamination with resistant bacteria, viruses and fungi and even with parasites.

Equipment to assist placement of the patient on the operation table is often reusable, used to adapt the patient to the operation table or to protect against pressure sores. It is packaged in plastic or leather, may be difficult to clean between patients and may transmit significant amounts of bacteria into the surgical wound if not disinfected and stored clean. In a study of primary hip operations, 11 of 13 patients used this equipment which was contaminated with *Proteus*, *Acinetobacter*, *Enterococcus*, CNS and coliform rods [193].

Non-sterile cotton, plaster, tape or bandages should not be deposited around the wound of recently operated patients. Cotton, cotton wool and tape used in the area, nearby wounds, must be sterile. Storages for plaster should be clean and protected from dirt and dust. Bacteria grow well in plaster, especially when tissue fluid is present.

Markers for indicating the surgical field may contain bacteria which pose risks for SSIs [194]. Markers should be sterile and disposable [194].

Oesophageal pressure gauge should be disposable because of risk of disease transmission [195]. Disinfection is expensive because it is fragile instruments. Single use is recommended in England.

Transoesophageal echocardiography (TOE) has caused outbreak of *Enterobacter cloacae* infection in a cardiovascular department in Japan [196]. The outbreak stopped after proper disinfection and modified routine [196].

Wound drain suction—reusable—may follow the patient from the operating room to the postoperative and later to and from the hospital. Lack of disinfection of internal components makes it necessary to treat this instrument as infectious. Medical devices that are cooled down with room air may concentrate internally bacteria, fungi, dust, organic materials and other dirt that next may be blown out into the room [181].

Actively heating systems for normothermia is not defined as a risk of infection [197].

Wet areas such as surgical hand disinfection rooms may generate large amounts of aerosols. Sterile equipment or clean equipment should not be stored in wet areas,

because of contamination of the external cover and a fast growth through the covering material.

Intravenous, sterile liquids should be stored in a clean and dry room [83, 84].

33.5.11.7 Anaesthesia and Equipment

Anaesthesia machines are often contaminated [198]. Focus on hand hygiene for anaesthesia personnel resulted in 27-fold increase in hand hygiene during work with the patient, reduction of bacteria on the anaesthesia machine and stopcock ($p < 0.002$) and reduction of postoperative infections, including SSIs, from 17.2% to 3.8%, $p = 0.02$ [198].

PC keyboard, including the PC of the anaesthesia personnel, is always contaminated with microbes from different users. Plenty of gram-negative bacteria, CNS, *Bacillus* and MRSA can be detected, depending on the local microbiology [199]. Only 17% of anaesthesia personnel in a study carried out hand hygiene before anaesthesia started, while the proportion was significantly higher, 64–69%, after anaesthesia or before lunch! [199] Proper cleaning and disinfection of the keyboard with alcohol resulted in drastic reduction of bacteria. Daily cleaning and disinfection of computer keyboard and hand hygiene compliance with change of gloves after each procedure is recommended to reduce the infection [199].

Intraoperative infection via the patient's intravenous "stopcock" (three-way) is associated with increased patient mortality [200]. Intraoperative infection of the stopcock occurred in a study in 11.5% of cases, and almost half (47%) of the contamination came from the staff. Spread of bacteria to the environment around the anaesthesia place occurred in most cases (89%), and 12% of these were from the staff [200]. Number of operating theatres the anaesthesiologist had responsibility for at the same period, age of the patient and patient transfer to an intensive unit were linked to an increased risk of transmission of infections [200]. Contaminated hands of anaesthesia personnel were probably a significant infection factor during surgery [200].

Bacterial deposits on the surface of syringes, IV sets of three-way taps and anaesthesia (ventilator) machines were studied among 101 elective and urgent surgical patients [201]. Culture of samples from the syringe surface and from the syringe content showed growth of bacteria in, respectively, 46% and 15% of cases [201]. The same bacterial strain was grown from both the ventilator and the syringe in 13% of the cases and was also detected on the IV set in two patients. There was a significant correlation between the urgent surgery and contaminated syringes. Risk was also related to the absence of the use of gloves and missing cap on the three-way tap after use. Particularly during ultraclean operations and a patient in a bad condition, intravenous injection of bacteria via the anaesthetic syringe may cause development of postoperative infections, including SSIs [201].

Laryngoscope blade and handle, etc. are sources of infection in the surgical department and for the patients, unless the devices are adequately disinfected and sterilized [202].

33.5.11.8 Technique and Complications

The risk of infection via equipment is related to the reuse of disposable articles, mishap, lack of coverage of sterile equipment, poor quality of gloves, sterile gowns that provide inadequate covering, compresses which leave fluff in incisional wounds and become “locus minoris” for infection, etc.

Lack of exercise and knowledge, particularly by the surgeon, poor surgical technique, contamination from the bowel (abdominal surgery), too much use of diathermy (the United Kingdom—recommends to avoid diathermy during skin incision because of prion disease), bleeding, haematoma and injuries to tissues, contamination of instruments, a too long operation time, and unnecessary use of drains often increases the risk of SSIs [1, 51–54, 203].

The number and type of bacteria in the surgical wound at the end of surgery, tissue necrosis, poorly oxygenated tissues and the use of drainage increase the risk of SSIs [20, 153–158].

Robot-assisted surgery has been associated with longer operative time and significantly more infections than open surgery but may be the result of a learning curve [98].

Drilling in bone and surgical wound debridement may cause splashing and scattering of tissues and microbes to the environment. This must be avoided, especially when the tissue is infected [204].

Adhesive plastic covers do not reduce recolonization of bacteria in the disinfected surgical area, compared with bare skin [205]. Recolonization on the skin occurs after 2–3 h [205].

Types of sutures and the number of variants used per operation type are discussed. For abdominal surgery it is claimed reduced risk of SSIs by using triclosan-coated sutures [206]. However, triclosan is not recommended for use as a disinfectant because of development of resistance and should not be used for sutures. The most important is use of fewer suture types, that experiences increase and that the sutures are both stored and treated sterile.

Lost equipment in the surgical wound occurs, despite of a mostly consistent control [107].

33.5.11.9 Diathermy and Suction

At the tip of diathermy needle, often large amounts of tissue debris may be found. This is specially a risk concerning prions [207]. In a study, the suction tip used in ultraclean surgery had one or more microbes in 41% of patients, comprising *S. aureus*, CNS, *E. coli*, *Proteus*, group B streptococci, micrococci and diphtheroides [208]. Similar findings have also been done by others. The compressed air from the wall may be contaminated with small amounts of CNS constituting risk when using

pneumatic tools in wounds. Suction regulators may be source of infection in surgical departments and other departments [209]. In one study, 37% of 470 regulators were colonized with bacteria like *S. aureus*, *Pseudomonas aeruginosa*, CNS, enterococci, *Bacillus* and *Micrococcus* species [209]. Miscellaneous medical devices with suction or compressed air or in-out air from the room itself are risks for patients and staff if not disinfected/sterilized/filtered and controlled properly [210].

33.5.11.10 Bandage Types

Meta-analysis shows that there is no significant difference in bandages if they are stored, processed and placed on the wound with a sterile method [211]. The storage of bandages is often not clean enough. Microbes can be disposed on the outer packages, released to the air by opening and thus transferred to the surgical wound by air or gloves. The storing of sterile bandages in surgical wards demands qualities like a sterile storage room and excellent cleaning.

33.5.11.11 Disinfection and Sterilization

Inadequate sterilization and disinfection is a great risk if introduced into sterile tissue or mucosa [212]. CDC does not recommend use of flash sterilization (CDC 1B) which is often a sign of lack of instruments at the department.

Biofilm is difficult to prevent unless the instruments are cleaned thoroughly. Instruments should not dry with biological materials on, especially with regard to an effective removal of prions [213]. Reprocessing of medical devices is currently being updated in the United States (FDA—Food and Drug Administration) [213]. It involves the following: (1) after use of the equipment, immediately remove and/or prevent desiccation of the material; (2) thorough cleaning of the equipment; and (3) disinfection (low, intermediate, high level) or sterilization [213].

Manual disinfection may be significantly poorer than semi-automatic or automatic disinfection; especially *E. coli*, other gram-negative rods, streptococci and enterococci are frequently isolated from the instruments after manual disinfection [214].

During a period of 3 months, 17 patients got lower respiratory tract infections with *Pseudomonas aeruginosa*, infected via a flexible bronchoscope that was not good enough cleaned [215].

Unsterile *anti-mist solutions* to treat scopes have caused outbreaks with *Burkholderia cepacia* [216]. *Mycobacterium cheloneae* was detected in bronchoalveolar lavage (BAL) from nine patients without symptoms, but the bacterium was detected in the scope, a contaminated bronchoscopic washing machine and in water [217]. Controls and good routines are important, especially where water sources have variable quality.

Contaminated arthroscopes transferred *Pseudomonas aeruginosa* (PA) to seven patients, which resulted in deep/cavity infections [218]. The bacterial strain was detected in the sink, the suction bottle, the wall suction system and in the scope. Tissue debris was left in the inlet and outlet channels of the scope and the “shaver

handpiece suction channel.” *Pseudomonas aeruginosa* survived flash sterilization and autoclaving—probably in tissue debris [218].

A gastroscope was a common source of infection in four cases (France, 2011) that was infected with a multidrug-resistant (MDR) *Pseudomonas aeruginosa* producing extended-spectrum beta-lactamase (ESBL) [219]. Observation revealed severe failures as inadequate cleaning, too short disinfection time, insufficient brushing and purging of channels and inadequate drying. The gastroscope was removed, the routines changed, and the outbreak stopped [219].

Infections with resistant bacteria resulting in death of the patients are reported connected to inadequate cleaning of endoscopes [213, 220].

Hepatitis C infection has been transmitted via colonoscopy from one to two other patients in France [221]. All three were examined by colonoscopy at 1-h intervals, the HCV-carrying patient first. The two infected got symptoms 3 months later. The index patient was known in advance and had 3.5 million HCV—virus particles per ml of blood. Colonoscopes had been cleaned, washed and treated for 5 min in 2% glutaraldehyde. But the biopsy channel had never been brushed, and biopsy forceps and diathermy tube were only treated with glutaraldehyde, never sterilized [221].

Reuse of disposable sterile equipment, labelled “single use” may still be used—to save expenses. Among 100 hospitals in the Nordic countries, there were 542 cases of re-sterilization of medical disposable sterile equipment including implants [222]. More than half of the hospitals used re-sterilization of single-use sterile equipment. Sterilization of disposable equipment can change the instrument’s strength, integrity, shape and other important properties as the transfer of organic material and infection between patients.

In Norway, this has been a widespread practice [222]. Re-sterilization has been done on unused single-use equipment of about 50 different products, essentially orthopaedic implants. Pacemakers were re-sterilized after use on patients, likewise catheter, knives, scissors, tweezers, needles, introducers, tubes, etc. There was lack of control by the sterilization method and many single-use instruments were re-sterilized 15 times or more [222]. Today, “single use” means that the instrument is discarded after one use in all hospitals in our country.

Work with sterile instruments relies on a comprehensive approach to the complete process. Dancer and co-workers described an outbreak of SSIs in approximately 20 elective orthopaedic patients, associated with deficiencies in autoclaving and drying and lack of control “all the way,” from the sterile central to the operating room [223]. Visually discoloured and partly wet instrument sets were delivered to the surgical department. Among 20 sets, half were discoloured exteriorly and more than half had bacteria on the interior surfaces. A total of 11 patients had to be reoperated because of SSIs [224].

Prion diseases such as Creutzfeldt-Jakob disease (CJD) and variant CJD (vCJD) transmitted from animals, like bovine spongiform encephalopathy (BSE—“mad cow disease”), must always be remembered, concerning cleaning,

disinfection and sterilization of instruments and other equipment in contact with/ perforation of the mucosa and perforation of the skin. There is a limited efficacy of steam sterilization, 134–137 °C for 3 min to inactivate vCJD [224]. Recently, dura mater graft-associated Creutzfeldt-Jakob disease in 154 cases was published from Japan [225]. A Lyodura dura mater product was associated with 140 of the cases [225].

See the chapters on disinfection and sterilization; 59–61.

33.5.11.12 Antibacterial Prophylaxis

Risk for SSIs depends on:

- 1: (a) Amount of bacteria in the wound, virulence and antibiotic resistance, (b) tissue damage around the wound and (c) foreign material in the wound.
- 2: (a) The patient's general condition and local immunity and (b) antibiotic prophylaxis.

In a study from Europe (2010), 17% of the total consumption of antibiotics in hospitals were used for surgical prophylaxis [226]. Among 1650 agents used in surgical prophylaxis, the cephalosporins dominated (first generation, 27%; second generation, 20%), followed by combinations of penicillins, 13%, and imidazole agents, 9%. Resistance driving and very important therapeutic agents, like fluoroquinolones, third-generation cephalosporins and aminoglycosides, were in sum used for almost 20% of the cases (8%, 5.7% and 4.4%, respectively) [226]. This is a serious development with regard to the use of resistance-driving antibiotics.

Effect of prophylaxis is evidenced in caesarean section in which the introduction of pre-incision antibiotics reduced SSIs from 10.8% to 2.8% [227]. Problems with the development of resistance is often associated with inappropriate use of antibiotics, including antibiotic prophylaxis [228, 229].

In a study from Switzerland, antibiotics were used inappropriate in half of surgical wards because of no indication for use; 30.3%, wrong choice of agents; 10.9%, not proper timing, dosage, duration etc.; 9.5% [230]. By changing the prophylaxis treatment to include a new dose at the duration of surgery for 3 h and reducing the duration of the treatment to 1.6 days (from previously 2.4 days), an intervention study found a significant reduction of SSIs with resistant gram-negative rods and MRSA [231]. New guidelines are more restrictive [232].

Antibiotic prophylaxis has many positive aspects but is a continuous risky excuse to relax in hygiene, cleaning and infection control, and while the bacterial resistance is easily selected, it happens little on the antibiotic front.

33.5.11.13 Planning of Surgery on Infected Patients

During surgery, precautions for contact transmission often may include precautions for airborne transmission when in direct work with infectious tissue. Dedicated operating rooms for patients with infections should be placed nearby the entrance to the operating department. It should be “stripped” of excess equipment, large enough,

sturdy and robust for chemical disinfectants and easy to clean. Positive pressure must be turned off and ventilation valves closed, and the room should preferably have a complete separate ventilation (not shared with other operating theatres). Negative pressure and possibility of gas disinfection of rooms and input and output channel after the operation should be recommended. Procedures should be established for gas disinfection of the inner machine parts for medical equipment that draws air from the room and that cannot be disinfected inside by chemical liquids [179, 233]. Introduction room should be used as a sluice with the same ventilation system as the operating room.

The patient is brought in a clean bed with clean linen directly from the isolate to the operating room in accordance with applicable isolation regime. Transport bed/stretcher is treated as infectious—after having handed over the patient. New, clean bed/stretcher is retrieved to postoperative transport. It is an advantage that the patient wakes up in the operating room and then brought directly to isolate in the postoperative phase. Operation at the end of the day or in an empty department may be required with very dangerous infective agents [233].

The severity of the infections determines the use of PPE. Note that airborne infection is a risk factor in patients with blood-borne infections (HIV, hepatitis, prions, etc.) and for infections in tissue (tuberculosis, etc.). This applies especially to the use of diathermy, “drilling” and suction. In England, there is recommended less use of diathermy because of the risk of prion disease.

33.5.11.14 Gas Disinfection After Surgery on Patient with Infection

Gas disinfection may be implemented, using mobile devices, preprogrammed for the volume of the room, and which is measuring the gas concentration down to 0 ppm—before the room is opened [180, 181, 234]. Dry hydrogen peroxide 5% may be used where high water vapour concentration may damage—corrode—instruments. Three disinfection cycles and spore test are used routinely to check the effects; spores will be killed by the gas [180, 181]. Disinfection time is 3–5 h. No gas type has been proven effective against *Mycobacterium tuberculosis*.

Surgical hand hygiene—see separate Chap. 34.

Operations department—operational activity—see separate Chap. 35.

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Surgical Hand Disinfection

34

Abstract

Surgical hand disinfection reduces transient and sometimes permanent skin flora on the hands and thereby reduces the contamination of the surgical wound through small lesions, holes and damages to the gloves. Perforations of surgical gloves have been associated with a surgical site infection rate of 5.7%, compared to no perforation: 1.7%. A high bacterial load on the hands may cause residues of staphylococci, gram-negative bacteria and other bacteria, even after repeated washing with soap and water and repeated hand disinfection with 70% alcohol. Up to 10,000 bacteria may pass through tiny holes in the surgical gloves during the period of operation. Well-performed surgical hand disinfection before wearing sterile gloves may significantly reduce this number of bacteria passing over from the skin to the wound during surgery. The quality of surgical hand hygiene is therefore important, including the use of effective disinfectants. Centers for Disease Control and Prevention (CDC) recommends antimicrobial soap or alcohol-based hand disinfectant with persistent activity. Disinfectants that satisfy both the short- and long-duration effects of disinfection are 4% chlorhexidine gluconate and alcohol-based agents >70%, combined with chlorhexidine.

Keywords

Surgical hand disinfection · Surgical site infection · Postoperative wound infection · Technique · Disinfectants · Chlorhexidine gluconate · Alcohol-based agents · Infection prevention

34.1 Purpose

- To reduce the amount of superficial microbial flora on the hands, wrists and forearms.
- To reduce the risk of surgical site infection via the hands of the operation team [1–14].

34.2 Comprise

Anyone involved in surgery (contact with wound surfaces and tissues and/or in direct contact with sterile equipment used invasively or on usually “sterile” mucous membranes).

34.3 Responsibility

The hospital management should ensure procedures for systematic training and update in surgical hand hygiene for all staff in the surgical department, including extra shifts and temporary workers. Systems must be established to provide students in medicine, student nurses and other relevant health professionals with formal and practical training in surgical hand hygiene.

Department management ensures the training and implementation of surgical hand hygiene, including a regular inspection. Good surgical hand hygiene depends on good washing options, proper disinfectants and disinfecting soaps, daily maintenance and cleaning of the room for surgical hand hygiene, hand washing basins, dispensers for soap and other hand hygiene products, paper towels, etc.

Employees follow procedures for surgical hand hygiene and avoid recontamination—before sterile work.

34.4 Practical Measures

The hands should not have rings, other jewellery or wristwatches (1B, recommended and well documented from CDC) [3–14]. The nails should be short (2 mm), clean and without nail polish, and artificial nails should not be used (1A, highly recommended from CDC) [4, 10, 12, 14].

The sink may usually contain gram-negative bacteria. Routines for decontamination of washing basins and the tap may be required. Avoid splashes from the washing basin to the clothes and do not recontaminate the hands after washing [14]. Surgical hand disinfection—type and methods—must be approved by the department’s management who ensure efficacy documentation. Below are described methods used in hospitals in Norway and in many other countries [2, 3, 5, 6, 8–15]. Surgical hand disinfection and washing with chlorhexidine are equated with alcohol-based hand hygiene [6, 10–15].

34.4.1 Hand Hygiene Disinfectants

34.4.1.1 Chlorhexidine Gluconate 4% (Hibiscrub, Hib) [4, 5, 13, 15]

Chlorhexidine gluconate (4% chlorhexidine gluconate and 6% isopropyl alcohol), in a detergent base:

- Good acceptance from users, not absorbed by the skin, gives few skin irritations and allergic reactions.

- Broad-spectrum bactericidal, most active for gram-positive bacteria, less for gram-negative bacteria.
- Good effect against more resistant bacteria like MRSA.
- Not active for mycobacteria, bacterial spores and viruses.
- Not as fast acting as alcohol.
- Residual antibacterial effect increases upon each application.

NB! Soap, skin creams and other anionic compounds can inactivate residual chlorhexidine due to opposite charge [10, 12, 15].

34.4.1.2 Ethyl Alcohol—70–85% [5, 13, 15]

- Broad-spectrum, fast-acting, denaturing proteins in bacteria.
- Effective against gram-positive and gram-negative bacteria; uncertain effect against mycobacteria and viruses and does not work against spores.
- Alcohol (70% and higher concentration) added 0.5% chlorhexidine works even better against gram-positive bacteria.

34.4.2 Procedures Recommended During the Hand Hygiene Process [1–14]

- Waterproof apron prevents wet clothes during washing. The bacteria grow quickly through wet clothes. Use a type of washing basin that protects against splashing on the clothes.
- Standing or sitting position, depending on the situation. The hands should be at the height *over* the elbows.
- Taps and basin/equipment/wash place should be practical and hygienic. The water should run smoothly during the washing process. Automatic faucet must not be switched off after a short period of time. During the washing process, the water should have skin temperature.
- Check the bacterial content of the water, preferably every month, if there are problems, and disinfect the water faucet and sink with hot water over 75 °C for 10–30 min. Think of atypical mycobacteria when taking samples—atypical mycobacteria need special cultural conditions.
- Written instructions for surgical hand hygiene should be posted on the wall in the washing room. Follow routines for the appropriate disinfectant [5, 10, 12–14].
- The water should flow from the hands towards the elbows, with the exception of after brushing and cleaning the nails.
- A clock on the wall must be present on all rooms for surgical hand hygiene—follow the time for hand hygiene!

34.4.2.1 Chlorhexidine Gluconate 4% (Hibiscrub)

First operation each day or after a longer break; 5–6-min washing process (CDC, 1B) [10, 12, 14]:

- Wash the hands and forearms with chlorhexidine ca. 1 min to remove transient flora—rinse from the hands to elbow.

- The nails and subungual regions are cleaned with (eventually sterile brush) plastic disposable nail cleaners [10]. This is important for the first operation every day and less important in the next operations.
- After cleaning the nails, rinse off from the elbow to the hands.
- Right hand and forearm—3–4 min:
 - Wash each side of each finger, between the fingers, both sides of the right hand and wrists: 1–2 min.
 - Continue with friction right forearm to approx. 10 cm above the elbow for 1 min; rinse off the hands towards the elbow.
 - Wash with friction the right forearm to the elbow for 1 min and rinse off the hands towards the elbow.
- Left hand and forearm: repeat the same procedure for the left hand and forearm.
- Do not shake the hands to remove liquid.
- Hands and arms up and out of from the clothes as the person enters the operating room [10].
- Wipe with sterile towels in the operating room. Wipe in circular movements from the fingers to the elbow; a sterile towel for each arm.

Next operation (<60 min after the last disinfection) at least 3-min wash (CDC, 1B):

- Wash the hands and forearms with chlorhexidine; wash 2 min × 2 chlorhexidine procedures with friction; rinse off from the hands to the elbow.
- Wipe with sterile towel: from the fingertips upwards towards the elbow.

34.4.2.2 Alcohol-Based (70%++) Surgical Wash with Persistent Activity (0.5% Chlorhexidine Is Added) [7]

First operation each day or after a longer break; at least 3-min wash (CDC, 1B):

- Clean nails—rinse off from the elbow to the hands [10, 12, 14].
- Wash the hands and forearms for approx. 10 cm above the elbow with regular soap approx. 1–2 min to remove transient flora—rinse off the hands with water towards the elbow (CDC, II) [10, 12].
- Thoroughly wipe your hands and forearms. This is important! [10].
- Automatic dispenser is recommended—check that the portion is correct.
- Rub an ample of disinfectant (portion of at least 10 ml) on the hands, wrists, forearms and approx. 10 cm above the elbow for 3 min.
- Finally a new dose for both hands and wrists is recommended.
- Let the disinfectant dry on the skin before sterile gloves are taken on (CDC, 1B) [10, 12].
- Do not remove any disinfectant or suspension.

Next operation (<60 min after last disinfection)—at least 3-min disinfection:

- Wash your hands with soap and water for 1 min and dry well.
- Rub an ample of disinfectant (portion of at least 10 ml) on the hands, wrists, forearms and approx. 10 cm above the elbow for 3 min.

- Finally a new dose for both hands and wrists is recommended.
- Allow the disinfectant to dry into the skin before wearing sterile gloves.
- Do not touch the outside of the disinfectant or dispenser as this may be contaminated!

34.4.2.3 During Prolonged Surgery, >3 h

- Replace gloves and disinfect the hands before new ones are taken on, approx. Every 3 h, especially if only alcohol is used as a disinfectant.
- Replace gloves without contaminating sterile areas.

34.4.3 General—For All Methods of Surgical Hand Hygiene [10, 12]

Change gloves and disinfect your hands with alcohol-based disinfectant during surgery at:

- Accidents, rift, puncture of gloves.
- If gloves are contaminated.
- When moving from less “clean” operation zone to the cleaner zone during surgery.
- When gloves are covered with large quantities of organic material.

After each surgery, wash the hands after removing the gloves!

34.5 Background Information

Surgical site infections (SSIs) are registered in 5–12% of patients operated [16–18]. SSIs may lead to readmissions and reoperations. An infected prosthesis, cardiac or abdominal surgery wound incurs extra cost and often fatal course. See section, Postoperative wound infections—prevention.

34.5.1 Skin and Microbes: Response to Hand Hygiene

Stratum corneum constitutes the outer part of the skin; a total of approximately 15 layers of cells are to be changed within 14 days or more. Every minute, skin particles dissolve from the skin and partly released to the air. About 10% of the loose skin particles may be carrying 5–12 bacteria/particle.

The hands are carrying plenty of bacteria and fungi: 40,000–5 million/cm², like *S. aureus*, CNS, gram-negative rods, yeast, etc., with individual variations. A study among 133 health workers in Sweden detected *S. aureus* on the hands of 16.7% of men and 9.6% of women; 50% came from the environment and patients [19].

Handwashing with soap and water removes fatty substances in the stratum corneum, which is normalized after 1 h in 20% and after 3 h in 50% of the cases.

Handwashing with soap and water has a clear but limited effect on the reduction of microbes, and the effect is short. Soap washing can leave a dry skin that increases the particle liberation from the skin a few hours after washing.

Alcohol-based products have an immediate maximum antibacterial effect. By the addition of glycerol, etc., the skin does not dry, and for a period of time, there is minimal shedding and release of microbes into the air.

34.5.2 Purpose of Surgical Hand Disinfection (“Surgical Handwashing”)

Surgical hand hygiene reduces transient and sometimes permanent skin flora and thereby reduces the contamination of the wound through small lesions, holes and damages to the gloves [19–23]. Cruse and Ford showed that perforations of surgical gloves were associated with a SSI rate of 5.7%, compared to no perforation: 1.7% [20]. About 40% of gloves of orthopaedic surgery team may be perforated during surgery while 16% during common soft tissue surgery [21]. One thousand to ten thousand bacteria may go through tiny holes in the gloves, which are reduced below 100 by surgical hand disinfection before wearing gloves [4]. Although the quality of surgical gloves is good, there is a frequent perforation of gloves during the operation, often not noticed before the end of the operation. Not all gloves are equally strong and resistant to pressure, drag, rift, etc.

34.5.2.1 Lack of Evidence

Evidence is still limited for hand disinfection and the use of disinfectants including duration and use of brushes and sponges [10, 12, 14, 24–28]. Lister (1827–1912) used carbolic acid disinfection and reduced postoperative mortality. He disinfected the hands and instruments before operations; bandages were disinfected, and he disinfected the air over the surgical wound with nebulized phenol. However, there is an agreement that hand hygiene with only soap and water before surgery is leading to a high rate of SSI [4, 7, 12, 29].

High bacterial load on the hands may cause residues of staphylococci, gram-negative bacteria and other bacteria, even after repeated washing with soap and water and repeated hand disinfection with 70% alcohol [30]. Chlorhexidine added with 70% alcohol is more effective in removing staphylococci than gram-negative bacteria [30]. Hand disinfecting agents from different products show that no one eliminates all bacteria (see Fig. 34.1) [31].

34.5.3 Surgical Washbasin Room

Surgical handwash should take place in a separate room next to the operating room, not in the operating room or in storage for sterile or clean equipment or on the corridor, due to aerosol formation. The room should be at negative air pressure in relation to the operating room to prevent the spread of aerosol. It should have plenty of

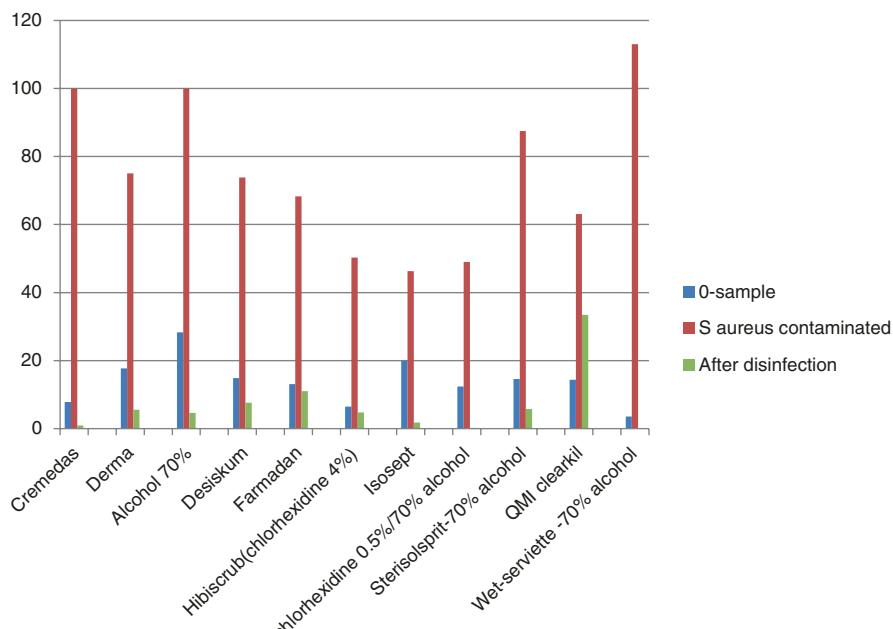


Fig. 34.1 Effect of different hand disinfectants. Number of bacteria—mean per fingertip—before and after contamination with *S. aureus* and after hand disinfection for 1 min. All types—except QMI ClearKil (USA)—available in Norway (Source: Ref. 31)

space and be designed to prevent the front of scrub suit against splashes that may increase the growth of microbes from the skin [14]. Good access to disinfectants, a clock on the wall to follow the time of the procedure, and direct access to the operating room with foot-activated doorway is important.

34.5.3.1 Cleaning of Surgical Washbasins and Dispensers

Infections via contaminated washbasins and dispensers are well known [32–34]. Packages with disinfectants and soaps must be disposable. Lack of cleaning results in bacterial growth, especially of gram-negative bacteria outside the equipment. In 19 of 28 investigated soap dispensers’ - outside, it was found resistant bacteria like *Acinetobacter baumannii*-totally resistant, *Klebsiella* and *Pseudomonas aeruginosa*-multidrug resistant, and a variety of other resistant gram negative rods and MRSA, whilst the soap itself was sterile [32]. Gram-negative rods may grow in the presence of disinfectants like chlorhexidine 1%, while MRSA can be inhibited by a chlorhexidine concentration of 0.0019% [32].

34.5.4 Surgical Hand Disinfection

CDC guideline for surgical hand disinfection points out that [4, 10, 12]:

1. Bacteria on the hands of the surgeon can cause SSI if introduced into the surgery area.
2. There is a rapid proliferation of bacteria on glove-coated skin.
3. Preoperative skin disinfection inhibits the proliferation of bacteria on the skin under the gloves.
4. Contamination of the surgical wound through perforated glove is reduced by disinfected skin.
5. Preoperative soap wash of the hands instead of normal preoperative hand disinfection has been the cause of at least one outbreak of postoperative infections.

Hand disinfectants are evaluated by:

6. Germ-reducing effect—*immediately*.
7. After the use of sterile gloves for 6 h—*persistent effect*.
8. After multiple applications within 5 days—*cumulative effect*.

Immediate and persistent effects are emphasized.

Immediate antimicrobial effect: Alcohols in concentrations 60–99% and alcohols 50–95% with added different disinfectant agents (quaternary ammonium preparations, hexachlorophene, chlorhexidine gluconate, etc.) have a significant and rapid effect on the number of bacteria on the skin immediately after surgical hand disinfection (CDC). The effect is greater than any other skin disinfectant (CDC). Secondly, chlorhexidine gluconate is more effective than iodophores, triclosan and soap in descending order (CDC).

Persistent antimicrobial effect is greatest for chlorhexidine gluconate 2–4%, followed by hexachlorophene, triclosan and iodophores in descending order (CDC). Use of hexachlorophene is now advised against because of absorption from the skin. Alcohols over 70% added with chlorhexidine 0.5–1% have approximately the same effect as chlorhexidine gluconate (CDC) [6, 11].

Antimicrobial soap or alcohol-based hand disinfectant with persistent activity is recommended! (CDC, IB).

The use of brushes and nail rinsers have been studied among 164 persons (randomized) [25]. There was no significant effect, at least for repeated surgical hand washes in the same day [25]. However, it is highly recommended that the nails are clean.

34.5.4.1 The Best Disinfectant

- Effects quickly on the skin's bacteria and have a broad-spectrum effect.
- Has persistent effect in excess of 3 h.
- User-friendly and environmentally friendly.
- Is not irritating to the skin.
- Is not inactivated by soap or skin creams.
- Is not harmful to use, non-flammable and cannot be misused [35].
- Is not contaminated by microbes (stay clean).
- Does not pose a risk of resistance development.

34.5.5 Disinfectants

The quality of surgical hand hygiene is important [2, 6, 24–28, 36–40]. However, the choice of disinfectants and methods are still under debate [38–40]. Glycerol added to alcohols may reduce the long-term effects [27]. Chlorhexidine gluconate is probably more effective than iodine- or hexachlorophene-containing products, but there are divergent results [29–31, 37, 40–45]. Large enough quantities are needed for effect, and contact time with the disinfectant is also important for effect on microbes [46–48]. Surgeons and nurses often prefer different hand disinfection methods [49].

The skin must tolerate the disinfectants. Among 1433 surgeons in Germany, 75% did not use skin cream due to concern for inactivation of the disinfectant [50]. Half of them had irritated skin problems, and 15% of these had microperforations of the sterile gloves [50].

Chlorhexidine gluconate 4% (Hibiscrub) is used in Europe for more than 30 years. The residual effect by binding to skin cells over several hours is important. The best effect on microbes is at pH 8. It is incompatible with anions such as soap, phosphates and nitrates and may be inactivated by blood, pus, secretions, etc. [15]. Antibacterial effect works on the bacterial wall with increased permeability, decomposition, leakage and death. The antimicrobial effect is broad, but the best effect is on gram-positive bacteria. It has effect on some gram-negative rods, may act on fungi, is effective against lipophilic viruses but has almost no effect on *Mycobacteria* and not on spores. The disinfecting effect comes slowly but remains over a long period, which is an advantage during long-lasting operations. Therefore, chlorhexidine is often regarded as the best disinfectant and used in combination with alcohols; the antibacterial effect is increased and prolonged. Studies on catheter infections have shown a more long-lasting effect than when using alcohols [41]. Chlorhexidine is usually not skin irritating, is not absorbed by the skin and is considered little allergenic. MRSA may have reduced sensitivity to chlorhexidine, compared with *S. aureus* (tenfold), but not at the concentration used. Chlorhexidine reduces colonization of MRSA and VRE and the risk of catheter-associated blood-borne infections and SSIs [51].

One hour after the hand disinfection, chlorhexidine has still a good antibacterial effect, as shown by fingerprint in an agar plate and then seeded with *S. aureus* [52]. After incubation, there was a rich growth of *S. aureus* on the plate, except for the fingerprints where there were no growth [52].

Alcohol-based agents: ethanol and iso- and n-propanol have the ability to denature protein rapidly and thus a rapid effect on bacteria, partly fungi and mycobacteria, and some viral groups [15]. They have been used in Europe for more than 80 years. Viruses with envelopes (HIV, herpes, etc.) are killed by alcohols, whereas nude viruses (adeno, entero, etc.) are more robust and resistant to 80–85% alcohol. Spores survive in alcohols for a long time. Alcohols have different antimicrobial effects related to the type of alcohol. A concentration of over 80% ethanol is equivalent to a slightly lower concentration of propranolols. Isopropanol 70% combined with chlorhexidine 0.5–1% is effective over 3 h. Alcohols are added with glycerol in order not to dry out the skin. Alcohols are not skin irritating, toxic or allergic.

Alcohols in concentrations 50–95% added chlorhexidine have a significant, rapid and persistent effect on the number of bacteria on the skin over several hours, corresponding to chlorhexidine gluconate. The effect of alcohols added with chlorhexidine is greatest against gram-positive bacteria and less for gram-negative [30, 48].

Iodine and iodophors: 7.5–10% of povidone-iodide affects microbes via the iodine component with oxidizing potential [15, 41, 53]. Microbes may survive high concentrations of iodine. The effect is best at lower concentrations. Povidone-iodide is most commonly used. The activity is somewhat slow, does not work very long, is easily deactivated by proteins and does not kill enterovirus, and the concentration is reduced by storage. Surgical hand disinfection for more than 3 min with 7.5% polyvidone-iodide-betadine may significantly reduce bacteria on the hands, compared with less than 3 min [53]. If the operation lasts longer than 95 min, there is increasing risk of recolonisation [53]. Iodine may be absorbed through the skin, have an effect on thyroid tissue and may cause skin irritation and allergy. Therefore, this disinfectant should generally not be used for surgical hand disinfection.

Hexachlorophene is discouraged to use, due to skin absorption, neurotoxic effects and limited efficacy against gram-negative bacteria.

Triclosan: chlorinated dioxy diphenyl ether (Irgasan DP 300) is mostly not used due to selection of bacterial resistance [54]. It has a destructive effect on the bacterial cytoplasmic membrane. Triclosan—0.4–2% in alcohol—is used in hand disinfection, has a slow effect and lasts relatively unaffected by organic matter. Effects on bacteria, fungi, etc. are variable. There is no described toxic or allergic effect of the drug. Because of problems with resistance development, triclosan is not recommended.

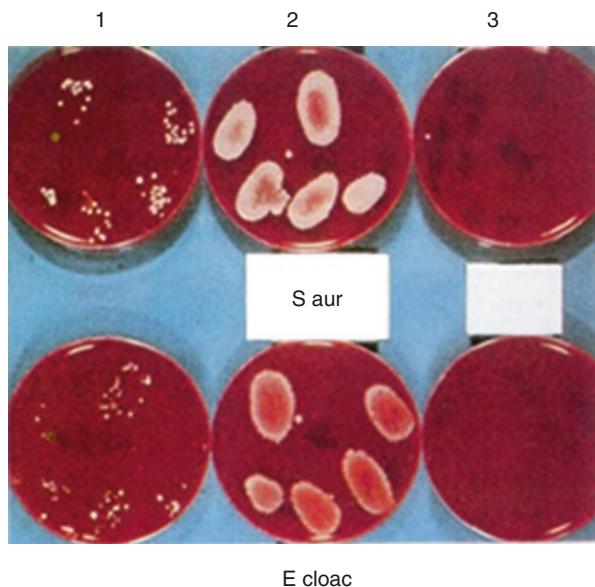
Newer agents and combinations are developed, for instance, from quaternary ammonium products as undecylenamidopropyl trimonium methosulphate and 2-phenoxyethanol. These are also used in the decontamination of MRSA. *Sterillium* is containing 2-propanol (45%), 1-propanol (30%) and mecetronium etilsulphate (0.2%) and shows good test results (EN 12791 protocol) [26, 39, 43, 44]. *Sensiva* contains 1-propanol (45%), 2-propanol (28%) and lactic acid (0.3%) and passes the disinfection test [26]. *Desderman N* contains 78.2% ethanol and 2-biphenolyl (0.1%), but did not pass the accepted test [26, 43]. *Spitacid* contains 46% ethanol combined with 27% isopropanol and 1% benzyl alcohol [43]. Numerous agents with combinations of 70% or higher alcohol concentrations up to 80% are often combined with 0.5% chlorhexidine [48] (Fig. 34.2).

34.5.6 Recommended Surgical Hand Disinfection

Antimicrobial soap or alcohol-based hand disinfectant with persistent activity is recommended (CDC Category IB).

After 30 days, the incidence of SSI was approximately similar after surgical hand disinfection with alcohol-based agents, compared with 4% chlorhexidine gluconate, used with the same disinfection time, 5 min [5]. In total 4387 surgical-treated

Fig. 34.2 (1) Normal finger-flora, (2) after contamination with *S. aureus* or *Enterobacter cloacae*, (3) after “bath” in chlorhexidine alcohol (Source: Kjølen, Andersen. J Hosp Infect 1992; 21:27–71) [30]



patients participated in this study. Alcohol-based agents seemed to be associated with fewer skin and eczema problems of the surgical team [5].

Disinfectants that satisfy both the short- and long-duration effects of skin disinfection are 4% chlorhexidine gluconate and alcohol-based agents >70% combined with chlorhexidine.

34.5.7 How to Perform Surgical Hand Disinfection?

Surgical disinfection time is unclear and not well studied and varies from 3 to 6 min [3, 4, 8, 10, 12, 14]. It is, however, important to not mutilate the skin using a hard scrubbing or strong disinfectants! Disinfection time >6 min may not reduce further microbes on intact skin, and shorter time than 3 min is usually not recommended [10, 12, 14].

Two operating teams—cardiac surgery and orthopaedics and approximately 25 surgical personnel—were followed during surgical hand disinfection [2]. Most of them used Hibiscrub (4% chlorhexidine). The heart team had a mean surgical hand disinfection time of 2 min and operation duration of 3 h and 20 min, while the orthopaedic team had disinfection time of 3.5 min and operation duration of 2 h and 40 min [2]. After performing surgical hand disinfection, before moving to the operation room and gloving, 94.1% had sterile fingertips [2]. Immediately after termination of the operation (before unsterile contact), 93.4% of the personnel had sterile glove fingertips. After the gloves were removed, 64.2% of surgeons still had sterile fingertips. There was a good residual effect of Hibiscrub after 2–3 h—even though the duration of the surgical hand disinfection was short [2].

Sternal wound infection with *Serratia marcescens* among six patients after heart surgery in 2003 resulted in contact tracing [55]. Environmental samples were negative. A nurse and a surgeon participated in all operations, but primary screening gave no upbringing. The surgeon operated with two rings on the right hand. Microbial samples taken from the rings on the palmar side of the hand showed the growth of *Serratia marcescens*. The rings were removed and the outbreak stopped [55]. Even with repeated surgical hand disinfection, microbes may survive under rings and other jewellery.

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Operation Department: Infection Control

35

Abstract

Infection control in the operation department is the result of many single factors and routines, based on experience, documentation and expert panels through more than a hundred years. Many factors and routines in surgery are evidence-based, but most of them are still lacking evidence and can probably never be investigated because of ethical problems. Consequently, consensus and guidance are used to a great extent. Surgery opens into sterile tissues for hours, where there is massive tissue damage by knife, diathermy, clogging of vessels, pressure against and drying of tissues, decreased blood supply, impaired phagocytosis and impaired infection defence. Microbes deposited in this devitalized tissues may find a good basis for growth and proliferation if there is lack of infection control and sterility. For patients with ongoing infections and who need surgery, special routines are made to prevent the spread of infections in the operation department. This chapter is a practical description of many important preventive procedures that may protect the surgical patient against surgical site infection (SSI).

Keywords

Surgical site infection · SSI · Postoperative wound infection · Organization and function · Personal hygiene · Scrub suits · Operation team · Sterility · Microbes · Ventilation and air pressure · Clearing and preparation of operating rooms · Cleaning and disinfection of rooms · Disinfection of equipment and instruments, Preoperative routines · Sluice functions · Postoperative phase · Patients with infections · Surgery on pulmonary tuberculosis

35.1 Purpose

- Prevent postoperative infection.
 - Prevent infection transmission from patients being operated to staff, instruments, equipment and environment.
-

35.2 Comprise

- All personnel including students, visitors, temporary staff, hospice aide, supervisor, service personnel, etc., as well as equipment, instruments and environment associated with the operation department. All patients and their beds and equipment brought in and out of the department.
 - Anyone involved in surgery (contact with wound surfaces and tissues) and/or in direct contact with sterile equipment used invasively or on usually “sterile” mucous membranes.
-

35.3 Responsibility

The hospital management should ensure surgical activities are in accordance with the quality standards of hygiene and infection control for patients and personnel and ensure that patients with infections or susceptible to infections get adjusted surgery and are protected against the spread of infection. Postoperative infections must be registered, assessed and followed up.

The department management should promote hygiene principles and ensure safe conditions during surgery for the patient and personnel concerning quality, safety, environment, functional conditions and resources.

Each employee shall comply with the department’s hygiene guidelines, infection control measures and personal hygiene.

35.4 Practical Measures

Infection control in the operation department is the result of many single factors and routines, based on experience, documentation and expert panels through more than a hundred years [1–13]. Many factors and routines in surgery are evidence-based, but most of them are still lacking evidence and can probably never be investigated. Consequently, consensus and guidance are used to a great extent.

Access control is a specific restriction for the surgical department to prevent transmission of infection. This control applies to patients, personnel, visitors, equipment and instruments.

35.4.1 Personal Infection Protection

- *The department is a green and clean area.* The uniforms are quickly burdened with bacteria [14]. Therefore, replace the uniform/private clothes with the surgical department's green uniform and shoes before entering the department. Use cap that covers the hair and ears, and wash the hands before entering the department.
- *Hand hygiene and gloves.* See Chap. 12 on hand hygiene and wearing gloves.
- *Jewellery (rings, bracelets, necklaces, earrings, etc.), watches or piercing* is not allowed in the operation department or with other patient-associated work.
- *Private clothing is not allowed* except for underwear. No private textiles will be used as headgear.
- *All equipment brought into the department should be disinfected.* Minimum personal equipment should be brought in. Disinfect mobile phones, searchers, pens, glasses, ID badges, etc. before bringing in. Use cloths with alcohol. ID signs and access cards may be heavily contaminated with microbes [15].

35.4.1.1 Blood-Borne Infections and Other Infections

In the operation department, the personnel may be exposed to infection from patients, or they may themselves become a source of infection with the risk of transmission to equipment, colleagues and patients [11, 16, 17].

- Avoid accidents like stabbing and cutting damage; wear double gloves for blood-borne infection and invasive procedures.
- Use surgical mask/cap and optionally visor/goggles during invasive procedures.
- Immediate measures: follow advice and measures if accident. See chapter on: "Accidents with blood- or tissue".
- *Hepatitis B vaccine* should be offered to all employees. Inform all newcomers. See also chapter on "Infection Control for Health Professionals".
- *Ongoing infection or carrier status.* Individuals with acute infectious or carrier state of defined blood-borne viruses (hepatitis A, B, C, D and E, HIV, HTLV, etc.) should not participate in invasive treatment. The same applies to carriers of group A streptococcal infection, MRSA, VRE and other multi-drug-resistant bacteria (MDRO). See chapter "Infection Control for Health Professionals".
- *Tracing of infections among personnel.* In case of MRSA infection transmitted to a patient, exposed personnel should be tested (see MRSA procedures). If there are two or more SSIs with group A streptococci, the operating team and other personnel present during the operations are tested for carrier status [16]. After infection from patient to personnel, it may be appropriate to test those who have been in contact with the patient [17].

35.4.1.2 Protective Clothing

The operation department is a “green and clean zone”. In this area, only clean green clothes (or selected colour) and clean socks, shoes and caps are put on before entering. Private clothes or shoes increase the burden of particles and microbes in the environment and are not allowed. Follow the routines and change to clean scrub suits every day and after visiting other departments, after taking part in a contagious operation and after contamination of the scrub suit. No green clothes outside the operation department! Exceptions are urgent activity or transfer of the operated patient to postoperative/intensive departments. During transfer, change shoes and use a clean white gown (changed after each shift or more often) over the scrub suit, and immediately return to the operation department. After working in scrub suit *outside* the department, change to a new green scrub suit upon return.

- *Surgical masks* for everyone in the operating room. The coloured side should be out, white side in. Bend the clamp to fit it over the nose. Tie up on the head outside the cap and down the neck. Take off the mask by first opening it in the neck and then on the head to avoid that it falls down the chest. Do not reuse the mask!
- *Respiratory protection (filtering half masks) without exhalation valve*—P3 mask—is used for operations with suspected airborne infection (see “isolation regimes” and “respirators”). Learn to take on and off the respirator.
- *Visor/goggles* are used during surgery where one knows there is a risk of splashing. Blood-borne virus may penetrate normal eye mucosa.
- *Sterile surgical gown* should be used by all working in the surgical area and/or with sterile instruments. During operations with larger amounts of blood/body fluids, the gown should have fluid-tight front and sleeves.
- *Sterile gloves* should cover well the cuff of the operating gown. Surgical hand disinfection (see separate section). Gloves have often holes, most commonly observed when removing the gloves. Use quality gloves that can withstand pressure and pull, etc., and wash the hands after wearing gloves.

35.4.1.3 Other Infection Control Measures

- *Covering*. Surfaces/areas that are expected to be contaminated with blood/body fluids are covered/shielded with liquid-proof material.
- *Compresses* are control-counted. Compresses should have high quality and should not release loose particles. Deposit of particles and debris in the wound poses a risk for SSI when establishing *locus minoris resistentiae*—a site for bacterial growth and infection.
- *Used instruments* are opened and brought quickly to cleaning and disinfection in instrument washer. Avoid drying of instruments due to the risk of prions.
- *Manual cleaning* of equipment and instruments before disinfection is not recommended. If such a procedure is to be carried out, for example, for air-powered tools, optical equipment, etc., special protective conditions should be available, and the process should take place under the fluid level to avoid splash.

35.4.2 Localities

See also Chap. 33 on “Prevention of Postoperative Wound Infections.”

The operation department is centrally located, easily accessible from intensive units and emergency services and shielded from transit traffic.

- *Green zone* with a high level of infection control is clearly defined with the best practices followed by the patients and staff.
- *Patient waiting area* should be in the green zone. Surgical personnel in scrub suits serve the patients. There is no access or transit traffic for other personnel.
- *Sluice systems* for patients and staff.
 - Patient sluice for bed, stretcher and 2–3 persons (from 16 to 18 m²) for any pre-treatment of the patient. Wash the basin and waste bin, but not the storage space.
 - Staff sluice with space adapted to the number of employees, visitors, students, etc. (1–2 m² per person). Ample wardrobe for dressing and with separate closets for private clothes, toilet, shower, cloth racks for used laundry and sink. From the wardrobe walk through a smaller sluice where cap and shoes (preferably washable) are put on, and hand hygiene is done before entering the department.
 - A separate textile storage room for green cloths (scrub suits, etc.) in connection to the wardrobe.
- *Storage rooms for operation tops (operating table) and one separate storage for clean cover material on the top.* Cover the operation top with single-use plastic after cleaning and preparing for the next patient.
- *Washing room for operation tops:* unclean and clean sides with separate exhaust air and sluice to avoid the spread of aerosols into the operation corridor.
- *Shoe washing machine* for washing and drying, unclean and clean sides with separate exhaust air and sluice to avoid the spread of aerosols into the operation corridor.
- *Surgical hand disinfection room:* 3–6 m² depending on the staff number, with shielded basin area to avoid splashes. Written guidance, only current disinfectants and soaps and clock are on the wall. No storage space due to aerosols - and no other functions. See Chap. 34, surgical hand disinfection.
- *Anaesthesia induction room* with ample space for patient bed and 2–3 people (ca. 16 m²). Wash basin and cabinets for clean equipment used in connection with induction.
- *Operating theatre:* good space for a minimum of five to eight people, patient and equipment. Necessary area is 40–60 m². Storage of equipment in the theatre is not recommended. If still extra equipment is needed to be stored, place it in tight, clean boxes, cleaned outside between operations. Coordinating staff assisting the operation team must have at least 2 m distance from the patient and sterile equipment, in all directions. Walls, floors and ceilings should be complete and well maintained, and the surfaces must withstand strong disinfectants. There should be zero tolerance for wires and hoses on the floor.

- *Storage rooms* and hygienic requirements for storage of sterile equipment. Clean/sterile equipment should be cleaned on the outside of the packages and stored in cabinets with glass doors to protect against dust. Storage rooms for sterile equipment should not be used as office, meeting room, storage room for unclean items, etc.
 - *Sterile storage room*: plenty of space ($16\text{--}20 \text{ m}^2$), dependent on activity, easy to clean, and a wash basin/dispenser for hand disinfection in close proximity—outside the door. Cabinets with glass doors. Cleaned daily and the surface of the benches is disinfected. Limited access due to burden of microbes and particles in the air. See “Guidelines for Storing Clean and Sterile Equipment”.
 - *Sterile storage room for anaesthesia*: $14\text{--}18 \text{ m}^2$, follow the guidelines described above.
 - *Sterile fluid storage room* should be in a separate compartment: $4\text{--}6 \text{ m}^2$, follow the guidelines described above.
 - *Storage for clean equipment, couch equipment (to place and adjust the patient on the operation table)*, etc. is surveyable, $16\text{--}20 \text{ m}^2$ and easy to clean, and the floor should only be used as storage space for equipment to be run on wheels/pulleys. Cabinets with glass doors to protect against dust. Couch equipment must undergo thorough disinfection after each use and must be stored clean or may be disposable.
 - *Storage of “clean-unclean” equipment*. A designated storage room ($16\text{--}20 \text{ m}^2$) for equipment and machines containing water, like water heater equipment, that cannot be disinfected satisfactorily after use. This equipment is constantly exposed to the growth of bacteria in the inner parts. If the cleaning process is unsatisfactory, it should be washed and disinfected thoroughly outside and stored separately. Connectors to the machines should be considered as potential sources of infection for gram-negative bacteria and mycobacteria.
 - *Storage of mechanical equipment* (CPAP, ventilators etc) with internal technical/electric parts that are air-cooled by drawing air from the room, should be evaluated for special handling and storage since the contamination of inner parts may be a risk for patients.
 - *Storage for plaster and equipment for plastering* should be a separate, clean and dry room, not stored with other equipment. Plaster is a good growth material for microbes, and it is mostly not sterile. Plaster should be placed in clean, dry cabinets with glass doors to protect against dust and microbes.
- *Disinfection room* ($16\text{--}20 \text{ m}^2$) is divided into a clean and unclean side. This room is a “wet room” that should have negative air pressure towards corridors and operating rooms. The decontaminator and instrument washing machine, etc. should be checked daily for temperature and logged at regular intervals. The floor should not be used as storage space and should be easy to clean.
 - A well-designed disinfection room for anaesthesia equipment (16 m^2) is needed.

- *Sterilization central* for disinfecting, controlling, packing, sterilizing and storing of sterile items is often placed nearby or in connection with the operation department, with a separate sluice for changing clothes. The central may also be outside the operating area, with a clean and direct transport path (elevator, trolleys, etc.) to the operation department. A separate room for washing and drying of the transport trolleys between each use is needed.
 - *Inspection/disinfection.* All disinfected and cleaned equipment, ultrasonic bath, instrument washing machine, etc. are checked during the process. A workplace and place for necessary equipment require approximately 10 m².
 - *Packing room—packing of clean equipment to be sterilized.* This clean room area is dependent on the operative activity of the hospital and the number of employees. The room should be at least 16 m² and 7–10 m² per workplace. Positive air pressure with filtered air in, as well as more than 15 air changes per hour.
 - *Autoclave room—sterilization room* with a sluice system. The area is dependent on the number of autoclaves, sizes and types. Through-fare autoclave is an advantage with one unclean input side and one clean side for out take. A separate steam exhaust ventilation and negative air pressure on the unclean side are needed. The central should be shielded from noise, heat and steam from this unit to avoid humidity on prepared sterile instrument packs. A regular control of autoclave and other sterilization machines is needed.
 - *Storage for sterile equipment.* The same quality as on sterile stock in the operation department.
 - *Unpacking* of goods that have outer packaging is done in a separate room with a sluice to the sterile central. The room should have a negative air pressure and exhaust ventilation.
 - *Other storage needs* are determined by the sterile and operation department's activities.
- *Other rooms* are waste disposal room (12–16 m², with negative air pressure and wash basin); textile room; toilet and shower (minimum one per ten employees); dining, rest and meeting rooms; and general office.

35.4.3 Bacteria, Ventilation, Humidity and Temperature

The number of airborne particles and bacteria in the operating theatre should be very low. There are specific requirements concerning colony-forming units (CFU) per m³ of air [6, 11–13, 18–23]. All equipment brought into this room should be clean and have a low bacterial burden. See also chapter “Prevention of Postoperative Wound Infections, Point D”.

- *Uncontrolled air currents* may occur from sudden and large movements in the room and increase the risk of bringing particles and microbes from the staff and environment to the sterile area and to the surgical site. Traffic in and out of the operating room creates uncontrollable air currents [3, 4, 12, 13, 18–23].

- *Tranquillity* and close the doors before the start of surgery for to settle airborne bacteria-carrying particles.
- *Persons* present in the operating room have an impact on the number of bacteria-carrying particles in the air [12]. Ideally, no more than eight persons should be present in a regular operating room. Local routines should be followed.
- *Clothing* reduces bacteria release from the skin into the air. Covering all the skin and using dense textiles reduce the release of skin cells, particles and bacteria even more.
- *Instruments* should be covered immediately after laying—until use. Check air currents. Avoid contamination of sterile instruments from persons that unaware come into the airflow that goes towards the instrument tables.
- *Ventilation* is 15–25 air changes/h. CO₂ level is <1000 ppm. Fresh air supply (filtered air) is minimum of 15 L/s/person + 2 L/s/m² surface in the operating room.
- *Positive air pressure* in operating rooms and sterile storage rooms in relation to the rest of the department.
- *Sterile storage room* is 10–17 air changes/h.
- *Humidity* is 35–40% in operating rooms. High moisture may increase bacterial growth, however weighted against a comfortable working environment. Humidity is 35–60% in sterile store rooms.
- *Temperature* is 18–25 °C. Higher temperatures can increase the growth of bacteria/release from the skin. Do not use fancoil or refrigerators. Condensation and dust collection lead to growth of bacteria and fungi in the exhaust air.
- *LAF ceiling* should be regularly checked by special procedures.

Bacterial load of the air is defined in colony-forming units (CFU)/m ³ air The following is recommended [6, 9, 11, 20–23]	
Operating room, common	<100 CFU/m ³
Operating room, ultraclean (LAF)	<10 CFU/m ³
Invasive investigations/laboratory operations	<100 CFU/m ³
Sterile storage/packing room	<150 CFU/m ³

CFU controls of clean rooms are done in defined systems where air samples are taken in a sterile method several times, before, during and at the end of surgical treatment. Air is fed quickly through a calibrated system, and bacteria are deposited directly on a growth medium. This is incubated in a culture system for 2–7 days, and the number of colony-forming bacteria is counted. Fungi are also noted. The presence of fungi in clean rooms is not in accordance with clean room work. (See chapter “Prevention of Postoperative Wound Infections”, point D for the performance of CFU control.) Measurements show that most bacteria in the air come from persons present in these clean rooms.

- *Airborne infection-ventilation system.* Patients with airborne infections should be treated in the operation department, if needed. This may be done without transmission of contaminated airborne dust particles, aerosols or droplets to

other parts of the department and ventilation ducts [6, 11]. The ventilation ducts of the actual operating room should be closed (and taped over) towards adjacent rooms and exhaust ducts (if the ducts are common with other operating rooms) [6, 11]. A negative air pressure (-25 Pa) can be established in the operating room and also later on used for airborne infections in the event of risk of aerosols, particles or droplets of infectious material. Negative pressure condition must be kept constant. “Reversible” pressure ratio rooms, used both as positive-pressure and negative-pressure room, can create uncertainty with regard to contamination within air ducts and filters, if not followed up [24, 25]. Operating rooms with LAF system should not be used for patients with infections. See Sect. 35.10.

35.4.4 Cleaning

Thorough cleaning between operations, final cleaning in the end of the day and disinfection and control in the morning, before the operations, are the basic requirements for all types of operating rooms in order to maintain “clean room standard” [19–23].

Cleaning products (soap and detergents) should be the same ordinary as used in the rest of the hospital and should satisfy safety requirements, including being free of microbial growth (see chapter “Cleaning of Rooms”). For cleaning at surgery departments, specially trained personnel are required.

35.4.4.1 Cleaning Equipment

- Cloths and mops must meet the quality requirements for release of particles and purity. Follow guidelines for handling used textiles.
- Clean equipment is used for each room.
- The mopstick is cleaned manually, and the bucket is disinfected in the decontaminator.
- Clean the cart and rack daily with soap and water.

35.4.4.2 Cleaning Frequency

Main Cleaning Two Times per Year

- Sluice systems for patients and personnel, operating rooms, anaesthesia induction rooms and surgical hand disinfection room.
- Windows.

Main Cleaning One Time per Year

- Storage rooms for clean and sterile equipment.
- Operation department—the rest of the rooms.

LAF System

- Splash and contamination must be removed after each surgery.
- Cleaned once per year with subsequent particle/air velocity check performed by a specialist (Table 35.1).

Table 35.1 Other regular cleaning

Other regular cleaning	Frequency
Wall, operating room	Daily/final cleaning Weekly wash at the height (180 cm)
Suspension of operating lights	Daily + needs
Suspension for surgeon pendulum	Daily + needs
Anaesthesia pendulum	Daily + needs
Ventilation valves	Weekly (daily at the operating rooms)
Cooling unit/of unit	In accordance with instructions for use <i>NB!</i> May be contaminated by bacteria and fungi. Avoid using it. If used, clean the outside daily
Drying cabinet	Weekly + daily at the bottom
Extractor fans	Weekly to monthly
Trolleys, instrument boards, carts, etc.	Daily cleaning + if required

Operation Top, Table and Shelf

1. Operation table top/table	Cleaned in the laundry after use
	When <i>infected during surgery</i> , disinfect the table top/table in the operating room, and follow the procedures for disinfection time before it is brought to the laundry room
2. Operation department without laundry	Clean or disinfect in the operating room
3. Plinth (base) for operating table	Cleaned according to guidelines
4. Extra cleaning of operating table/top	Weekly and when needed
Patient lift	Cleaned after use and weekly
Unit for single-use heater	Washed after use. The connection hose is cleaned in the washing machine if required
Anaesthetic wagon, trolley	See separate procedures
Anaesthetic apparatus, monitoring equipment	See separate procedures
Blood pack cabinet, heating cabinet	Weekly + when needed
Refrigerator/freezer	Every month/half year + if needed
Sterile storage rooms	Daily cleaning of floors and horizontal surfaces and monthly cleaning of shelves and inside of cabinets
Sterile storage room—Remote	Cleaning every 14 days
Medicine room	Daily, clean the floor, sink and bench
	Monthly, cleaned drawers, medicine shelves, cabinets and refrigerators
	C-bench, for preparing medicines
Other warehouses and clean rooms	Daily cleaning of floors and horizontal surfaces
	Quarterly cleaning of cabinets and drawers
Sluices, handwashing room, disinfection room	Daily cleaning of floor and horizontal surfaces × 2 + if required

Anaesthesia induction room	Floor and horizontal surfaces are cleaned 2 x daily + if necessary
Preparation room (tissue samples)	Monthly cleaning of cabinets and drawers Daily cleaning of floor and horizontal surfaces + if necessary
Corridor	Monthly cleaning of cabinets
Green elevator	Daily
Personnel rooms, wardrobes	Daily

35.4.5 Clearing and Preparation Before and After Surgery

35.4.5.1 Before Surgery

Operating room—morning: Operating lights, operating tables, technical equipment and all horizontal surfaces at work height are wiped off by 70% alcoholic disinfectant. Floor is moist-mopped [22].

Anaesthesia induction room—morning: Lamps and surfaces are wiped off with 70% alcoholic disinfectant. Floor is moist-mopped.

35.4.5.2 After Each Operation

Cleaning and Preparation of the Operating Room

After Each Operation [22]

Surgical nurse clears the operating room for instruments, sterile and used equipment.

Anaesthesia personnel takes care of own equipment.

Used textiles: Check and remove all from the room. Sort, i.e. wet/bloody textiles are packed in plastic bag before it is put in the textile bag; other textiles are placed unpacked in a textile bag that closes.

35.4.5.3 Waste

- Black bag: household waste and relatively little contaminated and moist waste.
- Yellow bag in risk box/box: wet through blood compresses, blood clots, drainage bottles that cannot be emptied into decontaminator, etc.
- Plastic cans/boxes: stinging/cutting waste.
- *Waste buckets:* cleaned/disinfected in flush decontaminator.

35.4.5.4 Suction Flasks, Etc.

- Drained, cleaned and disinfected in a flush decontaminator or emptied into a flush decontaminator and then cleaned/disinfected in an instrument washing machine.
- Accessories for suction flasks are cleaned and disinfected in the instrument washing machine optionally in a flush decontamination unit.
- Stand/holder for suction flasks. Manual cleaning.
- *Suction ejector:* follow local guidelines.

35.4.5.5 Cleaning and Disinfection

- *Fixtures, technical equipment, operation lamps, etc.* are cleaned with detergent and water.
- *Walls:* wash where there have been spills/splashes.
- *Floors* are wet-mopped.
- *Operation lamps, instrument tables, etc.* are wiped over with 70% alcoholic disinfectant.

The operating room is made ready for the next operation.

35.4.6 Operation of Infected Patient

Infection risk is considered before the surgical treatment and re-evaluated during operation.

Measures are depending on the degree of infection risk: larger and less risk of transmission.

Extreme dangerous infections, like Ebola, Lassa, SARS, MERS, Nipah, etc., are treated in a separate risk level 4 units.

35.4.6.1 Selection of Operating Rooms and Time

- Do not use LAF operating rooms for known infections, regardless of infection.
- Plan the infection operation at the end of the day, as assessed from the patient's condition and type of infection.
- Minimum equipment present in the operating room.
- Negative pressure is an advantage in terms of infections spread through air.
- *Airborne contamination:* choose an operating room with separate ventilation or ventilation that can be shut off and close to and from ventilation ducts with plastic and tape.

35.4.6.2 High Risk of Infection and Transmission (by Question, Contact Infection Control Personnel)

- Infected tissue with necrosis.
- Draining of pus cavities, abscesses, etc.
- Large, massive skin infections.
- Patients exposed to or colonized with or ongoing infection with multiresistant bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA) or other multidrug-resistant organisms (MDRO).
- Patients in contact with the health service abroad last year, where no microbiological survey has been made afterwards.
- Patient with blood-borne infection (HIV, hepatitis viruses, prions).
- Patient with bacterial or viral gastroenteritis.
- Patient with respiratory infection (influenza, tuberculosis, other airborne infections).

Preparation

Clean/cover. The operating room is cleared for unnecessary equipment, and fixed equipment is covered. Consider the use of complicated technical equipment that is difficult to clean/disinfect.

Ventilation: check for control of contaminated air.

Disposable equipment is preferably used if disinfection must be carried out chemically or when disinfection procedure is difficult to perform. Do not take in more equipment than necessary.

Collecting packaging: It should be enough for infectious waste and textiles.

Coordinating personnel present in the room are using protective gown over scrub suit and gloves.

Face protection is used: visor/goggles, etc., dependent on the type of infection.

Blood-borne infection: use double gloves and visor/goggles (see chapter “Isolation—Blood-Borne—Pathogens”).

Airborne infection: use respirator P3 mask at defined type of infection (see chapter “Isolation Airborne/Droplets”).

The door to the room is sign posted.

During Operation

Few participants: only necessary personnel are present.

The door(s) closed.

Controlled conditions: biological material and used equipment are kept under control.

- Minimal use of suction systems and of other aerosol-forming procedures such as diathermia.

After Surgery

Anaesthesia is terminated in the operating room.

Transfer of the patient to a clean bed or stretcher in the operating room.

Anaesthetist takes care of the anaesthesia equipment and package of infectious waste, textiles, etc. Bring risk-packed, reusable equipment for cleaning/disinfection. Disinfect trolley/cart and leave it on the operating room during the disinfection time.

Surgical nurse takes care of instruments and equipment and clearing the operating room.

Disinfection of the operating room: surgical nurse informs about the type/extent of disinfection to the cleaner. (See “Disinfection of Rooms and Surfaces”.)

Unused equipment is treated as used.

Waste/textiles are transferred to new, clean transport packaging in/at the doorway to the disinfection room or corridor.

Textiles and clothes are taken off. Personnel take off gowns and PPE inside the operating room—at the door. Shoes are left in the room.

The staff participating in the operation change—after shower—to clean scrub suits before new work.

35.4.6.3 Less Infectious Patient: Infectious Surgery Without Spreading to the Surroundings

Some interventions in infected tissue can be treated as a normal operation if spills/sprays/dispersion to the environment does not occur, for instance:

- Minor skin infections.
- Local abscesses.
- Acute appendicitis.
- Cholecystitis, etc.

If the degree of infection is uncertain or diffuse, or infection with multiresistant bacteria is suspected, the operation is prepared as described in Sect. 35.10.1. Surgical nurse and the responsible surgeon assess and decide which measures should be implemented before, during and after surgery. In case of doubt, contact the infection control personnel. If full infection control has been performed during the operation and the infected material has been adequately treated, only instruments and equipment used by the operation team should be treated as infected.

35.4.7 Disinfection of Rooms and Surfaces

During all surgical interventions, blood splash may be present near the patient. All biological material must be treated as potential infectious. In case of pus infections, special cleaning measures are required. In case of a high risk of spread of infection, a complete disinfection of the room is carried out. In case of minor risk, “spot disinfection” is performed.

35.4.7.1 A. General Disinfection, “Pus Wash” or “Infection Wash”

When To Be Done

- After surgery in infected tissue where infectious material has contaminated the environment, the situation has been out of control. Floors, walls, fixtures, etc. can be contaminated.
- Contagious disease where the room is considered to be generally contaminated, e.g. MRSA, VRE, other MDROs and tuberculosis.
- In cases where contamination of infected material is massive, the infection is serious and the delimitation is uncertain, general disinfection is carried out.

Line of Action

1. The person who performs the disinfection procedure:
 - (a) Single-use gown, waterproof with long sleeves and cuff.
 - (b) Gloves covering the cuff.
 - (c) Cap and mask.
 - (d) Visors/goggles.

2. Follow the recommendation for clothing as outlined in the hospital's "isolation regimes".
3. In case of massive contamination, most of the soil and biological materials are removed with absorbent material, packaged and treated as hazardous waste. Disinfectants—like chloramine 5% or PeraSafe—are applied on contaminated surfaces and equipment with cloth or sponge. Effect time is 60 min for chloramine and 30 min for PeraSafe.
4. Equipment used is packaged and treated as infectious. Buckets are emptied and disinfected in the decontaminator. Trolleys, carts and larger equipment are disinfected and left in the operating room.
5. Protective clothing is removed and packaged/treated as infectious.
6. Door(s) are marked with sign and kept closed during disinfection period.
7. After completion of the disinfection period, cleaning is performed. Finish with alcohol wiping of all horizontal surfaces.

Ventilation after Disinfection of Rooms

1. Calculate approx. 30 min from the start of cleaning to acceptable ventilation if the department has more than 17 air changes per hour in operating rooms.
2. Calculate at least 1 h after completed cleaning at conventional ventilation, less than 17 air changes and controlled ventilation.

Gas Disinfection

Hydrogen peroxide gas disinfection of the room is effective—except for tuberculosis [24–26]. Applied after defined guidelines for rooms, surfaces, ventilated medical devices, ducts/channels and filter. A defined spore test is always needed to check the effect [24, 25]. For more information, contact infection control personnel.

35.4.7.2 B. Spot Disinfection

Surgical nurse who participated during the procedure assesses the situation together with the surgeon and determines the extent of disinfection. It is only necessary to disinfect the area contaminated by infectious material if the procedure is defined as less infectious; see above.

1. Spill of blood and other organic matter is removed with gloves and absorbent material, packaged and treated as hazardous waste.
2. Suitable disinfectant—chloramine 5%—is applied on contaminated surfaces and equipment with cloth or sponge.
 - (a) Effect time—30 min (wiped-off surface).
 - (b) –60 min (dirty surface).
3. PeraSafe can be used instead—effect time 30 min.

35.4.8 Disinfection of Equipment and Instruments, Etc.

35.4.8.1 Autoclave

The inside of the autoclave is cleaned with soap and water one time/week. Follow the guidelines for cleaning, using and checking temperature curves and spore control. For other sterilization methods, follow written procedures.

35.4.8.2 Decontaminator

Flush decontaminator: The machine is designed for liquid waste and washing water with a short flush cleaning/disinfection programme, *not* suitable for cleaning/disinfecting instruments or highly contaminated equipment.

Instrument washer should not be used to empty liquid materials. The machine has a long programme of cleaning/disinfection of instruments adapted to the department's equipment park with various inserts.

35.4.8.3 Control

Daily: washing machines and flush decontaminators are inspected daily for soaps, chemicals and temperature. Strainers are cleaned and nozzles/washers are checked for cleaning.

Weekly: door gasket is cleaned and silicone treated.

35.4.8.4 Soaps and Detergents

Use only recommended means adapted to current machine. Select the means according to the type of equipment to be cleaned in cooperation with the supplier.

35.4.8.5 Thermal Disinfection

This is used for all equipment where possible. Automated thermal disinfection of equipment is made in decontaminators where the disinfection temperature should always be more than 85 °C for a specified time.

- *Flush decontaminator* is >85 °C for more than 1 min.
- *Washing decontaminator (instrument washer)* is >85 °C.
 - >3–5 min when disinfection cycle occurs after the cleaning phase (e.g. KEN machines).
 - 10 min when the disinfection cycle occurs during the cleaning phase (e.g. MIELÉ machines).
- Check all machines for the temperature and the purity of washed/disinfected equipment after undergoing thermal disinfection. Particularly enterococci, *Clostridium difficile* spores, certain other bacteria, norovirus, hepatitis B virus, hepatitis E virus and a number of other viruses are heat resistant and can withstand very high temperatures, especially combined with the rest of organic materials.

35.4.8.6 Chemical Disinfection (See Separate Chapter)

Agents used for chemical disinfection are approved by the National Medicine Agency and by the hospital's management. A variety of microbes such as gram-negative rods, viruses and fungi may be relatively resistant to chemicals. Therefore, observe working time and concentration of the agent used!

- Chloramine 5% to surfaces.
- PeraSafe for instruments (and surfaces).
- Aldehyde (glutaraldehyde 2%) for disinfection of special equipment (optical equipment) that cannot tolerate heat infection and/or is sensitive to other chemical disinfectants. Worked in cabinets with exhaustion and shall not be inhaled!
- Ethanol (alcohol) 70%: used only for disinfection of clean equipment, clean surfaces, etc.
- Ordinary chemical disinfection has no effect on prions. In case of suspected prion disease such as Creutzfeldt-Jakob's disease, contact the hospital hygiene personnel. See chapter "Technical Disinfection and Prions".

Follow the recommendation on the container's label regarding the durability, range, effect, working time, etc. All containers with disinfectant must be covered with a tight lid and placed with restricted admission.

35.4.8.7 Pretreatment of Used Equipment Before the Chemical Disinfection

- Biological material should not dry on the instruments.
- Wear gloves, waterproof gown and hood/surgical mask/glasses/visor. Do not mess or spray!
- Carefully remove visible contaminants with absorbent material.
- Composite equipment, instruments and objects are maximally dismantled before putting into the disinfectant.
- All surfaces must be below the liquid level. Any cavity may be filled with disinfectant. Follow the recommended effect time, and cover with lid.
- Clean and rinse with water to get rid of all disinfectants, and dry prior to storage, if desirable, or prepare for sterilization.
- Check if the disinfectant should be changed between processes—follow routines.
- Work is performed under exhaust and with a good ventilation.
- Hand washing after work with chemicals and after the use of gloves.

35.4.9 Preoperative Routines

(See also chapter on "Prevention of Postoperative Wound Infections".)

35.4.9.1 The Patient

Shower or body wash—including the hair—should be performed the day before and on the day of surgery. It should be done at least 2 h before the operation, to decrease the release of skin cells and bacteria from the body. Before ultraclean surgery (orthopaedics/heart/vessel), it is recommended to use chlorhexidine soap (for instance, Hibiscrub). Check if the navel and nails are thoroughly cleaned. Nail polish should be removed from the fingers and toes. The hair should be clean and washed with chlorhexidine shampoo. The patient should have a good oral hygiene. Jewellery, watch, makeup and face cream should be removed.

Clean linens and clean bed for transport to the surgery department, including emergency, if possible. Patients with open, infected wounds or other infection should have a new, clean bed the day of surgery. The contaminated bed will be left on the patient room and treated as infected with disinfection. New beds and linens to all after surgery!

For hair removal, if needed, use the electric/battery clippers or depilatory cream. Shaving increases the risk of wound infections. Avoid removing the hair if unnecessary. Clean and disinfect the clipper after use. Disposable heads of the clipper are used, with new blade for each patient.

35.4.9.2 Surgical Team

Surgical hand disinfection: see separate chapter for “Surgical Hand Disinfection” [27, 28].

Sterile Dressing (Gown and Gloves)

- Gowns are dressed just inside the door of the operating room. Avoid close unsterile contact with others.
- Preferably use double gloves during operations that may lead to perforation and during surgery on patients with blood-borne infections (hepatitis, HIV, etc.).
- The package with sterile gown, gloves and wipes is opened by others immediately before dressing to avoid contamination.
- The gown is folded inside out; lift the upper part.
- Keep the hands up; slip into the sleeves to the wrists of the gown.
- The assistant helps pull in place sleeves, from behind, and closes posteriorly. Do not make the outside of the gown unsterile.
- Take on gloves when the hands are still covered by the sleeve (closed method).
 - Gown front and gloves must not be made non-sterile.
 - Take the right glove with the right hand (right-handed) so that the glove’s fingertips are facing the shoulder.
 - Turn the glove around and on the hand.
 - Take the left glove with the right hand, and pull it around and on the left hand.
 - NB! Assisted dressing of gloves is the safest and prevents contamination [29, 30].

Change of Sterile Gown and Gloves Peroperatively

Coordinating surgical nurse in collaboration with sterile dressed executive surgical nurse—away from the area of operation:

- Drag the cuff of the sterile gown over the gloved hand.
- Remove the gown and gloves.
- Alcohol disinfection of the hands.
- New sterile gown and gloves, as above.

Opening of Sterile Packages and Drapes Equipment

Sterile executive surgical nurse should ensure that instruments and equipment are sterile and in proper condition and that the use and composition of the equipment are known for the surgical team. The laying of sterile instruments should take place without the other activity in the operating room. This is to reduce burden of dust and microbes on instruments. Afterwards cover sterile.

- No sterile packages are opened before the sterile executive surgical nurse is ready.
- The sterility of opened equipment is continuously monitored and covered until use.
- All implants are sterile covered after unwrapping. Implants should not be touched unnecessarily with sterile gloves because of undesirable coatings and risk of debris from small punctures in the gloves. Instead use, for instance, suitable sterile tweezers/forceps.

35.4.9.3 Disinfection of Surgical Fields: Field Washing

The size of the surgical area to be disinfected is decided by the surgeon. By insufficient disinfected area, the surgeon may come outside the area and make the operation unsterile. All disinfection should be dried on the skin (for effect), before the sterile covering. If the cover is wet by disinfectants, it may easily loose during operation and make the area non-sterile.

Sterile Cleaning Kit with Sterile Forceps and Sponges/Swabs

Containers with disinfectants should be used for only one operation and discarded afterwards!

Methodology for preoperative disinfection, time use, the number of applications of disinfectant, etc. may vary from 1–2 min to 5–10 min and is poorly documented; see background information. However, follow the local guidelines until others are decided!

- Intact skin: Chlorhexidine alcohol 5 mg/ml—Single use (disposable).
- Wound or mucosa: Chlorhexidine 0.5 mg/ml in aqueous solution or chlorhexidine 1.0 mg/ml in aqueous solution.
- Ears: Chlorhexidine is ototoxic!.

Two methods—A and B—are described; the author recommends Method B (see below).

1. General:

- Disinfect the outer frame, at least 10 cm outside the sterile area.
- Disinfect the surgical area thoroughly with plenty of disinfectant, but not so much that the patient lies on wet bedding.
- Start in the middle and disinfect outwards.

Method A: Two Times Disinfection—Washing Process, a Total of 2 min, and Additionally Drying

- Duration of disinfection process: at least 1 min.
- Reapplication starting in the middle.
- Finish with the outer frame. Avoid contamination from the non-disinfected skin.
- Duration of cleaning process: at least 1 min. Do not contaminate when sterile covering.
- Allow the area to dry before sterile covering.

Method B: Five Times Disinfection—Washing Process, a Total of 5 min, and Additionally Drying

- Disinfect the surgical field thoroughly with plenty of disinfectant, a total of at least five times.
 - Make first a border around the area of operation.
 - Field disinfected should be at least 10 cm larger than the sterile cover area.
 - Field within the framework is disinfected.
 - Start in the middle and disinfect outwards.
 - Let the disinfectant work for at least 1 min each time.
 - New application always starts in central operation field. Do not wash out as far as the last time (contamination from non-disinfected skin).
 - Let it act at least 1 min in the end until the skin is dry.
 - When sterile covering, the skin should be dry.
 - When disinfecting areas of the abdomen, the *umbilicus* should be disinfected first with Q-tips before the frame of the field is created and the rest of the field is disinfected.
 - *Contaminated zones* like fistulas and stomas are disinfected first before the rest of the field is disinfected as usual. Fistulas, stomas, etc. are disinfected using tufers and corn tongs (forceps), and chlorhexidine 0.5 mg/ml in water solution *before* the rest of the surgical area is disinfected with chlorhexidine alcohol 5 mg/ml.
2. Regular square disinfection:
- *Abdomen and minor surgery*: tufper/forceps.
 - *Large fields, orthopaedics and heart/thorax*: swabs/gloves.

3. Disinfection of extremities:
 - Disinfect from the highest point and down.
 - The outer edges are finally disinfected.
4. Disinfection of the perineum area.
 - Compress/forceps.
 - Disinfect first the genitalia and outwards to the outer frame. Disinfect the anal region finally.
 - Chlorhexidine 0.5 mg/ml in aqueous solution.
5. Fields with contaminated areas (anus, infected wounds).
 - Disinfect the area from the clean to the most contaminated area.

35.4.10 Sluice Functions

The patient is coming in clean linens and clean bed to bed sluice.

Staff are entering through the dressing room after retrieving “green cloths” on the textile room. Hand hygiene after changing clothes, before leaving the dressing room and before entering the surgical department. The same way out when leaving the operation department. Scrub suits should be used only in the operation department. After urgent care or other activities outside the green zone, the way back is via the sluice with the change of scrub suit. This applies to all traffic to and from the department.

Equipment and instruments mm. that is to be brought *out* of the operation department must be clean inside and outside. If disinfecting the inner parts is inapplicable, the equipment should be specifically labelled, and the receiver should be noted of the condition.

Equipment that is brought *into* the department must be clean inside and outside. It is also desirable that the particle quantity that follows the equipment is minimized. Reusable equipment that cannot be disinfected in an appropriate manner should not be taken into the department.

Equipment must not be brought to the surgical department for disinfection/sterilization. This should be done elsewhere.

35.4.11 Surgery on Cases with Drug-Resistant *Mycobacterium tuberculosis* [89–91]

(See also chapter “Strict Isolation”.)

35.4.11.1 *Mycobacterium tuberculosis*

- Survival for 1 year if not exposed to sunlight or UVC [91].
- Low infection dose; one bacterium may infect.
- Chloramine 5%, PeraSafe and glutaraldehyde may kill the bacteria. Alcohol and Virkon (Kalium persulphate 50%, sulphamic acid 5%) have no sure effect. There is no any known effect of gas disinfection [1, 26, 91, 92].

- Respirators—P3 mask (without valve)—provide respiratory protection if used properly.
- Patient with infectious tuberculosis is isolated as contact and airborne infection.
- During surgery, opening into foci with tubercle bacteria may result in contaminated air and environment in the room.

35.4.11.2 Pretreatment of Patient

- Apply Hibiscrub body disinfection in the evening and the morning before the operation.
- The patient is transported in clean clothes and in clean bed directly to the operating room. Disinfect the wheels of the bed before the transport starts.
- The patient uses a respiratory protection during transit, possibly surgical face mask.
- The bed is treated as “strict isolation”, is covered with plastic and is returned to the isolation unit for disinfection (see chapter “Strict Isolation”).

35.4.11.3 Time of Planned Operation/Functional Conditions

- Operations should take place at the end of the day.
- Minimal activity takes place in other operating rooms.
- Do not use LAF rooms—TBC particles may penetrate LAF ceiling.
- Preferably use a defined theatre with negative pressure—for surgery on infections.
- Regular operating room without negative pressure: switch off the ventilation for the operating room separately during surgery and 2 h after completion of disinfection, and close and cover all ventilators.
- The ventilation system should be test-run beforehand.

35.4.11.4 Ventilation—The Establishment of Mobile Negative Pressure

- Aggregates creating a negative pressure (-15 Pa) in the operating room may be installed. The exhaust air is disinfected/hepafiltered through a unit before sending it outside directly through channels in the wall or in the window (not in ventilation ducts). Air from all air-cooled equipment is also connected to the exhaust duct (unit). Hepafilters are put on air intake devices in the operating room to stop contamination of the inner parts of technical equipment.
- After use, disinfect all the equipment outside with chloramine 5% in 1 h or PeraSafe at the same time. The entire aggregate unit and other devices are then packaged in for further disinfection, if possible. Check if internal parts of the equipment can withstand immersion in PeraSafe or glutaraldehyde—see chapter “Disinfection”.

35.4.11.5 Preparation—Normal Operating Room Without Negative Pressure

- Remove excess inventory, and put plastic over the wall's solid materials in the operating room that are difficult to treat with chloramine 5%, and do the same for the hand hygiene room, induction room and disinfection room.

- Tape over all through-put closet. These should beforehand be emptied.
- Tape over the exhaust ducts and supply air ducts.
- Check the temperature of decontaminators and washing machines beforehand.
- Obtain necessary packaging for infectious waste and used equipment.
- Arrange for special transport of infectious waste for combustion.
- Drapes with instrument table must be completed and covered before the patient arrives. Make sure that all equipment necessary for the operation are in the room.
- For anaesthesia machines and equipment, use disposable equipment on a separate board.
- Signs of doors should be in strict isolation.
- Only necessary personnel should be present; use the intercom—preferably not the phone.
- Personnel who participate should be healthy (normal immune status), not pregnant and tuberculin positive.

35.4.11.6 Clothing and PPE—For All Present

- Gown with long arms and cuff—disposable surgical gowns.
- Operation cap covers the hair and ears.
- Hood covering the head and neck.
- Gloves (double for the operating and anaesthesia team).
- P3 mask—respirator (without valve).
- Room-bound shoes.
- Surgical and anaesthesia team uses in addition visors/goggles.

Close the doors—not permitted entrance during surgery.

If the doors must be opened, open it carefully due to the circulation of air and negative pressure.

35.4.11.7 Peroperatively

- Hepafilter on the ventilator opening sucks air from the room to cool the machine.
- Avoid diathermy and suction that cause splashes and aerosols.
- Work slowly and safely, using good time.
- The coordinating nurse is repacking the used equipment in infection bags/boxes as it is finished.
- External personnel on the disinfection room are using the same PPE and attire as internal coordinating surgical nurse and receive packaged equipment, infectious waste, etc. from the operating room for further treatment.

35.4.11.8 Postoperatively (Personnel-Equipment-Waste)

- Personnel who are leaving the room are moving to the door of the hand disinfection room and there take carefully off gloves, gown and finally mask and shoes, disinfecting the hands between each procedure. See strict isolation on how to do doffing.

- Disposable equipment is put in the infection sack and shoes in a separate sack for decontamination. Infection bags are placed in the operating room. Smaller sacks can easily be packed in infection containers.
- Wash the hands thoroughly in hand disinfection room, and then go directly to a predesignated shower, and change into new clothes (all items).
- Reusable equipment is placed in the metal boxes, disinfected externally with 70% alcohol before handover to the person on the disinfection room compartment. Put the whole box and equipment in the washer/decontaminator.
- Personnel in the disinfection room receives all infectious waste that is double packed in the doorway to the disinfection room.
- The outer packaging is disinfected with alcohol at the door to the corridor—from the disinfection room. It should be perfectly clean on the outside when the infectious waste is placed in a clean container (yellow box or bag) and brought to the transport unit.
- The transporter should be informed and is wearing gloves, ordinary surgical masks and gown (regular wash after use) during transport to the collection point.
- Infectious waste is transported immediately for direct combustion.

35.4.11.9 Samples for Culture—Pathology

- Samples for laboratory examination are double packaged as described above and brought personally to the laboratory. NB! Prior arrangement and information with the laboratory. Microbiological examination is very important for further antituberculous treatment.

35.4.11.10 The Patient

- Awake from narcosis in the operating room.
- Transfer to new, clean bed, and wheels are disinfected in the induction room before the patient is transported out.
- Transport for airborne isolation with negative air pressure. Anaesthesia personnel must follow, if needed.
- If the patient cannot breathe by himself, use handbag during transport.
- If the patient is on respirator, use a type that is easily disinfected afterwards.
- Anaesthesia/intensive personnel should—along with the rest of the team—take responsibility for the patient if ventilator treatment is necessary.

35.4.11.11 Disinfection of Rooms and Surfaces

- Disinfection of rooms and surfaces should be done with PPE in all rooms where the patient, equipment and personnel have been: operating rooms and corresponding rooms (hand disinfection room, induction room and disinfection room). See chapter “Strict isolation”.
- Chloramine 5% is used on all surfaces, including walls, ceilings, through-put cupboards and closets/drawers.

- Staff are using PPE as described above, end with a shower and change into clean clothes.
- See chapter “Disinfection”.

35.4.11.12 Tuberculin Test

All persons who attend per-postoperatively check tuberculin test in advance, if possible.

If Personnel Are Infected What Happens

1. If the above guidelines are followed, nobody should be infected with TB.
2. If it still should happen, about 10% of those infected can be sick.
3. If symptoms occur, early treatment is associated with a good prognosis.
4. If one gets sick/infected, it will be defined as an accident at work and treated as an occupational injury.
5. Accidents at work (not able to work) may lead (in Norway) to full salary for 2 years + a sum of compensation from insurance pools or other local solutions—check this.

35.5 Background Information

Infection control routines in the operation department are based on many single factors from experience, documentation and expert panels for more than a hundred years [1–13]. Procedures may be evidence-based, or not. Unfortunately, too many procedures may still lack evidence. Some factors, like hand disinfection versus no disinfection and surgical site disinfection versus no disinfection, may probably never be investigated because of ethical problems. Consequently, consensus and guidance are used to a great extent.

Surgery opens into sterile tissues for hours, during massive tissue damage by knife, diathermy, clogging of vessels, pressure against and drying of tissues, decreased blood supply, impaired phagocytosis and reduced local infection defence. Microbes deposited in devitalized tissues may find a good basis for growth and proliferation.

35.5.1 Clean Operating Environment

Already in the 1880s, a clean operating environment was important. Rubber surgical gloves came about in 1910, antibiotics were used from the 1940s and later on came diverse improvements on cleanliness and infection prevention in connection to operational activities [31]. Lister disinfected everything around him and moved operating rooms as far as possible away from other activities but operated in

private clothes. From 1930 on, clean air in the operating room was appropriate but quite necessary for prosthesis and transplant surgery from the 1960s [1–5, 12, 13, 18, 19].

Still are, up to 70% of surgical sites contaminated during surgery with microbes from adjacent skin areas, the air around the operation area and of the operational staff, or instruments that have been exposed and moved with particles and microbes toward the operation area.

A clean operating environment is dependent on clean air, clean room, clean equipment, clean patient and clean personnel. The bacterial number quickly reaches 300–600 colony-forming units (CFU) per cubic metre (m^3) of air, mostly freed from the skin, clothing, hair and upper respiratory tract from those present. In each CFU, several bacteria can be present simultaneously; thus, the real number is higher.

In a good operating theatre, the CFU value must be down to less than 100/ m^3 of air and in ultraclean rooms less than 10/ m^3 air. To accomplish this, personnel are dressed in clean scrub suits with cap and surgical mask, and the surgical team also uses sterile surgical gowns. In addition clean filtered air at a positive pressure is ventilating the operating room with 17–25 air changes per hour [22, 23].

35.5.2 Identification of High-Risk Patients

Surgical site infections (SSIs) were studied among 58,500 patients operated in the 1970s in the United States (SENIC study) [5]. More than 90% of high-risk patients could be readily identified in advance by four factors: abdominal operation, operating time more than 2 h, contaminated or highly contaminated surgical wounds and patients with three or more diagnoses [5]. By giving each of these factors weight one (1) and counted together, the infection rate with 0 point was low (<1%), with 1 point medium (3–4%), 2 points high (10.8%), 3 points even higher (18–20%) and 4 points highest (28–30%). A study of 59,400 operated patients (1975–1976) showed almost identical findings [5]. Later on more sophisticated methods were developed.

35.5.3 Sterile Gloves: Surgical Gloves

Surgical gloves must be strong and soft and have few holes. CDC estimates that from 1000 to 10,000 bacteria pass small punctations in surgical gloves, which are reduced to about 100 by good hand disinfection [28]. The occurrence of SSI after using sterile versus non-sterile gloves is never explored, nor effects of double gloves are well documented [32]. Double gloves reduce the perforation of the inner glove, and the use of indicator systems means that most holes are discovered during surgery [32].

Cruse and Foord found that if gloves were punctured, the proportion of SSI was 5.7% versus 1.7% without punctuation [2]. Perforation is greatest during complicated operations: for orthopaedic team about 40% and for soft tissue surgery 16% [33]. By hip operations, it is proven 1–2 perforations in 25% of operations, 8% with perforated both gloves, and this was detected during the operation only in a small proportion of the teams [34–37]. Most perforations are detected on the left index finger or thumb [34].

A study from Molde, Norway, proved a hole in one of the three gloves, which led to the use of double gloves during all operations [36]. In the Department of Neurosurgery, Oslo University Hospital, about 1000 gloves were examined after craniotomy [35]. There were holes in 16.5% of the outer glove, and in two of the three cases, this was not discovered during surgery. The surgeons had most holes (22%), mostly on the non-dominant hand. The use of indicator gloves gave a protection of approximately 99% [35].

Gloves become easily contaminated during the operation. After disinfection and sterile covering of the operation area, bacteria were found on 5/42 surgical gloves and before prosthesis insertion on 10/42 gloves [38]. Nineteen species of bacteria were detected, of which 16 different coagulase-negative staphylococci and 1 each of *Micrococcus*, *Enterococcus* and *Bacillus* sp. [38].

In one study, 6% of the surgical team had bacteria on fingertips immediately after surgical handwash and sterile gloving, and at the end of the operation, 6.6% of the gloved fingertips and 51% of fingertips without gloves were contaminated with bacteria [27]. In all, 96.6% of surgeons had sterile glove fingertips at the end of the operation [27]. *S. aureus* and 17 different gram-negative bacteria among common skin bacteria were detected, mostly before (after surgical hand disinfection) but also after the end of operation [27]. Gloves are replaced when possibly contaminated and always before moving from a contaminated to a more clean area.

Technique of sterile dressing of surgical gloves is discussed [29, 30]. It is easy to contaminate the sterile gown when dressing sterile gloves. Both open and closed technique may lead to 100% contamination rate, concentrated around the forearm and wrist [29]. This may be avoided by using assisted dressing by a sterile dressed surgical nurse [29]. Reversion of the glove cuff may happen relatively often during surgery [30]. The reversed part may be contaminated with the operator's hand flora. The assisted and closed technique will also reduce this problem [30].

35.5.4 Dressing of Surgical Teams

Dressing retains loose skin particles, the hair and bacteria in place in the surgical team while protecting against organic matter from the patient. Bacterial amount in the operation theatre comes mostly from the surgical team and from the environment. Each person is releasing millions of tiny skin particles every day and even

more during physical activity and sweating [39, 40]. About 10% of particles are carrying bacteria. Large amounts of bacteria in the facial-head-ear-neck area of the surgical team may be transferred to the surgical wound if special air currents and covering are not taken into account [39, 41].

Tight clothing is required [42–51]. Cotton clothing is comfortable but allows loose skin particles, 2.5–20 µm, go through the 80 µm-sized pores of the fabric, and movement increases the liberation of skin particles. Dense, particle-reducing textiles reduce the amount of bacteria and particles in the air and thus the deposition on surfaces, instruments and equipment [22, 23, 43, 44].

Proper attire in LAF rooms is important [18, 45, 46]. Microbes and skin particles are released from the eyebrows, forehead and ears, often in larger quantities from the ears than from the forehead and eyebrows [41]. Therefore, it is recommended to use exhaust helmet or good covering, especially of the ears and hair [41].

The surgical gown should be big enough and comfortable on, tight around the neck and cover well also the back. The arms with cuffs should not be too short, which may lead to excessive contamination. Some are using a seal around the wrist [52].

Packages with sterile surgical gowns and gloves are opened just before dressing since studies show that more than two out of three open sets quickly become contaminated with bacteria [53]. Bacteria survive long in textiles and constitute a source of infection [54].

35.5.5 Hood-Operation Cap

Hood or cap should cover the hair and ears and sit tightly on. Without a cap, the amount of bacteria in the air increases 3–5 times and sedimentation in the surgical wound ca. 60 times [18, 45, 46, 49].

Fake operations have demonstrated that in vertical ultraclean air, the CFU in the operation area increases more than 22 times in the absence of operation cap and surgical mask [46]. Using a cap without a surgical mask, the increase is up to 15 times, and using the surgical mask, without cap, more than 4 times, and by using cotton gown, the CFU in the surgical wound increases more than 6 times [46].

35.5.6 Shoes

In orthopaedic surgery, there is a large blood contamination of the personnel's shoes [55, 56]. Therefore, use washable shoes, with shoe washers and drying programmes to reduce transmission of infection—especially blood-borne infections—but also to prevent SSIs [56].

35.5.7 Surgical Mask (SM)

Cochrane studies show insufficient documentation for the efficacy of surgical face masks with regard to SSI [57]. Labelled albumin studies show continuous deposition of particles from the face and ears to the surgical wound and that this “flow under” the surgical mask if it is not sealed in the bottom [58]. Few bacteria are released to the air by quiet breathing through the nose but are increasing rapidly by whispering or speech [58]. In all, 24 people spoke against a blood agar plate 30 cm from the mouth—with and without SM. Without a surgical mask, there was a spread of bacteria, while the use of mask stopped the spreading [59].

Surgical mask prevents transmission of bacteria and droplets/saliva from the upper airway. In all, ten men with beards, ten without beards and ten women were examined [60]. They were talking towards agar plates 15 cm below the lips. By much movement of the mask (“wiggling”) came the most bacteria from men with beards and women, but not from men without beards. When the mask was set fast—not wiggling—significantly more bacteria were released to the air from bearded men than from newly shaved men and from women. The conclusion was to avoid loose unstable masks and to remove the beard [60].

Blood and tissue contamination. The use of surgical mask and eye protection (visor/goggles) reduces blood contamination of the eye mucous membrane and upper respiratory tract. Blood-borne viruses may penetrate the conjunctiva [61].

- In a study of vascular surgery, the visor and face masks were blood contaminated on the main surgeon in 51% and 32% of the operations, respectively; on surgeon 2, 36% and 42%; on assistant, 36% and 12%; and on surgical nurse, 10% and 4%, respectively [62]. Prolonged operation time increased blood contamination [62].
- Angio-procedures resulted in blood spill and splash in 23 of 100 procedures; eye protection and face masks were recommended [63].
- By vaginal and caesarean delivery, face visors were blood contaminated in, respectively, 32% and 50% of the cases [64]. At vaginal births, the contamination was undetected by half of the personnel and by caesarean undetected by 90% [64].
- Endo et al. [65] examined 600 surgical face masks with visors or face shield and found that 66% were blood contaminated: at eye level 37%, in eyebrow elevation 38% and face masks 60%. Surgeon 1 had contaminated masks with visors in 84% of cases, the surgeon 2 69% and surgical nurse 46% [65]. The greatest contamination occurred during vascular surgery (75%), neurosurgery (70%), gastrointestinal surgery (60%) and orthopaedic surgery (60%) [65].

Splash of blood is most often invisible. Blood contamination on the visor is in most cases less than 0.6 millimetres in diameter [66]. Most blood contaminations

are smaller than 1 mm. Most of the blood contamination during surgery is invisible, and staff must protect themselves against this [66, 67].

Despite different attitudes to the use of surgical face mask, there is little doubt that the mask and visor protect against blood/tissue transmission from the patient during surgery. If the staff is talking, coughs or sneezes, the surgical mask may protect against those secretions from the upper respiratory tract or otherwise may spread far away, also to the wound [58–62, 68].

35.5.8 Sweating: A Challenge

Many are sweating from the forehead. Sweat samples taken from 42 people during orthopaedic surgery showed that 42% were positive for microbes, mostly coagulase-negative staphylococci, *Klebsiella* sp. in one sample and MRSA in another [69].

35.5.9 Surgical Site Skin Disinfection

Cochrane studies cannot conclude regarding disinfection of the surgical field [70]. Out of ethical reasons, evidence studies are lacking, with respect to disinfection versus non-disinfection. It is believed that disinfection of the operation area reduces SSIs [70–72]. The methodology for the application, “scrub” or “painting,” of disinfectant is not well described [7, 8, 70–72]. Single studies vary in scrub and paint, and the time of the disinfection process varies from 1 to 5–10 min [72]. Chlorhexidine alcohol has a good long-term effect [70–72].

Recolonization of the disinfected skin area occurs soon afterwards [73]. Bacteria from the patient’s skin, relatively far away from the operation area, migrated into the area in 40 of 40 studies during orthopaedic surgery, despite good barriers around the wound. Bacteria can also come to the wound hematogenously or lymphogenously.

Adhesive coatings for protection of the surgical field; Cochrane and other studies find no good evidence—at all, and it may even increase the infection rate [74, 75]. Plastic wound retractors can possibly reduce the effect of bacteria in gastrointestinal surgery [76].

35.5.10 Technique

Technical expertise, well-functioning operational team and excellent checklists are essential for a successful operation and reduction of SSIs [12].

Stick injuries happen frequently—up to one in five operations. The use of double gloves protects. The glove may work like a pacifier by dragging off most of the

blood and tissues. A glove may reduce blood volume transferred with 52%. Gloves protect also the patient's tissue from the surgeon's skin flora and blood. Stick injuries are underreported.

- In England, 42 surgeons had 840 needlestick injuries during 2 years, hence 126 with bleeding [77]. Only one of four surgeons used double gloves, and when blood-borne viruses are known, only 50% used double gloves. Senior surgeons had more stick injuries and reported less frequently than junior surgeons [77].
- In Scotland, 1.4% of operating surgeons were infected with hepatitis C in 1999.
- Magnetic flat instrument deposition reduces puncture injuries by delivery of instruments [78].
- All types of blood contamination agents can be transmitted by needlestick injury—both ways. By aerosol, blood-borne viruses can be transferred through the conjunctiva [61].
- The use of bipolar diathermy increases air contamination of blood and tissue more than monopolar diathermy [61].
- Dentist, surgery and autopsy rooms have been examined for blood aerosols [79]. The rooms are all the same with regard to air samples; 38.6% were positive for blood, i.e. a mean of 0.10 µg of Hb per m³ of air [79]. There are many samples of blood-borne infections among the operating team during surgery [80].
- *Diathermy* needles can be highly contaminated with protein that should be removed between operations [81].

35.5.11 Storage in the Operating Room

Storage in operating rooms should not be established because of bioburden. Sutures are particularly susceptible to colonization with slowly growing *Mycobacteria*, coagulase-negative staphylococci and other robust microbes [82].

35.5.12 “Risk Personnel”

May be personnel with skin infections, infections or carrier state of group A streptococci, MRSA, ESBL and other MDROs, nasal carrier of *S aureus*, beard, unlimited activity and access, untrained personnel, and personnel that are not following personal hygiene, hand hygiene, glove and mask rules, dressing routines, behaviour in sterile areas, etc. These are known situations where personnel may pose a risk for the patient and for other staff.

35.5.13 Other Risk Factors

These are poorly organized department, inadequate management, insufficient space, lack of storage conditions, ventilation and pressure conditions that are not balanced, building activities, poor cleaning between operations, missing filter for intake air, open through-put cabinets that brings contaminated corridor air in, operating and preparing the next patient in the same room at the same time and other “shortcuts”, etc. [12, 83–85]. There may also be challenges associated with loaner instrumentation [86].

35.5.14 Postoperative Phase

Postoperative and intensive departments are challenges for recent surgery patients since bacterial load combined with high antibiotic consumption and often dormitory organization leads to a relatively high burden of infection [12, 87, 88].

An outbreak of 39 infections (17.5%) among 223 heart surgery patients in North Carolina, USA, was tracked to the cardiovascular intensive care unit where the infection appeared 1–6 days after surgery [87]. Pathogenic bacteria were found in and around a heavily polluted sink, on the hands of staff after handwashing, on contaminated “clean hands” and in the air near the sink. The sink was closely located to the patient beds where the air around the nearest bed had the same microbes as in the air around running water in the sink (aerosols). After actions, including closing off the sink, the infection rate was reduced to 5.6% [87]. Single-bed rooms in ICUs may reduce the number of infections, and length of stay becomes shorter [89].

35.5.15 The Ageing Wave: Prognoses

In the United States, it was calculated that during the period 2000–2020, there would be a 56% increase of infection in elderly over 65 years and cardiovascular and orthopaedic surgery would increase by, respectively, 42% and 28%. If infections with *S. aureus*, MRSA and other MDROs are increasing as is the fact today, the problems around SSIs may become much greater and more serious than for a few years ago. Therefore, a restrictive infection control combined with a restrictive antibiotic policy is very important preventive means to reduce SSIs in the future surgery.

35.5.16 Operation of a Patient with Multidrug-Resistant Tuberculosis

For example, patient is not well treated for *Mycobacterium tuberculosis* of the lungs [90–93]. The bacteria developed resistance to most drugs, first- and second-hand

choices, and caverns in the right lung occurred, while the left lung capacity was in order. The patient was prescribed new drugs (linezolid, augmentin, etc.). The bacterium was sensitive to these medications, but it was only a question of time before the development of resistance.

35.5.16.1 Advantages of Surgery for Lung Cavern and Multidrug-Resistant *M. tuberculosis*

- If caverns are not removed, resistance to new drugs may probably quickly develop due to poor penetration into cavern tissue and low concentration of the agent.
- Experiences from the United States show that if surgery is chosen, there must be effective drugs given in 24 months postoperatively. If there are no effective drugs (the bacterium is totally resistant), surgery will not provide any benefit for the patient. No treatment (resistance to all) will lead to a poor prognosis [90–93].
- The patient can be cured for multidrug-resistant pulmonary tuberculosis if surgery is done, combined with effective, intensive medication.
- If the effect of the treatment is curative, a severe, drug-resistant infection source is removed from the society.

35.5.16.2 Risks Associated with Surgical Treatment of Multiresistant, Pulmonary Tuberculosis

- Further development of tuberculosis in the rest of the lung tissue.
- Too small residual lung function—the patient does not come off the respirator.
- Fistula formation with pus secretion to the respiratory tract or externally.
- If there is no effect of the surgical and medical treatment, this would be a greater problem for the patient and for the environment than earlier (ventilator, fistula with pus, etc. and strict isolation until death).

(The patient was operated two times and the right lung was removed. He survived and was cured.)

See also chapters on “Prevention of SSIs, Strict Isolation, Tuberculosis”.

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Newly Operated Patient

36

Abstract

This chapter is a practical description of procedures that may protect the surgical patient against surgical site infection (SSI) during the early postoperative phase.

Keywords

Postoperative phase · Control of surgical site · Removal of sutures · Wound care · Change of bandages · Patients with infections

36.1 Purpose

- Prevent postoperative wound infection.
- Prevent infection transmission.

36.2 Comprise

- All personnel treating and observing wounds.

36.3 Responsibility

The hospital management should ensure surgical activities in accordance with the quality standards of hygiene and infection control. Postoperative infections must be registered, assessed and followed up.

Department management should promote hygiene principles and ensure safe conditions during postoperative period.

Each employee shall comply with the department's hygiene guidelines, infection control measures and personal hygiene.

36.4 Practical Measures

36.4.1 Daily Control of Operation Wound

- Check daily the bandage and surgical area. Do not touch the bandage, perform good hand hygiene and use gloves. Do not open or break bandage if closed, clean and free of leakage of blood/tissue fluid. The bandage should be dry and clean.
- The wound is covered with a sterile dressing for at least 48 h postoperatively and later on covered sterile and protected in this way until the wound is healed and stitches removed.
- Inform the patient about good personal hand hygiene and request not to touch on or around the bandage. Has the patient touched under the bandage, is complaining of itching, etc., check if there are allergies to plaster and replace the bandage—see procedure below.
- Ensure that the patient is assisted with daily body washing and other hygienic measures to avoid that the bandage becomes wet.
- When washing the body, cover the entire bandage with water-resistant plastic. Water contains bacteria that may come into the wound; partially resistant microbes can adhere to the sutures.
- Change clean bed linen and patient clothes at least once per day.
- Do not take off the bandage until the wound is completely healed, if possible.
- Remove sutures/agriffes aseptic—sterile—with sterile equipment and disinfect the wound area first!
- If there are problems with wound healing or other clinical symptoms, contact the doctor in charge.
- Check signs of infection such as redness, swelling, tenderness, warmth, pus, odour or fever.

36.4.2 Change of Bandage-Wound Care Without Signs of Infection

Indication: wet, soaked bandage, dirty or loosened bandage, suspected infection, inspection, etc.

Implementation—short version:

- Hand hygiene, gown, surgical mask and cap.
- Sterile procedure.
- Sterile instrument set for wound care.
- Sterile opening and laying of instrument set.
- Clean disposable gloves or sterile disposable forceps when carefully removing the bandage.
- Wear sterile gloves if in contact with the wound or with a sterile bandage.

- Use sterile disposable forceps for cleaning around the wound with physiological saline (0.9% NaCl) and then drying with sterile swabs. From clean to unclean in the area.
- Place on the new sterile bandage.

Equipment: sterile shift set, sterile scissors, disposable gloves, sterile gloves, sterile saline, sterile dressing and compresses, plasters, waste bag. Put everything on a clean, disinfected board.

- Patient-bound gown with long sleeves and cuffs, and perform hand hygiene.
- Clean nightstand and disinfect it with 70% alcohol before placing the equipment.
- Use disposable gloves and carefully take off the bandages that are placed in waste bag.
- Perform hand hygiene.
- Sterile procedure on a disinfected nightstand or a table. Open sterile shift set and add 0.9% NaCl to sterile sponges/swabs—aseptically.
- Put on sterile gloves.
- Sterile tweezer is used to remove the inner coating on the wound and wiping off with sterile swabs/compresses—start from the clean wound and outwards (from clean to unclean). Be careful not to contaminate the wound.
- Then use sterile tweezers to needed wash of the wound with sterile sponges/swabs—one stroke each time from clean to unclean.
- Wipe gently with a dry sterile compress from the wound edges and outwards.
- Add a new, sterile, dry gauze pad and strengthen with bandage on the outside—especially in patients who have a tendency to touch on the operation area.
- Do not use ointments or powders in or near the wound—because of bacterial contamination.

36.4.3 Removal of Sutures

- Hand hygiene.
- Patient-bound gown with long sleeves and cuffs.
- Surgical mask and cap.
- Sterile procedure.
- Sterile shift set.
- Procedure and preparation—see above.
- Open sterile shift set and eventually add 0.9% NaCl (sterile saline), chlorhexidine alcohol 5 mg/ml, and aqueous chlorhexidine 0.5 mg/ml to sterile sponges/swabs—aseptically.
- Put on sterile gloves.
- Sterile tweezers are used to dry off with sterile sponges/swabs and sterile saline—start from the clean wound and a little beyond.

- Thereafter, sterile disinfection of scar perimeter—*not in the wound*—with sterile sponges/swabs and chlorhexidine alcohol 5 mg/ml; one stroke each time from clean to less clean.
- Then disinfect actual operation scar with chlorhexidine 0.5 mg/ml; gently wipe.
- Sterile tweezer holds and pulls the suture while cutting off with sterile scissor. Pull the suture gently. Afterwards disinfect scar with chlorhexidine 0.5 mg/ml.
- Cover with sterile dressing ca. 24–48 h.

36.4.4 Suspected Postoperative Wound Infection

- Medical doctor is contacted for diagnosis and treatment.
- Sampling for microbiology.
- *Staphylococcus aureus* is most often the cause of acute postoperative wound infections.
- Written procedure for care of the wound is followed.
- Patients with wound infection should be placed in a single room and treated as contact infection with the use of gloves, gown, surgical mask and cap when caring for the patient.
- SSI may be caused by resistant bacteria like MRSA, VRE, ESBL or other resistant bacteria. Follow procedures, dressing and undressing of PPE and current isolation regimes!
- Care of the wound as described above.
- Perform hand hygiene.
- Used bandage and other equipment, and gloves are put in yellow waste bag.
- Textiles are put in separate bags for textiles.

NB! Do not contaminate hands when packing the waste. Perform hand hygiene before leaving the room!



Abstract

This chapter is a practical description of indication for, use and care of and control of wound drainages. Wound drains are placed under sterile conditions in an operating room, often as part of surgery. Unnecessary use of drainage should be avoided because of risk of microbial growth. Drains are usually put into deeper tissue structures and must therefore be treated as open surgical sites.

Keywords

Wound drainages · Indication for use · Control and care of drains · Open and closed drains

37.1 Purpose

- Prevent postoperative wound infection.
- Prevent infection transmission.

37.2 Comprise

- All personnel treating and observing wounds.

37.3 Responsibility

The hospital management should ensure surgical activities in accordance with the quality standards of hygiene and infection control. Postoperative infections must be registered, assessed and followed up.

Department management should promote hygiene principles and ensure safe conditions during postoperative period.

Each employee shall comply with the department's hygiene guidelines, infection control measures and personal hygiene.

37.4 Practical Measures

Wound drains are placed under sterile conditions in an operating room, often as part of surgery. Unnecessary use of drainage should be avoided because of risk of microbial growth inside and outside the drain, especially through open drainages. Drains are usually put into deeper tissue structures and must therefore be treated as open surgical sites, carefully and aseptically.

- Inform the patient not to touch the drain. Perform a special good hygiene when caring for the patient, linen, bandages, cleaning of the room and equipment, etc.
- Patients with drainages/catheters should not share room with other patients.
- Patients with infected drains (pus, abscesses, infection) should be treated as contact isolation.

37.4.1 Indication for Drainage [1, 2]

- Evacuation of blood and tissue fluid.
- Ensure free passage of secretions from the body and relieve internal sutures.
- Reduce the risk of infection (closed system).
- Draining abscesses.

Note: To perform a good care, it is important to know where and why the drain is used and if it is prescribed as active (active suction, vacuum) or passive drainage.

37.4.2 Active Drainage with the Use of Vacuum Suction

- Perform hand hygiene before and after care of drain. Use patient-bound, clean care gown with long sleeves, cap and surgical mask.
- Use non-sterile gloves by carefully removing the dressing.
- Then in aseptic method, use sterile gloves and sterile shift set placed in a well-cleaned area.
- Upon leakage, dry with sterile NaCl 0.9% nearest to the drain opening and then a skin disinfectant with chlorhexidine alcohol 5 mg/ml in 1 min—outside (but not in) the incision area.
- Dry sterile gauze around the drain opening.
- The drain is secured with a suture.

- Avoid tension on the suture by attaching the drain to the skin with a tape. Additionally secure the drainage on the patient's clothing or hook on the bed.
- *NB! Be careful! Avoid that the drain becomes contaminated from the floor and people are coming too close to the drain or too close to other patients. Leakages from the drain on the floor must immediately be removed with stain disinfection!*
- The effect of the plastic suction device is maintained until the suction device is almost full or as long as the device has a concave dent (inwardly of the flask—underpressure).
- Emptying the suction device and restoring the vacuum are achieved by squeezing the device flat with both hands; valves prevent backlash.
- Using *accordion suction* (folding device), the effect is reduced as the “accordion” is filled. Use shut-off cock when emptying the collection bag and restoring the vacuum.
- The collection bag should not be replaced before the permitted fluid level is achieved.
- Check for signs of infection around the drain opening.
- Check the amount and appearance of exudate.
- Temperature control daily.
- By preserving a closed system, the risk of infection is reduced.

There are several types of vacuum drainage. Read the manual for the version used where you work.

NB! All mechanical equipment used for vacuum suction should be disinfected afterwards, both outer surfaces and mechanical parts inside, which draws air from the patient room, etc. [3, 4]. This equipment should not be transported into the operating unit without being properly cleaned outside and inside!

37.4.3 Removal of the Vacuum Suction

- Perform hand hygiene before and after drain removal.
- Use patient-bound, clean care gown with long sleeves as when care of drain.
- Use non-sterile gloves upon removal of outer bandage.
- Then in aseptic method, use sterile gloves and sterile shift set by care of drain.
- Remove suture—aseptically as for wound care.
- Disinfect the area around the suture—like the wound care.
- Clear vacuum effect by loosening the drain from the tube.
- Support the skin around the drain opening.
- Pull drain out slowly with constant drag. If the drain does not detach immediately, maintain constant drag to release it.
- Vacuum drainage is placed in a yellow bag in the box labelled *hazardous waste*.
- Compress with a sterile bandage if necessary.
- Dry sterile gauze over the drain opening.

NB! Please note that removing the vacuum drain *can be painful*. If there is a strong vacuum, drains may stick to the tissue. This can cause tissue damage and new bleeding. Let possibly the drain lie 15–30 min without suction. *Call a doctor if the drain does not slide easily out.*

37.4.4 Passive Drainage

NB!—Passive drainage has greater risk of retrograde microbial invasion than closed drainage.

37.4.4.1 Tube-Drain-Closed Drainage

- Closed wound drainage is often used for passive drainage, without a negative pressure.
- The suction unit is marked clearly with *no vacuum*; otherwise care as by vacuum suction.

37.4.4.2 Open Drainage with Corrugated Drainage

- Perform hand hygiene before and after care of drain.
- Use patient-bound, clean care gown with long sleeves and cuffs, cap and surgical mask.
- Use non-sterile gloves upon removal of the bandages.
- Then in aseptic method, use sterile gloves and sterile shift set.
- By drainage of pus, *see Chap. 16 for contact isolation*.
- The skin closest to the drain opening is wiped with 0.9% NaCl and then skin disinfected with chlorhexidine alcohol 5 mg/ml in 1 min around but not into the wound.
- Corrugated drain is often secured with a suture.
- If the drain is to be shortened, removed the suture aseptically.
- Sterile safety pin is secured in the drain (90° angles) to prevent that the drain disappears into the wound.
- Add a sterile tupfer around the safety pin, to protect the skin.
- Cover with large absorbent, sterile bandage that is changed before it is soaked.
- At large secretion, a sterile bag is bound tightly around the drain opening, changed daily.
- Soaked bandage/bag is placed in a yellow bag in the box labelled *hazardous waste*.
- Consider the amount and appearance of secretion.
- Temperature control daily.

37.4.4.3 Removal of Corrugated Drainage

- Hand hygiene before and after.
- Use patient-bound, clean care gown with long sleeves and cuffs, cap and surgical mask.
- Use non-sterile gloves upon removal of outer bandages.

- Then in aseptic method, use sterile gloves and sterile shift set.
- Disinfect thoroughly around the drain.
- Remove any attached suture—aseptic!
- Support the skin at the drain opening with sterile tupfer in tweezers and pull the drain out slowly.
- The drain is placed in the yellow bag labelled *hazardous waste*.
- Dry sterile gauze over the drain opening.

37.5 Background Information

The use of drainage is not desirable since it may be a risk of infection, but in some cases, it is necessary [5–8]. Cochrane studies show no reliable evidence to support the routine use of drainage in orthopaedic surgery [6, 7]. The use of drain in hip or knee surgery is often associated with the need for blood transfusion that may lead to increased risk of SSIs and prolonged hospital stays [6, 7]. During primary closure of the surgical wound, uncontrolled bleeding/blood seepage in the wound should be avoided and that is linked to good surgical technique. It is important that the drain is treated closed and sterile and that it is removed during the first postoperative day to prevent retrograde infection and colonization by resistant microbes [5]. There is a greater risk of retrograde microbial infection by open than closed drainage [5]. The use of drainage should not extend antibacterial prophylaxis more than the usual time for clean surgeries [8].

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Part VII

Dialysis



Peritoneal Dialysis (PD) and Diagnostic Peritoneal Lavage

38

Abstract

Dialysis treatment may be carried out with peritoneal dialysis (PD), haemodialysis (HD) and filtering and dialysis (HDF). This chapter is a practical description of use, care and control of peritoneal dialysis. Peritoneal dialysis system is established under sterile conditions in an operating room and is treated aseptically as a surgical site. Peritoneum is a deep tissue structure with excellent conditions for growth of bacteria. PD must therefore be treated very carefully, as an open surgical site.

Keywords

Peritoneal dialysis (PD) · Diagnostic peritoneal lavage (DPD)

38.1 Purpose

- To prevent contamination/infection via dialysis catheters or drains.

38.2 Comprise

- All patients who require peritoneal dialysis or diagnostic peritoneal lavage.
- All personnel working with peritoneal dialysis patients and PD equipment.

38.3 Responsibility

The hospital management should ensure that the principles of good hygiene exist and that resources and formal qualifications for necessary treatment are present.

Department management has the overall responsibility for ensuring that written guidelines exist and are being followed and that the treatment is carried out with competence and in a hygienic manner.

A dedicated surgeon is placing the catheter and lavage as an operative, sterile procedure in the surgical department and decides whether to use active suction (vacuum) or passive drainage. Removal of catheter/lavage is prescribed by a doctor.

Nurse with expertise in peritoneal dialysis is responsible for observation and sterile handling of catheter/drain and for good information and education of the patient.

38.4 Practical Measures

- Peritoneal dialysis catheter is placed under sterile conditions in an operating room as part of an operation.
- Patients with dialysis catheters are more prone to infections than others since they have a drain that goes directly into the depths of sterile tissue peritoneum.
- It must therefore be handled as an operative wound, careful and aseptic.
- The patient must be informed and trained in good hygiene.
- Good hygiene with regard to patient care, change of bed linen, cleaning of the room, etc.
- The patient should be protected against infections and not be placed in the same room with patients with infections or with urinary tract catheters.
- Catheters with pus secretion and microbial infection should be treated in single room as contact infection, depending on the type of infection.

38.4.1 Peritoneal Dialysis [1–7]

38.4.1.1 Recently Operated Patient with Peritoneal Dialysis Exit (Called PD Exit)

- The bandages are changed after 7 and 14 days, provided it is not soaked with fluid/blood.
- Do not touch the wound if it is clean and dry. Optionally shift aseptically (see below) and disinfect with chlorhexidine-alcohol 5% (not directly in the wound).
- Not showering/bathing on the first 14 days; instead use body wash each day.
- When removing old dressing, gloves are used.
- Bandage change occurs aseptically; see below.

38.4.1.2 Care of Newly Operated PD Exit, i.e. First 14 Days After Catheter Insertion

Equipment: gown, surgical mask/cap, clean gloves, sterile gloves, shift set, catheterization kit, sponges, sterile gauze 10 × 10 cm, chlorhexidine-alcohol 5%, sterile NaCl 0.9%, swabs with adhesive edge, transparent dressing and sterile tape.

- Disinfect table before placing equipment.
- Hand hygiene before and after bandage change. Use patient-bound, clean gown with long sleeves, surgical mask and cap.
- Use clean gloves by gently removing the bandage and then change to sterile gloves.
- Then by aseptic method, use sterile gloves and sterile catheterization kit.
- If there is a stitch around the PD exit, remove this after consultation with a doctor. Then follow the procedures for removing sutures; see wound care in convalescent patient.
- A swab moistened with chlorhexidine-alcohol 5% is used to disinfect (wash) the catheter and the end.
- Carefully hold the end of the catheter with the chlorhexidine-alcohol compress under the following points:
 - At reaction-free PD exit: the wound opening is treated dry.
 - Otherwise washed with chlorhexidine-alcohol 5% for 1 min.
 - Regardless of reaction, disinfect an area of skin 20 × 20 cm around the PD exit with chlorhexidine-alcohol 5% for 1 min.
- Place the catheter end with the alcohol compress down on the disinfected skin. Put sterile cloth under the catheter end and remove the alcohol compress in the same operation.
- Check that the infusion plug or catheter extender is attached to the adapter.
- Without catheter extender: place dry, sterile compresses with adhesive edge over PD exit site, catheter with infusion plug and surgical incision. The bandage must be solid.
- With catheter extender: place dry, sterile gauze with adhesive edge of surgical incision. Dry, sterile compress with adhesive edge over the PD exit site in the direction of the catheter coming out. Below is placed a transparent bandage in the same direction to fix the catheter. Should overlap a bit, but not so much that it covers the actual exit site. Then the catheter can be bent into a natural bend without pull and twist and fastened to the belly with PD belt (clean every day) or clean tape.

38.4.1.3 Maintenance of Healed PD Exit: Three Times per Week and Always After a Shower!

Equipment: shift set with sterile tweezers and sponges, sterile NaCl 0.9%, chlorhexidine-alcohol 5%, clean gloves, sterile gloves, sterile gauze with adhesive edge, transparent dressing (Tegaderm, etc.) and sterile tape.

- Patients with perfect PD exit can shower without dressing, but the catheter must be fixed. In case of redness, crust, granulation or infection, use shower bandage.
- Patients are advised not to swim in general, and bathing in bathtub is not allowed. If bathing in the sea/pool is appropriate, a stoma bag must be used to cover the catheter.

- Disinfect table before placing equipment.
- Hand hygiene before and after bandage change.
- Use clean gloves by gently removing the bandage and then change to sterile gloves.
- Aseptic method with sterile gloves and sterile replacement kit.
- Inspect the catheter exit for redness, swelling, secretion and crust.
 - At reaction-free PD exit, wash with sterile NaCl 0.9% closest to the opening.
 - By redness around the exit, wash with chlorhexidine-alcohol 5%.
- Dry, sterile compress with adhesive edge over the PD output in the direction of the catheter coming out. Below is a transparent bandage in the same direction to fix the catheter. Should overlap a bit, but not so much that it covers the actual output. Then the catheter can be bent into a natural bend without pull and twist and fastened to the belly with PD belt (clean every day) or tape.
- Check that the adapter is well screwed and that the catheter extender is screwed firmly.

38.4.1.4 Care of Infected PD Exit Site: Daily Care Until the Infection Is Gone, Usually for 14 Days

When there are signs of infection, redness, swelling or secretion: Take bacteriological sample first and provide treatment in accordance with susceptibility testing. Usually begin with Fucidin ointment around the exit for 14 days (according to resistance pattern). The exit is washed with chlorhexidine-alcohol 5% and if pain use chlorhexidine-alcohol 0.5%. Otherwise, use the same procedure as for healed PD exit. The patient is treated as contact infection and wastes are treated as contaminated.

38.4.1.5 Care of Granulated PD Exit Site

In granulation tissue: Place (Mesoft) 5 × 5 cm compress flat under the catheter until the exit site by each care. In addition, Lapis may be used one–two times a week only on granulated areas.

38.4.1.6 CAPD (Continuous Ambulatory PD Every 4 h)

CAPD bag shift with dialysis fluid, usually three–five times a day

- Disinfect table before placing equipment.
- Hand hygiene before and after.
- Aseptic technique during filling and disconnecting. Use surgical mask and cap and disinfect hands.
- Do not contaminate coupling on catheter extension!

38.4.1.7 Replacement of Catheter Extensions, Done as Needed and Anyway Two Times/Year

- Disinfect table before placing equipment.
- Hand hygiene before and after bandage change. Use patient-bound, clean gown with long sleeves and surgical mask/cap.

- Aseptic technique with sterile catheterization sets and use of sterile gloves by changing the outer extension of PD catheter.
- Drain some dialysis fluid afterwards to rinse the coupling.
- Do not contaminate coupling on catheter extension!

38.4.2 Diagnostic Peritoneal Lavage (DPL) [2]

Diagnostic peritoneal lavage is performed if there are suspected blood in the abdomen, abdominal bleeding associated with acute trauma, impaired consciousness and other special situations.

Hand hygiene before and after caring for diagnostic peritoneal lavage.

38.4.2.1 Insertion of DPL

Insertion of DPL is an operative procedure and should be aseptic placed under sterile conditions in an operating room, using sterile protection, sterile gown and gloves, cap and surgical mask.

38.4.2.2 Bandage Replacement or Removal of DPL

Bandage replacement and removal of DPL should be done with aseptic technique and use of clean gown, sterile gloves and surgical mask/cap.

- Hand hygiene before and after bandage change.
- Use gloves and gently remove the bandage and then change to a new sterile glove.
- Then in aseptic method, use sterile gloves and sterile shift set.
- If there is leakage, wash with sterile NaCl 0.9% nearest to the insertion site, followed by disinfectant with chlorhexidine-alcohol 5%, but not in the wound!
- Apply sterile dressing over the surgical site.

38.5 Background Information

Peritoneal dialysis catheter Patients with dialysis catheters are more prone to infections than others since they have a drain that goes directly into the depths of sterile tissue peritoneum. The risk may be high if not good hygiene and aseptic technique is used by personnel and the patient [1–4, 6, 7]. The peritoneal part of the dialysis catheter will often last for months and even years and careful monitoring and control of hygiene is important. Infections in the catheter can lead to severe disease and risk for the patient and to unnecessary consumption of antibacterial agents, as well as the risk of resistance development.

A prospective study of 125 double-cuffed, coiled, swan-neck catheters placed by open surgery in 120 patients showed that the catheter was retained for 2 years in 97% and for 5 years in 92.2% [8]. There were few exit site infections per patient year (0.125 episodes) and peritonitis episodes per patient year (0.149). Other complications were herniation (8%), leakage (6%) and blood in the dialysate (3%) [8].

A low infection rate over time is dependent on good installation techniques and subsequent verification [8].

38.5.1 Peritoneal Dialysis Methods

- CAPD—continuous ambulatory PD every 4 h.
- CCPD—continuous cyclic peritoneal dialysis, at night.
- CIPD—chronic, intermittent peritoneal dialysis.
- Infections; CAPD > CCPD > CIPD. Studies have shown that the more own manipulations of the system, the more infections. Lowest risk is for CIPD: 0.4–0.9 episodes per patient year.

38.5.2 Peritonitis and Tunnel and Exit Site Infections [5, 7–9]

- *Exit site infections:* 0.2–0.7 episodes each year.
- *Peritoneal dialysis peritonitis:* usually 0.5–4% of the patients. The risk is increased from 36% after 6 months and 60% after 1 year to 80–90% after 3 years. But about half of all the episodes occur in 25% of patients. While 20% may have peritonitis three or more times per year, there are others who do not have infections at all for more than 3 years.
- *Symptoms of peritonitis are* fever, nausea, vomiting, abdominal pain and stiffness—12–36 h after peritoneal dialysis and eventually cloudy dialysis fluid [5, 7].
- *Microbes most common are:*
 - Coagulase-negative staphylococci: 25–30% of all infections.
 - *S. aureus, S. epidermidis:* 55–80%.
 - Gram-negative rods: *E. coli* and other *Enterobacteriaceae* and rarely *Pseudomonas, Burkholderia, Acinetobacter*, etc.

Avoid these infections by aseptic processing of the dialysis system, including dialysis fluids. Peritonitis frequently leads to recurrence and is the main reason for a transition to haemodialysis (Fig. 38.1).

38.5.3 Special Risks of PD Infection

- Children treating themselves.
- Underlying other disease.
- Diabetes—prone for exit site peritonitis.
- Low personal hygiene.
- Lack of motivation, social and health support.
- Double-cuffed catheter less risk than single.
- Connection Y-set, sterilized joint (UV)—fewer infections.
- Intraperitoneal self-medication.

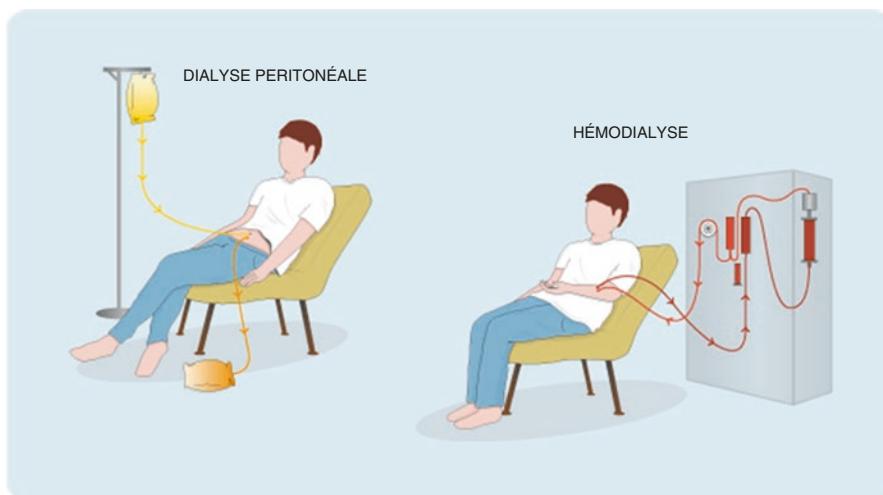


Fig. 38.1 Peritoneal dialysis and haemodialysis. Source: www.ameli-sante.fr

- Peritonitis and exit site infections—often in combination.
- Nose carrier of *S. aureus*.
- Diabetes—more often *S. aureus* infections than others.

38.5.4 Other Types of Infection Transmission

- Infection via machines (CIPD), water bath for dialysis fluid bags, contaminated disinfectants used for disinfection.

38.5.5 Prevention of Peritoneal Dialysis Infections

- All measures that reduce manipulation and manual opening of systems may reduce risk of infections.
- Motivates the patient for sterile technique.
- Good personal hygiene for the patient; change to clean personal cloth daily, clean bed linen and clean room and good hand hygiene.
- Catheters inserted with sterile operating technique are well attached.
- Y-sets and sterile connector sets should be treated sterile.
- All dialysis equipment is stored clean and treated sterile in a clean room.
- Avoid manipulation of the PD system.
- Good hand hygiene before and after contact, and avoid unnecessary contact.
- Daily cleaning/disinfection and inspection.
- *Note:* Remember cleaning routines for the machine, if used.
- *All infections are treated immediately to avoid haematogenous spread [7].*

- Note: Inform the patient on symptoms of infection and immediate contact with the healthcare system [7].
- Good nutrition and clinical follow-up.

38.5.6 International Guidelines [4, 6]

(Modified)

- Establish a dedicated peritoneal team.
- Insert the PD catheter at least 2 weeks before PD. If dialysis is started earlier, use small volumes.
- Protocol and procedures should be used for the care and control of PD perioperative, including antibiotic prophylaxis.
- Note MRSA and *S. aureus* test from the nose.
- Local expertise for inserting and choice of PD methods and implement this immediately if necessary.
- The PD catheter should be removed immediately, if necessary.
- Surgical responsibility for necessary support and follow-up of PD patients.
- Designated operation area for insertion/change of PD catheter.
- No catheter seems to be better than others, but size should be adapted.
- Can be inserted as day surgery if the quality is not impaired.
- PD can only be inserted by trained operating personnel.
- Personnel should be trained on the care and treatment of PD.
- Audit/multidisciplinary meetings every year to follow up the results.
- More than 80% of hospitalized PD catheter should be in order after 1 year [6].

Requirements for low complication rate in connection with inserting PD [6]:

- Bowel perforation <1%.
- Bleeding <1%.
- Exit site infection within 2 weeks after the PD entry: <5%.
- Peritonitis within 2 weeks of PD entry: <5%.
- Functional PD problems requiring manipulation or readmission or leading to technical errors: <20% [6].

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Abstract

The need for haemodialysis is rapidly increasing throughout the world—so quickly that the capacity is not followed up. This results in overcrowded and understaffed dialysis departments, also seen in Norwegian hospitals. A too small bed capacity and understaffing may lead to a high transmission pressure of microbes and risky infectious conditions for patients and for staff.

This chapter is a practical description of use, care and infection control of haemodialysis.

Keywords

Haemodialysis · HD · Infection control · Water systems · Disinfection
HD machines · Contamination risk

39.1 Purpose

- To prevent contamination, infections and infection-related events in connection with haemodialysis.

39.2 Comprise

- Patients requiring haemodialysis and personnel, machines and the environment around the patient.

39.3 Responsibility

The hospital management should ensure updated and written hygiene principles and procedures and that resources, localities and formal qualifications for necessary treatment are available. The hospital's management is responsible for immediately addressing serious shortcomings reported by the dialysis department.

Department management has the overall responsibility for ensuring that written guidelines exist and are being followed and that the treatment is carried out with competence and in a hygienic manner. The management is also responsible for immediate notification to the hospital's director if the conditions under haemodialysis expose the patient or personnel for serious infections.

Surgeon with expertise in vascular surgery and haemodialysis is responsible for establishing arteriovenous fistula or grafts or central venous catheters (CVCs) for patients being treated with HD, as an operative, sterile procedure in the operation department [1, 2].

Nurse with expertise in HD technique is responsible for observation and sterile handling of catheters and dialysis machines and for good information and education of the patient.

39.4 Practical Measures

The need for haemodialysis is increasing rapidly throughout the world—so quickly that dialysis departments are often overcrowded [3]. A too small bed capacity may lead to a high transmission pressure of microbes and risky infectious conditions for patients and for staff. HD is a complicated process with dialysis machines that have difficult cleaning and disinfection processes. The many variants of dialysis machines may pose a challenge for personnel and patients.

HD is done on (a) inpatients, (b) day-care patients in hospitals and (c) self-dialysis patients under supervision of special personnel and (d) at home. In all these situations, the principles of hygiene and infection control should be followed. However, in those departments where many patients are gathered at the same time and on the same rooms, the greatest environmental impacts occur if the conditions are not adapted for good hygiene and infection protection. Here, HD is described as day-care treatment, also used during admittance periods in the hospital.

39.4.1 Protection Against Infections in Haemodialysis

39.4.1.1 APIC Guide—Sums Up These Core Areas [1]

1. Clean and disinfect the environment.
2. Clean and disinfect the equipment.
3. Hand hygiene.
4. Vaccination and screening of patients and employees.
5. Medication/injection safety.
6. Patient/family/employee—education and training.

7. Prevention of infections—before and after surgery.
8. Common hygienic guidelines—for example, by infection.
9. Prevent bloodstream infections.
10. Water treatment and testing.
11. Infection surveillance.
12. Quality-enhancing programme. [1]

39.4.2 Patients in Haemodialysis Treatment

- Patients receive training in hand hygiene before and after haemodialysis and before/after contact with HD machine or other equipment [2].
- Patient and companion are also trained in hand hygiene before and after stay at the department.
- The patient is trained in personal hygiene and meets for dialysis in clean clothes.
- Patient carpets and textiles are sent to the laundry (85 °C) after each use [3].
- Each patient should have own locker for outerwear. The locker is washed regularly.
- Do not place clothes from infected patients in a common wardrobe [3].

39.4.3 Special Staff for HD

Professionals: Haemodialysis is academically challenging and requires a specially trained personnel who have technical knowledge, professional skills within a complex field of medicine, high level of expertise in infection control and care and time for often very poor patients. Training and verification of knowledge are required by appointment and a reminder one to two times a year [1, 2].

Staffing: Personnel-to-patient ratio should be at least one to one. There should be separate technical personnel for the dialysis unit, for disinfection of systems, machine maintenance, sampling for tests, etc. In addition, there should be separate assistants for daily cleaning, food and drink serving, and storage of disposables, sterile equipment, sterile dialysis fluids, etc. Due to infection protection, it is important that these tasks are kept separate [3].

39.4.4 Special Infection Control Routines

Note! All openings directly to blood/tissue fluids must be sterile and treated with strictly sterile procedures! [1–5].

- *Blood-borne viruses (hepatitis A, B, C, D, E, HIV, HTLV, etc.):* patients and personnel should be tested for blood-borne viruses when starting haemodialysis or work in the dialysis department. A zero test is important with respect to work-related infections, injuries to the patients, infection control and compensation. In the event of blood-associated accidents, the hospital's procedures are followed (see separate chapter). Blood may spread through air by spills—and most droplets are not seen.

Blood-borne viruses like hepatitis B and C and HIV can invade normal eye conjunctiva [6]. Hepatitis viruses survive in dried blood for days to weeks.

- *Resistant bacteria:* if the patient or staff are exposed to, or infected by, special resistant bacteria, follow the routines for testing and isolation procedures. Actual infectious agents are MRSA, VRE, ESBL and other particularly resistant gram-negative rods [7]. See separate chapter.
- *Tuberculosis:* tuberculosis guidelines are followed for exposure or illness. See separate chapter.

39.4.5 Patient Room and Organization

Dialysis department should be a separate unit which is easily accessible for patients for day treatment, with a direct entrance from outside. Hand dispensers with advice on hand hygiene before and after stay at the department.

Single-bed patient rooms for all HD patients (about 20 m²) with anteroom (for outerwear) and toilet (entrance from the patient). The room should be well ventilated, large enough for the patient bed, HD machine, other equipment and any companion. Walls and surfaces should be complete and robust, easily washable and withstand strong disinfectants. There should be washing stand and dispensers for hand hygiene products. The room should be equipped with modern surveillance systems and glass wall for monitoring, to protect the patient from transmission of infection and for personal integrity.

Isolates for infections: with negative air pressure and separate ventilation for patients with resistant microbes, *Clostridium difficile*, and pathogenic infections; minimum of 4 isolates per 20 treatment sites. See Chaps. 14–21 on isolation.

Isolate for patients with impaired immune defence: with positive air pressure and separate, filtered ventilation.

Monitoring and control in a separate room associated the ward office, optionally less dialysis units with common surveillance of 2–3 patients.

Medicine room should be spacious with glass doors in front of shelves; monthly cleaning of lockers and daily of benches. Hand wash and hand disinfectants. One dose medications and multi-doses units are used only *once*, to only one patient, and then discarded [6, 7].

Storage rooms are important since there is a great need of good storage space and several different storage rooms. The need for storage space for dialysis fluids depends on how the department is organized.

- Clean storage for HD machines—cleaned and disinfected inside and outside. Ready for next patient.
- Separate storage room for HD machines used for blood-borne infections (hepatitis A, B, C, D, E, HIV, HTLV), cleaned and disinfected inside and outside. Ready for next patient with blood-borne infection. Mark the machine which type of infection it is used for—or preferably—use a defined machine only for a certain patient, not for others.

- Sterile equipment store—large. Sterile equipment is stored in cabinets with glass doors for easier overview and protection against dust and microbes. Cabinets are cleaned inside at least once a month.
- Store room for dialysis fluids—large (16 m^2).
- Store room for clean equipment.
- Textile—store room.
- Store room for large equipment (wheelchair, walker, etc.).

Disinfection and cleaning room, separate for HD machines.

Disinfection and cleaning room, separate for other reusable equipment, textiles etc., with decontaminator.

Kitchen unit for patients, only be used by separate dedicated personnel who do not treat patients. Do not combine patient work with cooking because of risk of infection! The meals should preferably be ready to eat, covered, and served on a clean table to each patient [3].

Treatment/examination/interview room—at least 20 m^2 .

Laboratory tests of the patients are to be treated in a separate room—never into the medicine room! *Waste disposal room*—often large volumes of infectious waste.

Corridors—should not be a storage space for HD equipment, dialysis fluid, infectious waste, patient care or workplace for personnel! Corridor is only corridor [3].

The patient's outerwear should be kept in anteroom of single bedroom or in a spacious wardrobe. In case of known infection, outerwear is following the patient.

39.4.6 Cleaning and Disinfection

- The department should be organized and maintained to carry out a good daily cleaning. Patients are particularly vulnerable for infections and the department must have a high level of hygiene.
- There should be daily cleaning of all service rooms, patient rooms, treatment rooms and ward office.
- *Each patient room/treatment place* (chair/bed) must be cleaned thoroughly after each use with soap and water. The room with floor and horizontal surfaces and sink should also be cleaned between each patient.
- Also a good room cleaning every day for inpatients admitted to the hospital.
- *Biological material* is removed with spot disinfection on local areas if spilled on floors and surfaces. Afterwards, regular cleaning is done.
- *Room for patients with infections* are disinfected and cleaned in accordance with the relevant procedures. See Chaps. 14–21 on isolation.

39.4.7 Hand Hygiene and Uniforms for Staff

- Hand wash and dispensers, easily available for hand hygiene.
- No artificial nails or nail polish.

- No jewellery at all—or piercing.
- Monthly review of hand hygiene with employees is recommended [2].
- Use gloves—for each patient and when handling used equipment.
- Learn how to remove the gloves.
- Do not expose the glove box to contamination.
- Wash/disinfect hands before and after glove use and before and after contact.
- Remove gloves after care of a patient.
- Use the hospital uniform, change daily or more often. Patient bound gown for each patient. Learn how to dress and undress gown and other PPE, especially when caring for infected patient.
- Surgical mask, cap, gown and eye protection when working with vascular connection, opening and closing.

39.4.8 Prevent Spread of Infection

- Cough hygiene, not using the elbow bow, not on the uniform!
- Patients with respiratory symptoms/infections are isolated and use surgical mask when together with others (transport, etc.).
- Patients with hepatitis A, B, C, D, E, HIV, HTLV or other blood-borne viruses should be isolated.
- Contact-airborne isolation for patients with resistant/special bacteria or tuberculosis.

39.4.9 Vaccination and Screening for Tuberculosis

- Vaccination status at the start of HD treatment; patients and staff.
- All patients are immunized against hepatitis A, B, tetanus, pneumococcus and influenza. Hepatitis B immunization may fail in HD patients and should be checked.
- CDC recommends start screening for tuberculosis.
- Employees: immunized against “childhood diseases” (measles, parotitis, rubella), pertussis, diphtheria, tetanus, hepatitis A and B and influenza and screened for tuberculosis annually (locally dependent on vaccination).

39.4.10 Medication; Security and Hygiene

- Hand hygiene and good personal hygiene.
- Only single-dose glasses or vials.^{CDC}
- Never multi-dose glass/ampoule.^{CDC}
- Prepared in clean medicine rooms.
- Do not use medicine trolleys.
- Follow antiseptic, sterile guidelines.

39.4.11 Pre- and Per-Surgical Intervention

- Do not shave the hair, possibly cut.
- Check for MRSA—if MRSA should sanitation be done—preferably preoperatively.
- Preoperative antiseptic bathing/shower.
- Operation is performed on the operating department with full sterile technique [1, 2, 4].^{CDC}
- Full barrier precautions and skin antisepsis with chlorhexidine alcohol 5%, before inserting HD CVC.
- Transfer from temporary (CVC) to permanent (AV fistula) when possible—preferably within 3–4 weeks [1, 2, 4].^{CDC}
- AV fistula coupling between the vein and artery takes 6 weeks to 4 months. When it's working and cared sterile, there are a few complications.

39.4.12 HD Catheter Treatment

- Only trained personnel are treating the catheter.
- Chlorhexidine alcohol is used for all skin and HD catheter treatment [2].
- HD catheter and vascular access, bandaging, etc. are reviewed with staff four times a year [2].

39.4.13 Used Equipment

- Disposable equipment is discarded after use in contaminated waste.
- Reusable equipment (scissors, forceps, etc.) are decontaminated or sterilized between uses. Disinfection with a textile cloth is not good enough.
- Equipment that cannot be cleaned/disinfected as plasters, tape, etc. are used in small portions and discarded after each use.
- “Priming waste bucket”; use disposable container to avoid cross-contamination.
- Shift external venous and arterial transducer filter/protectors for each patient.
- The dialysis device used is transported in a tight container to infectious waste—use gloves.

39.4.14 Transducers and HD Machine

- External pressure transducer filter/protector—single use.
- External vein-artery pressure transducer—changed between each patient.
- Internal transducer filter—may be a problem?
- Internal parts of the HD machine—the internal way of the dialysate—heat disinfected at the end of the day.
- If suspected blood leakage, disinfect the HD machine *internally* before the next patient and always after blood-borne infection.

39.4.15 Water Treatment

- Follow official procedures for water treatment, dialysates and concentrates [1, 4, 5, 8].
- Sampling for control of microbes and endotoxin and for testing.
- Hygiene check. Check where water is taken in and out. Check that there is no cross-contamination between clean water in and unclean out in drains.
- Disinfect the water distribution system regularly.

39.4.16 Control

- Heat disinfection of internal parts once a day is recommended.
- Inactive HD machines must be disinfected before use.
- Routine bacteriology and endotoxin testing—suggestions [1, 4, 5, 8].
 - Every month two machines—rollers so every machine is checked at least once a year.
 - Portable equipment—home equipment—tested at minimum of 3–4 times per year.
 - Max 200 CFU/ml and 2 EU/ml endotoxin [4, 8].
Reaction and measures when the values are: 50 CFU/ml and 1EU/ml [4, 8].
- Monthly control of blood contamination, hepatitis B and C and liver transaminases.
- Monthly monitoring of the number of infections and other accidents in HD treatment and this should be centralized [2].

39.4.17 Preparedness

Emergency preparedness plans for HD patients must exist—for example, power outage, fire, etc. that put the HD centre out of activity [1].

39.4.18 Kidney Transplant Patients—HD

- Are immune suppressed.
- Often with ongoing virus infections.
- Are treated prophylactic.
- Dialyzed—some in different phases after transplantation.
- More than 50% have infections first year [9].
- Protective isolation for treatment in hospitals and at dialysis units. See Chap. 20 on protective isolation.

39.4.19 General Hygiene; Remember!

- Change uniform daily and more frequently if contaminated.
- Use own shoes in the unit.

- Inform about possible infection related to some patients and plan a schedule for the patient.
- Check that adequate infection tests are implemented and followed up.
- Gloves in all contact with patients and change gloves and hand hygiene between each patient.
- Gown, cap and surgical mask with visor when opening/closing sterile systems!
- Do not store any equipment in the patient room.
- Clean hands and attire before collecting equipment in storage rooms!
- Separate medicine room for clean treatment of equipment/medication. No dose—sharing between patients!
- Clean and unclean side for patients and their equipment.
- Good cleaning between each patient.
- Cleaning of environmental flooring etc.,—one to two times per day or more often when spills.
- Spilled blood is treated as infectious!
- All waste is treated as infectious!
- All food/beverages are handled by separate personnel—not by personnel who treat the patients!
- All patients with infections/carriers are isolated and treated separately (blood contamination, for contact, airborne infection, etc.).
- All water inlets and drains, as well as connections, should be treated as possible source of infection of gram-negative bacteria.

39.5 HD Performed as Self-Dialysis Under Surveillance

In self-dialysis, routines described above are followed. Self-dialysis is carried out on smaller units where patients should *not* be carriers of blood-borne infections or special/resistant bacteria.

- Patients and their families should go through a standard training programme in hygiene and infection control around HD [2].
- The unit for self-dialysis must have the same high standards of cleanliness and sterility as in a regular HD department, with daily cleaning of all floors and surfaces, dialysis equipment and patient seat/bed and monthly cleaning of all cabinets and storage shelves.
- Storage organization should be as in a regular HD department.
- Serving of food from a separate kitchen is done by personnel who are not treating dialysis patients.
- The patient should only be in contact with his/her own equipment and should not go in common storage rooms, the kitchen or other service rooms.
- Patients who are infected or exposed to infection at home or abroad should not be on self-dialysis. This is to avoid spread of infection to other dialysis patients. The patient is advised to report infections, stays abroad, exposure to infection, etc., before arrival to the department every time.

- Eventually testing for resistant microbes and blood-borne viruses may be planned with the patient beforehand, for instance, after stay abroad or exposure to infections.

39.5.1 The Patient—Personal Hygiene

- Performs good hand hygiene on arrival and later during the procedure.
- Arrives in clean clothes and has showered in the morning.
- Own wardrobe space and take off outerwear and shoes (shoe covers).
- Goes directly to designated space.
- Exits the dialysis unit directly, afterwards.
- Carpets and other equipment are used only once—no storage of the patient's "assets".

39.5.2 Self-Dialysis—Serving of Food, Medicine, Etc. [3]

- A common "buffet" of food is not recommended!
- The meals should preferably be ready to eat, covered and served on a clean table to each patient. No preparing of food—combined with dialysis treatment on the bedside. Food is made ready on the equipped kitchen.
- All equipment, including serving trays, is washed in dishwasher—>85 °C.
- All medication from the medicine room follows conventional hygienic procedures.

39.5.3 Self-Dialysis—Cross-Contamination Risk

- All equipment must be stored in a clean closed cabinet in separate, complete packages.
- The patient should not touch anything other than what he/she is going to use.
- Outer packaging should be removed outside the department—not stored in boxes on the bench and floor.
- The department must be clean with daily cleaning.

39.5.4 Self-Dialysis—The HD Process

The patients' ability to understand and follow procedures and hygienic competence are very important factors for a successful performed HD. The process is partly done by the patient, partly be a trained nurse.

39.5.4.1 Patient

- Hand hygiene between different procedures.
- Hand disinfectants—dispensers are recommended.

- The patient opens the hose sets, the kidney filter and the washing set. Fixture kidney filter in the rack, connect hoses, hang up the fluid bag to the rack and make ready the wash kit (add chlorhexidine alcohol, open syringes and remove backing paper).
- Flushing of the HD machine is started (NaCl). Removing air by tapping the kidney filter and tubing or with clean scissors. Hoses and filters are filled up with dialysis fluid.
- The patient does not connect the dialysis water.
- Note: In dialysis water—like all other kinds of water—it may grow gram-negative bacteria; it is easy to contaminate.

39.5.4.2 Trained Nurse

Nurse connects the patient to the HD machine.

Connecting—artery/vein fistula or CVC (jugular vein).

- The vein has arterial pressure, so there is a risk of splash/aerosol formation during puncture!
- Nurses should wear surgical mask with visor, cap, sterile gloves and disposable gown—change between each patient.
- Skin disinfectant with chlorhexidine alcohol (60 s).
- Add a clean towel or similar below for spilled blood.
- Insertion site is treated as a CVC-sterile procedure.
- All catheters must endure chlorhexidine alcohol disinfection.
- Nurse pulls up sterile NaCl from a sterile cup in a sterile wash set; one NaCl bottle for each patient.
- The system is flushed.
- The places for insertion changes every time.

39.5.5 Disconnection of Needles

- There is a risk of needle-stick when removing the needles.
- Therefore a system is recommended where the needles enter a sleeve.
- Nurses should wear surgical mask with visor, cap, sterile gloves and disposable gown—change between each patient because of the risk of splashes and spills.
- Dialysis fluid is considered as blood and treated as blood.
- Use a sterile glove for compression of the insertion site. Put on clean plaster (disposable roll). Avoid circular bandage because of the risk that the graft may be clogged.

39.6 Background Information

Before patients come to HD treatment, they usually have a chronic kidney disease or infection over many years. Often contact with the healthcare system and many antibiotic cures may have led to selection of resistant bacteria. Patients from abroad

with infections and drug addicts with blood-borne infections have been increasing patient groups for dialysis treatment, also in Norway [3, 10].

Many people receive dialysis treatment while on vacation or visiting their home country, and there is often a more resistant flora. MRSA, VRE and other multidrug-resistant organisms (MDRO) increase and are selected from those which get a lot of antibiotics.

Decreased immune function, poor general health and a lot of treatment of various additional diseases make that this group of patients should be well protected against infections and accidents and protected from infecting other people in the same situation. This is done by adding conditions for a proper HD of each patient and to ensure that the patient is understood and helped in an experienced manner—before, during and after haemodialysis.

39.6.1 Prevalence and Need of HD

Internationally, there is an increasing proportion of the population in need of HD. In the United States, there are more than 450,000 patients with end-stage renal disease (ESRD) and more than 350,000 on HD treatment [4]. It is an increase of 6–8% each year [4]. At the same time, there is increasing mortality of HD infections and of patients infected with antibiotic-resistant bacteria. Invasive resistant MRSA infections also increases and affects 45 per 1000 HD patients [7]. It is 100 times more than in the general population [7]. Dialysis patients constitute 15% of all in the United States with invasive MRSA. Most dialysis patients with MRSA have blood-stream infections (86%), most are requiring emergency hospitalization, and 17% die from the infection [7].

Like other countries, the need for haemodialysis has increased rapidly in Norway for the past 10 years, without increasing the capacity and treatment places, correspondingly [10]. In January 2012, 4329 patients were dialyzed, either by haemodialysis/haemodiafiltration (HD/HDF—1029), peritoneal dialysis (PD 186) or graft (3114). Nearly 900 per million inhabitants received some form of dialysis treatment. In 2011 162,192 HD treatments was completed—a 6% increase from 2010 [10].

At Ullevål University Hospital (Oslo), the number of HD treatments increased from 12,300 per year in 2005 to just over 18,600 per year in 2011, without increasing the number of treatment beds [3]. Instead, patients were concentrated into ever smaller areas of a dialysis department that already 10 years earlier was designated by the health authorities and the hospital management as “worrisome” because of the building-related decay and poorly maintained state [3]. This situation resulted in an outbreak of VRE in the department [3]. Among a number of risk factors that were detected were overcrowding, many patients together on small areas, under-staffing, lack of isolation conditions and mixing of patients with and without infections, personnel who did everything from patient care to food service and lack of storages for HD machines and dialysis fluid and other equipment [3]. The outbreak stopped after a month, following a series of hygienic measures, and 1 year later, all patients were VRE negative, and the department was rebuilt and expanded [3].

39.6.2 Nosocomial Infection Occurs Readily by Haemodialysis [3, 4, 7, 11–19]

The most important sources of infection in HD units are source of water, mixture of water and concentrate of dialysis fluid, pumping systems for the mixture through the dialysis machine and when the blood is pumped through and the waste goes over to the dialysis fluid [4]. Haemodialysis patients are exposed to 300–600 L of water each week, while most people drink 16–24 L of water per week [4]. Water and water quality are of great importance to dialysis patients. Serious complications can occur because of contamination of microbes, endotoxin and chemical materials (aluminium, copper, zinc, fluoride, calcium, etc.) in water [4]. Dialysis water can be a great risk as regards bacteria, endotoxin and fungi if not treated in a proper way. In eight dialysis units in Italy, 980 water samples were studied, and more than 10% of ultra-pure dialysate solutions were contaminated with both fungi and yeasts [12].

39.6.2.1 Water Quality-Bacterial and Fungal Growth

- Environmental bacteria grow easily: *Acinetobacter*, *Alcaligenes*, *Aeromonas*, *Enterobacter*, *Klebsiella*, *Burkholderia*, *Ralstonia*, *Stenotrophomonas*, *Flavobacterium*, *Pseudomonas*, *Serratia*, etc.—and all forms plenty of endotoxin (“poison” in the wall of gram-negative bacteria; equally effective even if the bacteria are dead) [1, 4, 5, 11].
- Non-tuberculous mycobacteria (*Mycobacterium chelonae*, *M. fortuitum*, *M. gordonae*, *M. scrofulaceum*, *M. kansasii*, *M. avium intracellulare*, etc.) may multiply in water and are often resistant and not detected by conventional bacteriological culture [4, 11].
- Fungi, like *Candida* and other fungi, are not detected by conventional bacteriological culture [12].
- Biofilm formation of bacteria, like *Staphylococcus epidermidis*, etc., is almost impossible to remove [4, 15].
- Bacteria may grow well in distilled water, deionized water, reverse osmosis, etc. It may reach 10^{5-7} bacteria/ml before the water looks opalescent [4].
- Dialysis fluids are rich growth media; 10^{8-9} bacteria/ml may result in a turbid, opalescent solution [4].
- Water from community system or water supply companies is chlorine treated as a rule, but in peripheral pipelines, the chlorine concentration is often 0 ppm—no effect. Thus, drinking water often contains 10–100 bacteria/ml and is contaminated with endotoxins.
- Surface water has a particularly high level of endotoxins and bacteria [4].
- Groundwater has endotoxins and bacteria but lower levels [4].
- Standard for water for dialysis—dialysis water—should be below 50 CFU/ml and endotoxin <0.125 EU/ml [1, 2, 4, 5, 8].

39.6.2.2 Water Treatment Can Increase Bacterial Growth [4]

- Ion exchangers (water “softeners” and deionized systems) do not remove bacteria and endotoxins and form the basis for bacterial growth.

- Carbon filter—may increase bacterial growth and does not remove endotoxin.
- Pre-filter can become colonized by bacteria and release extra amounts of endotoxin—and grow through filters in a few days [4].
- Absolute filter does not reduce endotoxin [4].
- Filters must be cleaned with the dialysis machine—every time.
- UVC-treated water: gram-negative bacteria can be resistant and UVC does not destroy endotoxin.
- Reverse osmosis removes bacteria and endotoxin from water—but gram-negative rods and mycobacteria may pass the system, therefore regularly disinfection.

39.6.2.3 “Hard Water”—Recommended Measures [4, 11, 16]

- Pre-filter.
- “Softener”.
- Carbon adsorption—at least two series.
- Particle filter.
- Reverse osmosis unit.
- Deionized unit.
- Ultrafilter, optionally more sets.
- Note! There may be an increasing number of bacteria and endotoxin during the flow through the system; therefore use ultrafilter in the end.

39.6.2.4 Distribution Systems of Water [4]

Central or local systems for mixture of water with dialysis concentrate.

- Pipe systems with larger diameter—and longer than necessary—may increase bacterial growth.
- Reduced throughput in the pipes may result in increased bacterial growth and endotoxin level because of larger wet surfaces for bacterial growth and protective biofilm formation which cannot be disinfected, except by high heat.
- Overnight growth can lead to bacteria-protective biofilm.
- Pipe systems should not have “dead ends” due to stagnant water with increased bacterial growth.
- Smooth pipe system, with no dead ends and with drain point highest in the system so that the system can be completely disinfected, should be used.
- The entire water system with pipe distribution should be routinely disinfected—heat disinfected.
- Avoid storage tanks, because of stagnation, growth and biofilm production.

39.6.2.5 Dialysis Machine—Disinfection [4]

- Follow the department’s routines and contact the manager for deviations from routines!
- Do not disinfect the same way as the dialysate is submitted—if still done, the intake port of the dialysate may not be disinfected; bacteria may grow here.
- Check that adequate disinfection reaches all parts of the system’s piping systems [4].

- Best effect and should be done: machine heat disinfected inside with hot water of 90 °C for about 32–45 min between each patient.
- Citric acid is added twice a week to prevent formation of a biofilm, but it is often recommended that it should be added each time.
- Disinfection of the whole system: water treatment, piping and dialysis machine.

39.6.2.6 Disinfectants [4]

- Follow the department's routines! Contact the manager for deviations from routines!
- Chlorine-based chemicals—when starting up the machine 20–30 min—can be used, but chlorine may corrode [4].
- Chlorine-based chemicals may be used between shifts a day and other disinfectants at the end of the day (glutaraldehyde, peracetic acid, etc.) that can be left in the system (high concentration and in 24 h for mycobacteria) [4]. Disinfection of mycobacteria may be very difficult or impossible. Glutaraldehyde, peracetic acid, etc. are also used. The rest of chemicals in the system may be a risk.
- Best effect and should be performed: machine heat disinfected inside with hot water of 90 °C for about 32–45 min between each patient. Heat disinfection is carried out for the entire system before use. This is a good disinfecting system for microbial control and without chemical rests.

39.6.2.7 Control of Bacteria and Endotoxin [4, 8]

- Water and dialysis fluid controls are taken every month near water and dialysate mixture.
- Before and after the dialysate in the machine.
- Frequent, once per month—preferably every week.
- Tested within 30 min or in the refrigerator at 4 °C to be tested within 24 h.
- Special growth conditions for bacteria in bicarbonate dialysis fluid—notify the microbiological laboratory!
- Total number of bacteria after 48 h of growth.
- During outbreaks: qualitatively + quantitatively + non-tuberculosis mycobacteria growth 7–14 days.
- Remember special media if suspected mycobacteria or fungi.

39.6.2.8 Dialysis and Fever Reactions [4]

- Pyrogen reaction: freezing or temperature >37.8 °C (oral) and no signs of fever before dialysis.
- Fever and chills 1–5 h after dialysis.
- Hypotension, headache, myalgia, nausea and vomiting.
- Sepsis or endotoxin reaction or combined.
- Only endotoxin decreases after a few hours.
- Blood culture should be taken and clinical examination conducted.
- Check the dialysis fluid—upstream and downstream; cultivation and endotoxin.
- Bacteria and endotoxin may occasionally pass through the dialysis membrane.

- Outbreaks in connection with dialysis priming liquid (waste handling option) are described; it may be caused by “backflow” and contamination of the openings.^{CDC}
- Note: contaminated disinfectants used in the system!

39.6.2.9 Risk Factors Dialysis

- Haemodialysis reuse [4].
- Lack of disinfection or incomplete disinfection of dialyzer or of water treatment system, specially concerning mycobacteria [4]. Outbreaks of mycobacterial infections (*M. chelonae*) in five patients, of which two died after incomplete disinfection [4, 17].
- High-flux dialysis—higher pressure—has greater membrane pores; bacteria and endotoxins may pass more easily into the patient’s blood, more often pyrogenic reactions [4].
- Bicarbonate in place of acetate dialysate—faster growth of bacteria and endotoxin increases—particularly in combination with high flux! [4].
- Outlet for dialysis fluids—and electrolytes are often common in a “sink” at the wall behind the dialysis machine. Here is also the drain for the used liquid:
 - Drain and outlet (for fluid and electrolyte concentrate) for dialysis machines are often too close to each other.
 - Spray from drains with gram-negative bacteria could contaminate the outlet to the dialysis machine.
 - Outlet unprotected—risk of cross-contamination and retrograde growth [4].
- Disinfection between connections—should be implemented.
- “Hansen couplings” for dialysis liquid, if used. Should be protected with hood due to risk of contamination/splash of used dialysis fluid during disconnection. These links are disinfected between each patient in a bucket. The bucket/and the like must be disinfected after use.

39.6.2.10 Risk Factors—Others

- HD—connection to the lower extremities more than upper limbs.
- Thrombectomy.
- Graft revision.
- Trauma/haematoma, dermatitis and scratching marks.
- Poor patient hygiene.
- Not good technique.
- Age, diabetes.
- Number of punctures.
- AV fistulas give less complications than synthetic grafts and central venous catheter.
- Nasal carrier of *S aureus* may be at increased risk for infection in vascular connection.
- *Endocarditis* risks: patients on pacemakers, heart surgery, heart failure, long duration of HD treatment, low serum albumin during insertion of HD, the use of non-cuffed dual-lumen and MRSA (also increases mortality) [7]. Mortality from infectious endocarditis may be up to 60% [13]. About 2–6% of HD patients get endocarditis/year [13].

39.6.2.11 Bacterial Infections and Location

- A total of 230 infections in HD patients at 27 HD centres in France were investigated [18, 19]. Nearly one out of three (27%) were in the blood from the vascular connection location, and the residues were infections elsewhere as respiratory and skin/soft tissue [18].
- Vascular connectors—*S. aureus* is the most frequent cause of infectious. During dialysis via CVC, *S. epidermidis* is the most frequent bacteria, and by vascular access in lower extremities, it is often gram-negative bacilli.
- Infections from the vascular site can metastasize to the lungs, skin, heart, bone, joints, brain, nails, etc.
- Biofilm containing bacteria can be formed in both dialysates and needles [15].

39.6.2.12 Virus Infections

- There have been a number of outbreaks of blood-borne virus infections at dialysis units around the world, both among patients and personnel [1, 2, 4, 6, 11, 14, 16, 19]. In 2005, there was reported 17.7% (3–71%) prevalence of hepatitis C (HCV) in European dialysis centres [14]. Among 1323 patients in 26 centres in France, the prevalence was 16.6%, and among 61 patients in Lyon, the incidence increased more than 36% during 1 year [14].
- HCV contamination was detected on the hands of employees, in the environment, as internal contamination of machinery and equipment, and on common equipment used between patients [14].
 - Risk was particularly related to nurses who connected the dialysis machine and who just before had connected an HCV patient to a dialysis machine.
 - Personnel who went from HCV-infected patient to a not infected at the same shift!
 - Understaffing, lack of education, knowledge and training and breach of hygiene principles.
 - Often inflow of blood in the double filter on the arterial pressure side.
 - Conclusion: hands were a transmission problem, and it led to contamination of internal components of the dialysis machine [14].

39.6.2.13 HD Catheter Risks

HD catheter may pose a risk to bacteraemia and septic conditions. A permanent (cuffed) HD catheter represents a sevenfold increased risk for sepsis than arterio-venous fistula [5]. A study of outpatient HD treatment in the United States found increased incidence of bloodstream infections and resistant bacteria (MDRO) among HD patients [5]. At the same time, there was a lack of implementation of hand hygiene after contact with HD machine and before non-invasive procedures. All equipment was located close to the patient's treatment chair, and it lacked cleaning between patients. Catheter handling was done without disinfecting the opening ("hub"), and the patient was not asked to wash their hands before each procedure. To correct these problems, several measures were put together, "bundle of best practices" [5]:

- Catheter hub was disinfected before use with chlorhexidine alcohol.
- Hand hygiene and use of gloves before contact with patients and equipment.
- Patients are helped to hand hygiene before dialysis.
- All equipment stored around the patient was removed—stored centrally.
- Housekeeping and cleaning were strengthened.
- Chlorhexidine gluconate-impregnated bandages on exit locations in high-risk patients (prior infection, femoral catheters, limited access).
- Implementation and strengthening of a fistula establishment programme [5].

Result: catheter infection was reduced from 2.4 per 100 patient months to 0. Use of fistula increased. However, the occurrence of resistant bacteria was unchanged [5].

39.7 Summary of Practical Guidelines from The Renal Association for Haemodialysis [16]

It is modified and selected by the author (each point has a separate guide in the Renal Association guideline [16]).

1. HD offered to the patient [16]:

- Dialysis unit must be in good, defined locations, tailored for the treatment.
- Have sufficient specialists for proper treatment.
- HD unit should be placed less than 30 min from the patient's home and those who need transport to be collected within 30 min before dialysis and get home within 30 min after the end of dialysis.
- HD capacity should be increased in stages in relation to the need. The number of national HD patients per million inhabitants in the previous year represents a minimum figure for the capacity in each area.
- HD treatment places should be based on that each place should be used by two patients three times a week. This is done so that the patient can choose for more frequent haemodialysis if needed, for holidays and for the expansion of patient numbers.

2. HD equipment [16]:

- All equipment must be CE marked and follow European standards.
- All sterile and disposable equipment must be CE marked and comply with relevant standards.
- HD machines should be replaced after 7–10 years, or after use in 25,000–40,000 h, depending on the machine condition.

3. HD concentrates [16]:

- Commercial concentrates are classified as medical devices, and CE marked and other equipment as well as water for HD used in this treatment shall be consistent with the requirements of the European Pharmacopoeia (sixth ed. 2007).

- Water treatment systems for HD must fulfil specific ISO requirements. Chemical contaminants, microbiology and endotoxin should also follow specific ISO requirements.
- Ultrapure dialysate is recommended with microbiological contamination <0.1 CFU/ml and endotoxin <0.03 EU/ml.
- Monitoring HD water, etc. should be regularly carried out with written procedures and with respect to deviations.
- Bicarbonate is recommended as buffer.

4. Biocompatible haemodialysis [16]:

- Discussion of various membrane types, haemofiltration and high flux.
- HD sterilized with ethylene oxide is discouraged.
- Some drugs have ability to interfere with HD synthetic membranes.

5. Minimum frequency for HD [16]:

- HD at least three times per week to almost all patients. It is not acceptable to reduce to two times per week due to lack of capacity. Minimum of 4-hour dialysis per adult patient.
- HD results in demands for organic effect for each patient.
- Certain vulnerable and sick/unstable patients need more HD than others – where time and frequency will be expanded.
- Residual renal function is to be saved as far as possible by avoiding hypotension and nephrotoxic substances.

6–8. Monitoring and Treatment [16]:

- Blood samples, biochemistry, bicarbonate, phosphate, calcium, aluminium, haemoglobin, etc.
- Anticoagulants—different use.
- Hypotension problems.

9. Home Dialysis [16]:

- Anyone who can/want to carry through home dialysis must be informed and trained.
- Trained at a HD centre.
- Self-treatment—daily short—or dialysis overnight [16].

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Part VIII

Bloodstream Infections



Peripheral Intravenous Catheters

40

Abstract

Bloodstream infections (BI) bacteraemia/sepsis, are serious and increasing in European hospitals, with an estimated incidence of 2.7% and death in one out of five hospitalized patients. Most cases (73%) are nosocomial and dominated by *Staphylococcus aureus*, *Escherichia coli*, *Staphylococcus epidermidis*, *Streptococcus pneumoniae*, and *Pseudomonas aeruginosa*. Among all microbial agents, 53% are gram-positive cocci, and 41% are gram-negative rods, while fungi and anaerobic bacteria constitute approximately 5%. Studies from CDC show that up to 70% of all nosocomial bloodstream infections may be prevented. The following chapters are focused on practical measures to control and prevent bloodstream infections in hospitals.

Keywords

Bloodstream infections (BI) · Catheter-associated bloodstream infection
Peripheral intravenous catheter (PIVC) · Central line-associated bloodstream infection (CLABSI) · Infection control · Hygiene

40.1 Introduction (BI)

Bloodstream infections (BI) and bacteraemia/sepsis are serious infections increasing in European hospitals, with an estimated incidence of 2.7% and death in one out of five patients [1]. Most cases (73%) are nosocomial and dominated by *Staphylococcus aureus*, *Escherichia coli*, *Staphylococcus epidermidis*, *Streptococcus pneumoniae* and *Pseudomonas aeruginosa* [1]. Among all microbial agents, 53% are gram-positive cocci, and 41% are gram-negative rods, while fungi and anaerobic bacteria constitute approximately 5% [1]. In Norway, 1 out of 100–200 hospitalized patients has nosocomial BI, dominated by *S. aureus*, other staphylococci and *E. coli* [2, 3].

The starting point for BI is often infections of the lungs, urinary tract, skin, gastrointestinal tract, surgical wounds, pressure ulcers and other organs, particularly in highly immune-compromised patients with widespread damage to mucous membranes and in transplant patients [4–7].

Direct introduction of infectious agents via infusion or injection of microbe contaminated liquids, or by use of contaminated multi-dose containers and drugs, is well known. All types of contaminants are transferred to the bloodstream by contaminated fluids and equipment [8–20]. The problem is avoided by prefilled, disposable single doses and by ensuring production of pharmaceutical preparations [19–22].

Guidelines to reduce nosocomial bloodstream infections have been made for the last 30–40 years, without significant improvement [23–34]. Norwegian guidelines are, like other countries, based on guidelines from CDC, USA [35–37]. Central, catheter-associated, BIs (CLABSI, central line-associated bloodstream infection) are reported to the CDC from the network of 4400 American hospitals [38]. More than 250,000 BIs are reported each year, hence more than 80,000 in intensive care units, and 65–70% of these can be prevented [39, 40]. A large proportion is associated with haemodialysis, 37,000 in 2008 [39].

40.2 Peripheral Intravenous Catheter

Definition: Peripheral intravenous catheter (PIVC), “Venflon”, is a sterile catheter with one needle inserted into smaller, peripheral veins.

40.3 Purpose

- To protect the patient from severe catheter-associated invasion of bloodstream microbes and other complications such as thrombophlebitis, bleeding or air embolism.

40.4 Comprise

- Everyone who inform about, insert, control, work with, treat and remove peripheral venous catheter.

40.5 Responsibility

Hospital management should ensure that all procedures for indication, placement and control of peripheral venous catheter are performed in a proper manner.

Department management is responsible for implementing and training current procedures concerning the use of peripheral venous catheter.

Health professionals, who insert, check and take care of PIVC, should follow the actual procedures in a hygienic and safe manner and inform patients/relatives. The insertion of PIVC can be delegated to specially trained personnel or “infusion team” [29, 30, 33].

Physician in charge has the responsibility for the indication of use of PIVC; for insertion, control and removal; and for advice concerning problems that may occur.

Nurse taking care of the patient with PIVC should control the catheter position, local area and bandages and report to the responsible doctor if there are displaced catheter, occluded catheter, resistance to injection, leakage of fluid/blood through the dressing, accidental contamination, local or systemic infection symptoms, suspicion of thrombophlebitis or other complications.

40.6 Practical Measures

40.6.1 Indication for the Use of PIVC

Need for intravenous therapy, fluids and/or drugs that cannot be administered in any other way.

Note! Patients that are moving between departments and healthcare levels: check the catheter on arrival and assess if it is still necessary!

40.6.2 Information, Training and Control

- The patient/relatives are informed of the intravascular catheter and how to insert and check [29–33].
- The patient/relatives report if there is pain, burning, swelling or bleeding around the injection site [29, 33].
- The patient/relatives are trained in good hand hygiene and are advised to remind health personnel of hand hygiene if this is not done; if necessary, report lack of hand hygiene [33].
- Trained and defined competent personnel insert the catheter and provide maintenance and control [29, 33, 41].
- Training is important and should be checked [42].
- Catheter insertion is documented in writing: date, type of catheter, anatomical site inserted, name of the catheter, fluid/medication inserted, control and when the catheter is to be removed [33].
- Sepsis, other infections and complications are monitored and reported [33].

40.6.3 Risk of PIVC Infection

Infected peripheral venous catheter leads often to thrombophlebitis, localized vein infection, fever without known cause or sepsis. Medicines and fluids can be

irritating or directly harmful to the blood vessels (pH without normal value, osmolarity, chemical substances), such as potassium chloride and vancomycin [33, 41].

40.6.3.1 Risk Increases

- A high number of bacteria on the skin around the catheter that is a presage of infection.
- Lack of sterility when the catheter is inserted.
- Frequent openings of the access to the catheter; “heparin lock” [41].
- Type of catheter and size [41].
- Number of days in place.
- Where it is located—least risk on the forearm [41].
- Poor/inadequate hand hygiene [43].
- Relative risk increases significantly after 48–72–96 h, depending on sterility and treatment.
- Lack of education, training and control of personnel [29, 33, 41].
- Lack of monitoring and registration of catheter-related septicaemia.

40.6.3.2 Risk for the Staff

- Needle sticks during catheter insertion and control.
- Spray and spill of blood from the PIVC site.
- See Chap. 11 on accidents and needle stick injuries.

40.6.4 General Information

- Two persons participate in catheter insertion to ensure sterility.
- Do not palpate the insertion site after skin disinfection [29, 33].
- Avoid skin lesions around the injection site.
- Avoid the use of steel cannula due to risk of damage to the vein and stick accidents.
- Gently fix the needle.
- Use sterile gas compression to cover the insertion point. Avoid contamination of the site by unsterile dressing/plaster contact.
- Date is noted on the outer part of the bandage/separate tape and in the journal.
- A catheter inserted without necessary sterility should be considered to be replaced as soon as possible [44].
- Intravascular fluids are stored in clean cabinet/clean storage. Intravascular fluids, catheters/infusion sets, etc. with expired date are discarded.
- Replace the intravenous administration set (IV tubing) every 3–4 days, except for blood/blood products, lipid solutions, etc. where it is replaced after completion of each infusion [29–33, 45–47].
- *Infusion solutions* should preferably not be used for more than 12 h (lipid solutions) and not over 24 h. Additions to commercial infusion solutions must be prepared aseptically in a suitable LAF (laminar air flow) bench.

- Particle filters do not significantly reduce the risk of infection, but may be used in blood transfusions [33].
- In case of clinical suspicion of catheter infection, the catheter is removed immediately.

40.6.4.1 Preparing PIVC

Insertion of venous catheter may be performed in the patient's room. A clean environment is important.

Sterile procedure: Sterile preparation and aseptic technique. The insertion is performed by a sterile procedure with sterile equipment and liquids and in a clean environment.

Insertion site: Usually the underarms/hands in adults (vena basilica or vena cephalica) and head vein/hand/foot in infants/toddlers. Use good veins, preferably on the hand/forearm, and avoid the veins around joints. Use preferably non-dominant forearm. If a previous catheter has been used, choose a new insertion point proximal to the previous one. Catheter sat in further up on the arm; "mid-line" is used occasionally since it can last longer [30]. Check the insertion site in advance.

Take care of the skin, especially in the elderly with fragile skin and fragile veins. A strong tap or excessive use of the stasis hose may cause venous and skin bleeding. If necessary, warm up the insertion point with a warm cloth for a few minutes before puncturing the vein.

Note! Patients who are going to be in dialysis or other long-term IV treatment—consult a physician for how to "save" important veins.

40.6.5 Implementation—Practical Performance

40.6.5.1 Two Personnel Participate

Equipment: cannula (1.0–1.4 mm depending on the size of the vein), infusion set, sterile syringes and needles, sterile closures (props), eventually Y extension with 10 cm extension hose, tourniquet, sterile gauze pads, sterile sponges, sterile tape, bandage, special dressing with cleavage, disinfectant (70% alcohol with chlorhexidine (2) – 5 mg/ml = chlorhexidine alcohol), heparin rinsing fluid, sterile saline (NaCl 9 mg/ml), optionally a predrawn syringe with 3 ml sterile saline (prefilled), sterile gloves, surgical mask and patient-bound gown. For children <2 months, skin disinfection can be used with 0.5–1% chlorhexidine [29].

1. Inform the patient/relatives.
2. Hand hygiene.
3. Inspect the insertion area and check the veins that can be used.
4. The patient's arm/hand must be clean; optionally wash with soap and water and wipe well afterwards.
5. If hair has to be removed, use a cutting machine, not shaving.

6. Local anaesthesia and creams/patches on children. This may form biofilm with growth of bacteria. Therefore, it must be removed with soap and water before insertion [33].
7. Prepare the infusion set aseptically and hang the infusion tube on a clean stand. Note the proximity to the sink and danger of splashing of water on the infusion set!
8. Check catheter type/vein cannula.
9. Place the patient in a correct position.
10. In hand hygiene, wash or disinfect the hands, wrists and forearms for at least 1 min [33]. Do not wear jewellery or watches.
11. Disinfect the table to be used as a base.
12. Place the equipment on the table; disinfect the stasis hose before and after use.
13. Apply surgical mask/cap/eye protection and patient-bound gown and disinfect your hands.
14. Open the equipment and make everything clear—sterile preparation and aseptic technique.
15. Place of insertion is usually the underarms/hands in adults and head vein/hand/foot in infants/toddlers.
16. Disinfect the insertion site and an area around (10×10 cm) with chlorhexidine alcohol, and let it work for 60 s and dry. Do not touch the disinfected area. If so—new disinfection.
17. Apply sterile (unsterile) disposable gloves (gloves in open glove boxes may be highly contaminated!).
18. Stasis hose is placed 15 cm above the stitch site, immediately before insertion of vein catheters.
19. Insert the vein catheter: check the needle, fold down the wings, tighten a three-point grip in the needle, tighten the skin below the insertion point and punctuate the skin and vein at a low angle. The mandrel is pulled back a little—5 mm—and the catheter itself is inserted into the vein.
20. Remove the stasis hose and then the steel mandrel, and connect the infusion set directly and check that the intravenous fluid flows freely into the vein.
21. Optionally: Rinse slowly and carefully through the inserted catheter with 3 ml of sterile saline (NaCl 9 mg/ml) before connecting the infusion set (note—no air bubbles in the saline!). Other measures for young children!
22. Fasten the vein catheter with sterile tape—do not tape directly over the insertion site, wipe away any spills and cover the injection site with sterile compression/dressing.
23. The couplings are covered with sterile compresses.
24. Enter date, time and signature on the outside of the bandage and on the curve/journal.
25. Dispose used vein cannula in container for used syringes and disinfect the stasis hose.
26. Remove gloves, disinfect hands and remove gown and surgical mask/visor/cap.

40.6.6 Daily Check of PIVC Twice or at Each Work Shift

Sterile preparation of equipment when changing bandages, etc. and aseptic technique.

40.6.6.1 Check at Least Twice a Day

- Good hand hygiene before contact with catheter/infusion set/dressing, etc. Do not touch the insertion point and, as little as possible, the bandage.
- Daily inspection (twice) of the insertion site for bleeding, infection, thrombophlebitis, etc. and more frequent control of children and inspection at least every hour during infusions.
- Wet, dirty, bloody-spilled compress is removed, and insertion point and vein are inspected. The area is disinfected with chlorhexidine alcohol 5 mg/ml before new sterile compress is applied. Eventually change sterile compresses every other day if necessary. There should be no liquid (water, sweat, etc.) around the insertion site.
- In case of tenderness, inexplicable fever, etc., inspect the insertion site.
- Contact a physician for signs of infection or other complications.
- Remove the catheter as soon as possible and by signs of bleeding/infection.

40.6.6.2 Use of PIVC

- Do not open the infusion system unnecessary due to risk of infection.
- Disinfect outside of the couplings with chlorhexidine alcohol before and after all on/off connections.
- Use a separate “port” on the vein catheter for direct intravenous injection of medication. Disinfect the “port” with chlorhexidine alcohol 5 mg/ml before and after injection and at least 30 s before injection of medicaments.
- Rinse with 3 ml of sterile saline (NaCl 9 mg/ml) before and after injections. Pre-filled syringes are recommended which can replace “heparin lock”. Other measures for young children.
- Caution with flush so that pressure on the vessel wall is not too large.
- Optionally, use a heparin lock between infusions instead of flush.
- Sterile stopper changed for each infusion/injection.
- The couplings are covered with sterile compressor.
- Follow the instructions for using sterile infusions in plastic bags (infusion bag).
- Disinfect the cap on the drug stopper with chlorhexidine alcohol before and after injection of medication into the infusion bag (infusion bag). Do not use multi-dose glasses.
- Infusion solutions should preferably not be used over 12 h, and intravenous set should always be changed after infusion of blood and nutritional solutions.
- Do not take blood samples through the catheter (other than diagnostic in suspected catheter infection).

40.6.6.3 Remove/Replace PIVC

- Good hand hygiene, surgical mask/eye protection/cap, gloves and patient-bound gown.
 - Remove PIVC as soon as possible and press carefully for 1 min. The site is disinfected and covered with a compression.
 - PIVC that is stopped up must be removed immediately. The insertion site is disinfected and covered.
 - Remove catheter by signs of bleeding/infection; insertion site is disinfected and covered. There should be further observation and treatment when needed.
 - Replace vein catheter/infusion hose and insertion site approx. Every 3–4 days (performed as above) [33].
-

40.7 Background Information

There are four common causes of catheter infections: (1) external and internal invasion from the patient's skin along the outside and inside of the catheter, all the way to the catheter tip; (2) the hands of the staff or the environment of bacteria and fungi, the same route as the skin flora; (3) spread via blood from an infected focus to the catheter tip; and (4) via contaminated infusion solutions or infusion openings of the catheter, which happens relatively frequently.

Most patients admitted to somatic hospitals; 50–90%, are treated with intravascular (IV) catheters. Bacteraemia/sepsis derived from peripheral venous catheter can be detected in approximately 0.2% of the cases [2, 3].

In 2002, with relatively few resistant bacteria, laboratory-confirmed nosocomial sepsis had a high mortality rate in some studies (35–41%) and increased stay in hospital of 20–25 days, and the cost was approximately 16,400 Euro per patient [48]. A study from 2013 found that 82% of patients in hospitals had one or more intravenous catheters, hence mostly (95%) peripheral catheter [49]. Infections at the insertion site were detected in 5% of the patients. Almost every fifth catheter was unnecessary and there was no overview of catheter use. The authors recommended improvements [49].

Infections derived from intravenous catheters increase concerning resistant bacteria such as MRSA, VRE and gram-negative rods, which creates additional problems and costs [50, 51].

Exposure to blood-borne virus infections is also increasing, which may be unknown to both the patient and the staff. Stitching injuries are not uncommon and can have consequences [52, 53]. Hepatitis A, B and C and HIV may also infect via eye mucosa [18]. By little visible spillage can high amounts of invisible small blood particles spread into the air [18, 54–56]. Therefore, surgical mask/eye protection and cap are recommended when working with intravascular catheterization.

Environmental contamination is little emphasized. However, the preparation of intravenous sets and the addition of drug mixtures under unhygienic conditions, for instance, in medicine rooms with a low hygiene standard, may result in significant contamination both outside and inside infusion sets and fluids [12]. It is still large

outbreaks of serious sepsis and other infections associated with contaminated fluids and medications that should be sterile [19, 57].

An important cause of infection is the external and internal invasion of bacteria along the outside and inside of the catheter to the catheter tip.

- The amount of bacteria (especially resistant) on the skin is a clear warning about risk of catheter-related infections [25].
- Frequent openings of accesses to the catheter; “heparin lock” is clearly associated with increased number of catheter-related infections.
- Needleless connections—*injection-free* couplings—are problems with regard to contamination and disinfection [58].
- Hand hygiene is central concerning prevention of catheter infections [43]. A prospective, multicentre study of 1132 patients with inserted peripheral venous catheters showed that normal hand wash was no more effective than no hand wash before insertion of the cannula [43]. On the other hand, there were significantly fewer complications as infections if hands were disinfected or sterile gloves were used, prior to insertion [43].
- Peripheral needles inserted into the operating room had a significantly lower complication rate than catheter placed in the bed post [43]. So, the higher the level of hygiene and sterility, the lower the rate of infections.
- The relative risk of complication increases significantly after 48–72 h [23, 59].
- Educating and training the executive personnel reduce the risk of complications [29, 41].
- It is recommended to monitor and record catheter-related septicaemias per 1000 catheter days, especially in intensive/postoperative units.
- Alcohol combined with chlorhexidine skin disinfectants is probably more effective than non-alcoholic povidone-iodine.
- Closed-system peripheral IV catheter (COS PIVC) reduces phlebitis and risk of infection—at an additional cost of only 0.09 Euro per day—compared to open-system catheters (MOS PIVC) [60]. Closed catheter system can be indwelling for more days, with significant savings [60].
- “Midline catheter” is similar to peripheral catheter but somewhat longer and is placed higher up (antecubital fossa), entering into larger veins (v basilica/cephalica), but is not a central catheter [25]. It can last a longer time without complications (0.8 infections per 1000 catheter days) [25].
- In a multivariate analysis that included 3300 patients with expected indwelling peripheral catheter for more than 4 days, the conclusion was that the catheter worked best using forearm, with suitable diameters of the catheters, and inserted by intravenous team or other specialists [41].
- The use of “care bundles”—a set of different preventive measures—has been shown to reduce infections in relation to the use of peripheral catheters [31].
- Sepsis patients on a good clinical standard treatment may achieve equally good results concerning survival in 60 and 90 days and after 1 year, including the use of peripheral venous catheter, compared with the use of central venous catheters [61, 62].

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Central Intravascular Catheter (CVC)

41

Abstract

Bloodstream infections (BI), bacteraemia/sepsis, are serious and increasing in European hospitals. Bacteraemia originating from catheters in large vessels is estimated to be 2–8% of cases. Most catheter infections are associated with central venous catheters or central arterial catheters. Risk arises in intensive care units (ICU), medical units, during cancer therapy, and in haemodialysis centres. An increasing percentage is recorded outside the ICU or outside the hospital. Sepsis has a high mortality rate (12–35%) and increases the stay in ICU for 4–14 days, and the cost may be 4000–13,000 Euro per patient. Educating and training personnel in aseptic care and treatment of CVC or other intravascular catheters may reduce infection rates, especially concerning catheter-related *Staphylococcus aureus* infections. The procedures need time and quietness so that sterility is properly addressed. Infection risk is reduced by removing catheters as soon as possible and avoiding use of the femoral vein in adults. Catheter contamination is caused by the patient's skin flora or contamination of the infusion set, catheter openings and other sterile equipment. This may occur in the absence of aseptic technique and the presence of large environmental loads of microbes. Most hospital-associated, bloodstream infections can be prevented. The following chapter is focused on practical measures to control and prevent central catheter-associated bloodstream infections in hospitals.

Keywords

Central intravascular catheter (CVC) · Bloodstream infection (BSI) · Catheter-associated bloodstream infection · Central line-associated bloodstream infection (CLABSI) · Catheter-related bloodstream infections (CRBSI) · Hickman Broviac · Swan-Ganz · Peripherally inserted central venous catheter (PICC) · Infection control · Absolute sterility · Hygiene

41.1 Purpose

- To protect the patient from severe catheter-associated invasion of bloodstream microbes and other complications such as thrombophlebitis, bleeding or air embolism.

41.2 Comprise

- Everyone who inform about, insert, control, work with, treat and remove central intravascular catheter (CVC).

41.3 Responsibility

Hospital management should ensure that all procedures for indication, placement and control of peripheral venous catheter are performed in a proper manner.

Department management is responsible for implementing and training current procedures concerning the use of peripheral venous catheter.

Health professionals, who insert, check and take care of PIVC, should follow the actual procedures in a hygienic and safe manner and inform patients/relatives. The insertion of CVC can be delegated to specially trained personnel or “infusion team” [1–3].

Physician in charge has the responsibility for the indication of use of CVC; for insertion, control and removal; and for advice concerning problems that may occur.

Nurse taking care of the patient with CVC should control the catheter position, local area and bandages and report to the responsible doctor if there are displaced catheter, occluded catheter, resistance to injection, leakage of fluid/blood through the dressing, accidental contamination, local or systemic infection symptoms, suspicion of thrombophlebitis or other complications.

41.4 Practical Measures

41.4.1 Definitions and Short Description [1–6]

- Central intravascular catheters have one or more lumens (canals) and are inserted in large, central blood vessels, most often veins (CVC). Other types are catheters placed in arteries, haemodialysis catheters and peripherally inserted central venous catheters (PICC).
- Non-tunneled and tunneled (under skin) (Hickman and Broviac) catheters with or without “Groshong” tip [1].
- Other types are totally implanted intravascular catheter accesses, called “port” (vein port), central arterial catheter (Swan-Ganz), pulmonary artery catheter and arterial catheter [1–6].

- CLABSI: Central line-associated bloodstream infection; central intravascular catheter-associated bloodstream infection.
- CRBSI: Catheter-related bloodstream infection- or central venous catheter-related bloodstream infection.
- BSI: Bloodstream infection- or intravascular catheter-related infection.
- *The definitions may be mixed, but the same infection-preventive measures are used for all types of catheters!*
- *Note! Always follow local written routines for use and control of CVC.*

41.4.2 Indication for the Use of Central Intravascular Catheters

- Total parenteral nutrition, prolonged intravenous therapy, haemodynamic monitoring or temporary haemodialysis.

41.4.3 Information

- The patient/relatives are informed of the intravascular catheter, how to insert and check.
- The patient/relatives report if pain, burning, swelling or bleeding is around the insertion site.
- The patient/relatives are trained in good hand hygiene and are advised to remind health personnel of hand hygiene if this is not done; if necessary, report lack of hand hygiene.
- Educated, trained and defined competent personnel insert the catheter and provide maintenance and control [3].
- Training is important and should be checked [3].
- Documentation written: date, type of catheter, anatomical site inserted, name of the person inserting the catheter, liquids/medications inserted, control and when the catheter is to be removed.
- Sepsis, other infections and complications are monitored and reported.
- Due to risk of blood contamination and an increasing number of patients with unknown type of blood-borne infections, personnel should always use surgical mask/eye protection/cap/patient bound gown and sterile gloves by direct contact with—and care of—CVC.
- Since the number of patients with antibiotic-resistant bacteria is increasing—especially in intensive care units—patient-bound care gown should be used and changed every work shift. Unsterile gloves can be colonized with resistant bacteria and should therefore not be used when working with catheters.

41.4.4 Insertion of Central Intravascular Catheters

Surgery in operating room with full operation barrier reduces CVC infections and is recommended for insertion of all types of catheters in large, central blood vessels

[1–6]. In situations of medical emergency, the procedure may be performed in post-operative or intensive care unit, with the same requirements for sterile barrier. Replace within 48 h if suspected contamination during the procedure.

Insertion site: Vena subclavia has the lowest risk of infection; is easier to keep still; is covered with bandage, etc.; and should be preferred if possible. Option is vena jugularis. Occasionally, vena femoralis is used, which gives the highest risk of infections. After choice of insertion site, always position the patient so that air embolism is avoided.

41.4.4.1 Procedure

- This is a surgical procedure that should be performed in an operating room with full barrier control.
- Inform the patient and relatives.
- Place the patient in the correct position—obs air embolism.
- Surgical handwashing.
- Sterile gloves, sterile gown, cap and surgical mask/visor.
- Sterile preparation of sterile equipment.
- Cut the hair if necessary, not shaving. Note! Ask the patient about allergy against chlorhexidine.
- Insertion site and surrounding area (preferably 20 × 20 cm) are disinfected for 60 s with chlorhexidine alcohol 5 mg/ml. Let dry thoroughly.
- Large sterile covering of the insertion site.
- Use best suited catheter, insertion site, and avoid multi-lumen catheter.
- Use a sterile sleeve for all pulmonary artery catheters [3].
- Fix (tape or suture) the catheter to the skin to minimize moving of the catheter in the wound canal and thus less invasion of microbes.
- Cover the puncture site with sterile cotton dressing.
- Cover all connectors with sterile cotton bandages.
- Note the date of insertion of CVC on the dressing edge or on separate tape outside the bandaged area and in the journal.
- Avoid wetting the bandages.

41.4.5 Use of Central Vascular Catheters: General Information

- Sterile areas are the insertion site, CVC catheters with one or more lumens, Y-line (“three-way line”), hubs (opening in the end of CVC that connects to lines or cap), plugs or caps (stopper) to cover openings, connectors and bandages. Only sterile equipment, sterile bandages and tape, sterile gloves, etc. should be used in this area.
- Sterile plugs (caps, stoppers) are changed every time after each opening of the system for injection of medication, infusion, etc. and are disinfected before opening.
- Chlorhexidine alcohol (70% alcohol (ethanol) with chlorhexidine 5 mg/ml) is used as a disinfectant in the sterile field (effect time 60 s).

- Sterile gauze compresses are used to cover insertion site, Y-line and connectors. Transparent sterile dressings may be used if changed and disinfected skin and system every 48 h (can be too airtight).
- Use a sterile sleeve for all pulmonary artery catheters [3].
- All infusions/injections begin and end with sterile saline; NaCl 9 mg/ml. “Heparin lock” of hubs are seldom used in CVC.
- Shift infusion lines and set every 3–4+ days and always after blood/lipid and other solutions (propofol) which promotes bacterial growth [3].
- Shift clear infusion within 24 h.
- Good hand hygiene and use surgical mask/visor/cap, clean gown and sterile gloves when performing control, use and care of central venous catheters and similar catheters.
- Inform the patient and relatives of the procedure, particularly with regard to hygiene and sterility.

41.4.6 Control of CVC

41.4.6.1 Each Work Shift (6–8 h)

CVC/catheter position is checked, measured and documented (number and cm). If this entails direct contact with sterile areas, sterile parts of bandages and equipment, use aseptic technique:

Equipment: surgical mask/visor/cap, clean gown, two pairs of sterile gloves.

Perform hand hygiene, and put on sterile gloves before direct contact with the sterile space under the bandage.

41.4.6.2 Daily Check: CVC and Insertion Site

Equipment: surgical mask/visor/cap, clean gown, two pairs of sterile gloves:

- Surgical mask/visor /cap, clean gown, thorough handwashing (before and after), and put on sterile gloves prior to contact with the sterile areas of the bandage.
- *Note: This is not necessary if only inspection through transparent dressings.*
- If tenderness/fever/inexplicable malaise: take off the bandage and check the insertion site with respect to exudate, blood, swelling, redness, sweating and temperature.
- Check back flow in the catheter daily and after each injection/infusion to assess whether the catheter is correctly positioned.

41.4.6.3 Every 48–72 h, Care of Insertion Site Until Healed

Dressing change ca. three times a week until sutures are removed and the wound is healed. This is done using aseptic technique.

Equipment: surgical mask/visor/cap, clean gown, two pairs of sterile gloves, sterile shift set, chlorhexidine alcohol (colourless), sterile dressing and sterile tape:

- Should be carried out by two trained persons.
- Inform the patient/family.

- Disinfect or wash hands thoroughly.
- Disinfect the table to be used with 70% alcohol.
- Disinfect hands.
- Place the equipment on the table.
- Use surgical mask/visor/cap, clean gown and disinfect hands.
- Put the patient flat with faces away from the insertion site.
- Disinfect hands.
- Open the equipment and make everything ready—sterile procedure.
- Put on sterile gloves, remove the used bandage without pulling the catheter and take off the bandage carefully from the side.
- Inspect the insertion site (redness, puss/blood/exudate/sweating, swelling).
- Disinfect hands and take on new, sterile gloves.
- Wash gently around the insertion site with sterile sponges and sterile forceps for at least 60 s with chlorhexidine alcohol 5 mg/ml. Aseptic technique. Wash from the insertion site and outwards with circular motions. Wash the catheter from insertion and outwards. The catheter may not be moved—not slipping in and out of the insertion site. Allow the area to air-dry. New sterile cotton dressing is applied so that the insertion site is located approximately in the centre of the dressing.
- Take off gloves and disinfect hands.
- Place the patient in a satisfactory position and clear away used equipment.
- Remove the gown, surgical mask, visor and cap, and disinfect hands.

41.4.6.4 Later Care and Control of Insertion Site

Care and maintenance of insertion site is done later as described above—one time per week—also outside the hospital. Do not use airtight, dense, plastic-coated bandages, except for covering when showering and body washing. Good individual training of the patient and/or relatives reduces long-term central venous catheter infections by about 50%!

41.4.7 Change of Infusion Set, Press Set and Y-Line

- Should be carried out by two trained persons.
- *Infusion solutions* with clear liquids and administration sets should not be used beyond 24 h because of the risk of microbial growth in the solution.
- *Change infusion set* with press set, Y-line, etc. ca. each 3–4+ day by infusion of clear liquids.
- *Change infusion set and Y-line after each infusion of blood/lipid solutions/lipid drug solutions (propofol).* Replace the complete system until the direct connection with the catheter.

Equipment: sterile shift set, infusion set, Y-line, sterile stoppers, surgical mask/eye protection /cap, clean gown, two pairs of sterile gloves, chlorhexidine alcohol (colourless), sterile dressing and sterile tape:

- Inform the patient/family.
- Disinfect or wash hands thoroughly.
- Disinfect the table to be used with 70% alcohol.
- Disinfect hands.
- Place the equipment on the table.
- Use surgical mask/eye protection/cap, clean gown and disinfect hands.
- Put patient flat with face away from the insertion site.
- Disinfect hands.
- Open the equipment and make everything ready—sterile procedure.
- Put on sterile gloves, remove the used bandage without pulling or contaminating the catheter, and take the bandage carefully off from the side.
- Inspect the skin in the area (redness, puss/blood/exudate/sweating, swelling).
- Disinfect hands, and put on new sterile gloves.
- Disinfect gently around the insertion site with sterile sponges and sterile forceps for at least 60 s with chlorhexidine alcohol 5 mg/ml. Aseptic technique. Wash from the insertion site and outwards with circular motions. Disinfect the catheter from insertion and outwards and let air-dry. The catheter may not be moved—not slipping in and out of the insertion site.
- Lift up and hold carefully the sets/Y-line while disinfecting thoroughly with sterile forceps/sterile sponges and chlorhexidine alcohol over the Y-line, caps and connectors. Allow the area to air-dry.
- Sterile cloth from the shift set is placed under the Y-lines. New Y-lines are connected sterile into infusion set—aseptic technique.
- *Clamp the CVC catheter, while the old Y-line is disconnected and the new Y-line(s) is filled and connected.*
- Sterile gauze is wrapped around Y-lines and closed with sterile netting tube.
- Ensure that the Y-line and connectors are closed before leaving the patient.
- Take off the gloves and disinfect hands.
- Place the patient in a satisfactory position and clear away equipment.
- Remove the gown, mask, visor and cap, and disinfect hands.

Note! If the patient is breathing, lay him flat while Y-lines, etc. are disconnected. If accidentally, air is sucked into the catheter (air embolism), for example, by disconnection of the catheter by accident, the patient is placed on the left side with the head tilted slightly downward. Contact physician immediately. Symptoms of air embolism can be dropped in blood pressure, confusion, headache and loss of consciousness.

41.4.8 Bolus Injections of Drugs

Equipment: surgical mask/eye protection/cap, clean gown, two pairs of sterile gloves, sterile shift set, sterile plugs (stoppers, caps), chlorhexidine alcohol (colourless), sterile NaCl 9 mg/ml for rinse or heparin at less frequent injections (optionally sterile dressing, sterile tape):

- Should be carried out by two trained persons.
- Inform the patient/family.
- Disinfect or wash hands thoroughly.
- Disinfect the table to be used with 70% alcohol.
- Disinfect hands.
- Place the equipment on the table.
- Wear surgical mask/eye protection/cap, clean gown and disinfect hands.
- Open shift set and do everything ready—sterile procedure.
- Put on sterile gloves and open the compress covering the Y-line. Disinfect carefully and thoroughly plugs and Y-line with sterile forceps/sterile sponges/chlorhexidine alcohol. Let it dry.
- Inspect bandages and the insertion area (redness, puss/blood/exudate/sweating, swelling).
- The plug is unscrewed and discarded. Inject the drug without touching the Y-line. Put on a new sterile plug.
- Disinfect gently with sterile sponges/sterile forceps with chlorhexidine alcohol over plugs and Y-line before covering with the compress again. Replace the compress if soiled, wet, etc. The catheter should be at rest during the entire process—not slide in and out of the insertion site.
- Take off the gloves and disinfect hands.
- Place the patient in a satisfactory position, and clear away equipment.
- Remove the gown and mask/visor/cap and disinfect hands.
- NB Check that the connections (couplings) are stuck together and that they do not draw air into the system!

Note! If very frequent injections—such as 50 a day—the above routines may be difficult to follow. Hand hygiene is particularly important. Personnel must be specially trained in sterile handling of central intravascular catheters to avoid contamination of the catheter and openings. Individual routines may be organized in collaboration with the medical doctor responsible. There must always be calm and good time for such work.

41.4.9 Removal of Central Intravascular Catheter

Physician responsible for the CVC treatment: ensure that the catheter is removed as quickly as possible, preferably within 3–4 days if there is no long-term catheter.

Suspected—catheter infection: Remove the catheter as quickly as possible. Consider antibiotic treatment if the CVC tip is infected with *S. aureus* [7].

Pulmonary artery catheter should be removed within 4–5 days.

Pressure monitoring system should be replaced every 4–6 days (disposable).

Equipment: surgical mask/eye protection/cap, clean gown, sterile shift set, sterile suture remover, chlorhexidine alcohol, sterile compresses and tape:

- Should be conducted by two competent persons and in cooperation with the physician in charge.
- Inform the patient/family.
- Disinfect or wash hands thoroughly.
- Disinfect the table to be used with 70% alcohol.
- Disinfect hands.
- Place the equipment on the table.
- Wear surgical mask/eye protection/cap, clean gown and disinfect hands.

Put the patient flat with the bed tipped with the head slightly down (the head lower than the heart—Trendelenburg position), if this is not contraindicated (such as heart disease or CVP value 0 or lower—ask the physician). Instruct and prepare patients that are breathing self-about Valsalva manoeuvre (breathing with closed mouth), or exhale while the catheter is withdrawn:

- Disinfect hands.
- Open shift set and do everything ready—sterile procedure.
- Remove used bandage without pulling the catheter; take the bandage gently from the side. The catheter should be at rest.
- Inspect the insertion site (redness, puss/blood/exudate/sweating, swelling).
- Disinfect hands and take sterile gloves on.
- Disinfect gently around the insertion site with sterile sponges/sterile forceps and use chlorhexidine alcohol. Disinfect from the insertion site and outwards with circular movements. The catheter should be stable—not slipping in and out of the puncture site. Allow the area to air-dry.
- Remove sutures aseptically.
- *Pull the catheter carefully out while the patient makes Valsalva manoeuvre (exhaling with mouth closed) or exhale (check with the physician).*
- Compress the insertion site with sterile gauze for at least 3 min.
- Apply dressing.
- Optionally, microbiological examination is done—of sterile handled catheter tip: cut 5 cm from the proximal end with sterile scissors in a sterile container and send it to the microbiology laboratory prescribed by a physician.
- Take off the gloves and disinfect hands.
- Approximately 10 min after the catheter is removed, the patient is placed in a satisfactory position—with elevated upper part of the body—and clear away equipment.
- Remove the gown and mask/visor/cap and disinfect hands.

41.5 Background Information

Educating and training of competent personnel in aseptic care and treatment of central venous catheter or other intravascular catheters may reduce infection rates, especially concerning catheter-related *Staphylococcus aureus* infections [1, 8–15].

The procedures need time, and there should be quietness so that sterility is properly addressed. Infection risk is reduced by removing catheters as soon as possible and by avoiding use of the femoral vein [2–4]. The subclavian vein should be preferred [2, 3]. Arterial catheter should be treated as carefully as central venous catheter [16–20].

Catheter contamination is caused by (a) the patient's skin flora or (b) contamination of the infusion set, catheter openings ("hub"), Y-line, needleless connectors (needleless system), etc. This may especially occur in the absence of aseptic technique and presence of large environmental loads of microbes [1].

Intensive care units are at increased risk for catheter infections [21]. "Home therapy" of children may reduce CVC sepsis and increase time between changes of the administration set [22].

41.5.1 Prevalence, Cost and Mortality

- Bacteraemia originating from CVCs is estimated to be 2–8%. Over 90% of catheter infections are associated with central venous catheter or central arterial catheter, Swan-Ganz, for example.
- Risk arises in intensive care units (ICU), in medical units, during cancer therapy, and in haemodialysis centres [1]. An increasing percentage is recorded outside the ICU or outside the hospital [4].
- Laboratory-confirmed sepsis had for more than 10 years ago a high mortality rate (35–41%) and increased the stay in hospital for 20–25 days, and the cost was approximately 16,400 Euro per patient [23].
- In 2014, central catheter-associated bloodstream infection (CLABSI) was estimated to cost 3700–39,000 USD per patient in the United States [4]. The risk is increasing for each catheter day [1].
- Mortality is estimated to be ca. 12.3% (case fatality rate) in the United States and up to 50% in countries with few health resources [24, 25]. Infectious thrombophlebitis of large vessels and endocarditis are serious risks of central intravascular treatment [1, 26].
- Intensive care units in four European countries (France, Germany, Italy, United Kingdom) have great variations in catheter-related bloodstream infections (CRBSIs): 1.12–4.2 per 1000 catheter days [27].
 - In France, it was in 2005 estimated over one million central catheters per year, used for about 12 days on average (per patient); 2.8 infections per 1000 catheter days and 14,000 infection episodes [27].
 - *Mortality* was estimated to be approximately 25% in France, 12–15% in Germany and 17% in Italy.
 - *Prolonged hospital stay* was estimated to be 10–14 days in France, 5–7 days in Germany, ca. 13 days in Italy and 4.2 days in the United Kingdom [27].
 - *Cost* per patient with CRBSI was 8000–11,444 Euro in France, 4200 Euro in Germany, 13,000 Euro in Italy and about 9200 Euro in the United Kingdom [27].

- In Sweden, the incidence of arterial catheter-related infection was 1.55/1000 catheter days and of culture-positive catheter tips 7.66/1000 days in an intensive care unit [17]. The aseptic technique was strictly followed and the catheter duration was short. In all, 14/456 (3.1%) had catheter-related infection, dominated by coagulase-negative staphylococci and *Candida* [17].
- Incidence of CVC-related infections in leukaemia patients was in one study from 2002 6.5/1000 CVC days (1.9 microbiologically proven, 2.3 suspected, 2.3 possible/1000 days) [28].
- In neonates, catheter-related sepsis has been noted in 26% of 113 catheters. In one neonatal intensive care unit, 191 patients had 202 CLABSI episodes; 4 per 1000 central line days [29]. Total mortality was approximately 9%, median 8 days after start of the CLABSI. Half of the infections were coagulase-negative staphylococci, while 11.5% was *S. aureus*. Intra-abdominal pathology and lung pathology were largely underlying disease [29].
- Approximately, 0.5–1% of patients in Norwegian hospitals have nosocomial sepsis—primarily in connection with CVK [30, 31].

Extra bed days and cost. A patient with catheter sepsis will result in approximately 4–14 extra bed days in intensive units and an additional charge of 6250–25,000 Euro (50,000–200,000 NKr) or more per patient.

The overall costs per patient in the United States is estimated to be 34 500 to 56 000 USD/infection (“attributable”) (i.e. 238,000–392,000 NKr in ICU). Generally, the estimated additional cost of catheter sepsis may be 25,000 USD/infectious episode (175,000 NKr).

Mortality associated with catheter sepsis varies; prospective studies show up to 35% mortality; estimated to 12–25% if all infections are included, not only on intensive units.

41.5.1.1 Risk Factors Quoted and Translated from the Guideline of Marshal et al. 2014 [4]

1. The patient admitted for a time in the hospital before insertion of CVC [4].
2. Prolonged use of CVC.
3. Skin colonization—large amounts of microbes at the insertion site and poor body hygiene for the patient.
4. Heavily microbe-contaminated infusion openings—catheter “hub”.
5. Catheters inserted into internal jugular vein.
6. Catheters inserted in the femoral vein in adults.
7. Neutropenia.
8. Prematurity.
9. Reduced intensive care nurse-to-patient ratio.
10. Total parenteral nutrition.
11. Poor handling of the catheter—excessive manipulation of the catheter.
12. Blood transfusion—blood products—especially in children [4].

41.5.1.2 Other Risk Factors

- Catheter type and method used [1, 3, 6].
- Multi-lumen catheter greater risk than single lumen (by total parenteral nutrition—the user has only one defined catheter or lumen for this). But multi-lumen is mostly used for ICU patients.
- Hickman catheters have greater risk than Broviac catheter, and PVC catheters are adhering bacteria (plastic more than steel catheter).
- Unimpregnated catheters—more than catheters impregnated with antimicrobials (particularly employed when prior catheter infection). Catheters with antibiotics are not used routinely and are discussed [1, 6].
- Poor technique and un-sterility by insertion and care of the catheter are risk in many overcrowded ICU's. "Others" may be associated with greater risk than specified "IV teams". In a study of 106 patients with CVC in 721 catheter days, violations of hygienic care of CVCs were proven in 45% of the cases [32]. Bandages were not complete and clean, and use of unsterile caps (stoppers and plugs) was regarded as the most serious violation of the care of CVCs with, respectively, 158 and 156 violations per 1000 catheter days [32]. During the study period, 5.5 CLABSI's per 1000 catheter days were recorded. The focus should be more directed on the implementation of the best practices [32].
- In a study of 2595 CVK episodes in 2018 patients was the local insertion site infection statistically higher for femoral than for jugular localization of CVC and statistically higher for jugular than for subclavian [33]. Similar finding was detected for CVC-related sepsis [33].
- Use of non-tunneled CVCs is associated with a higher infection risk than tunneled CVC, which in turn has a higher risk than the implanted catheter. The latter is used particularly as a long-term catheter >30 days.
- To lay bare large central vessels for insertion (tissue fluid and oedema) increases invasion of microbes.
- Poorly attached catheter—get some sort of pumping effect which facilitates invasion of microbes from the skin and bandages inwardly along the catheter.
- Impermeable plastic bandages >48 h, moisture under the bandage with organic material makes good growth conditions for microbes.
- Number of manipulations of the catheter and number of opening/closing, and blood sampling may increase the risk.
- Replacement via guidewire is made occasionally and may be a risk [34, 35].
- Increased risk of infection when administration of blood/lipid solutions.
- Granulocytopenia, immunosuppressive therapy, burns, major skin lesions, psoriasis, infections elsewhere.
- Emergency service involves a greater risk than elective treatment.
- Duration of CVC infection risk increases rapidly after 3 days to 2 weeks.
- Thrombosis CVC increases the risk of infection.
- Understaffing, low or unstable ratio between personnel (few/ inexperienced nurses) and patients, constitutes a major risk.

- Medicament mixing in sterile fluid under unsafe and not hygienic conditions.
- Syringe pumps—not properly cleaned between use and storage—and other technical equipment.
- Needleless connection, needleless connector, has created many problems that have not yet been resolved [36–39].

41.5.2 Invasion of Microbes

Intravascular treatment facilitates bacterial invasion which increases the longer the catheter is inserted, depending on the method and care [40–47]. Entrance via catheter outside and lumen, from contaminated connectors, infusion lines, hubs, caps, Y-line, syringe nozzles and heparin lock, or by contaminated liquid or haematogenous to the catheter from elsewhere during ongoing bacteraemia. Skin microbes migrate (spread) into the subcutaneous tissue along the outer surface of the catheter when it is inserted or at some later time (1 week or more).

This is caused by capillary activity through oedema/tissue fluid which increases as the catheter moves. The bacteria can—within an hour—reach the catheter tip, and this takes place the first week of catheter insertion because it is then most tissue fluid in the tunnel entrance around the catheter. In spite of good skin antisepsis, coagulase-negative staphylococci may be introduced from the skin and may be isolated from the catheter tip in up to 15% of cases. In children and others with severely impaired immune systems, diphtheroids and other harmless skin bacteria may cause serious infections [45]. Hands of personnel that are handling catheter non-sterile are an important source of infection. The same is colonization of gram-negative rods in skin flora on the body of ICU patients. A mixed catheter flora of several types of bacteria is suggestive of significantly contaminated catheter.

By gram-negative CVC sepsis, the CVC is recommended to be removed within 48–72 h to prevent relapse [40]. The same applies to VRE and fungal infection [42, 47]. Bacteria are growing in biofilms and biological deposit both inside and outside catheters, and this is difficult to eradicate once it is present [43, 48]. Precipitation of crystals increases bacterial colonization 30 times more than CVK without this deposit [48].

Action over several years in the United States indicates that the percentage of CVC infections are reduced, particularly concerning enterococci, gram-negative rods, Candida and *S. aureus* in adults [12, 46]. But there is no decrease of catheter-related *S. aureus* sepsis in neonatal intensive care units [46].

41.5.3 Bacterial Density and Type of the Skin

It is denser bacterial growth on the thorax than the forearm due to higher skin temperatures: 50–100 colony-forming units (CFU)/10 cm² on the arm/wrist, while

1000–10,000 CFU/10 cm² on the thorax/neck, especially in long-term ICU patients. Large amount of bacteria on the skin around the insertion site increases the risk of catheter-related infection.

Bacterial type of forearms and hands is usually coagulase-negative staphylococci and diphtheroids, unusually gram-negative rods or fungi, while these are more common on the thoracic/neck/throat area, especially in poor body hygiene. *Candida* and other fungal infections are increasing.

41.5.4 Disinfection of Skin and Insertion Site

Disinfection before insertion and then to reduce the flora around the puncture site is important [32, 49–51]. Chlorhexidine alcohol (70% alcohol with chlorhexidine 2–5 mg/ml) is better than most disinfectants, if the effect time is long enough: 60 s. Chlorhexidine-based disinfectants, 2%, with gluconate are reducing catheter colonization by 50% compared with iodinated disinfectants. Disinfecting the skin with chlorhexidine wipes have been effective in reducing infections.

41.5.4.1 Bandages—Transparent But Airtight Dressings—May Increase Risk

Polyurethane bandages, “Opsite and Tegaderm”, are transparent dressings that because of density have been associated with increased colonization of the catheter or catheter infections [52]. Catheters are often used longer than 48 h, 7 days or more. Used for 48 h, this bandage type is in order. Used for 5–7 days, there may be a tenfold increase in density of skin flora (compared with gauze bandage) which can be associated with a 50% increased risk of CVC infection [52]. If “Tegaderm” and similar types are used, it should be changed every 48 h, and the skin and insertion site should be cleaned thoroughly with chlorhexidine alcohol.

Increased moisture under the bandage promotes bacterial growth and increase the risk of insertion-colonization and CVC infection, compared with dry sterile gauze bandage.

Chlorhexidine-impregnated bandages and sponges/pads have been used around the insertion site for critically ill patients [50, 51].

A French multicentre study in the ICU of 11,000 bandages (two dressing changes) in connection with the use of central catheter showed a high proportion of “disruption” of the bandages; that was not in order [53]. Bandage disruption was partly associated with extended use of CVC, catheter inserted elsewhere than in vena subclavia, and critically ill patients [53].

41.5.5 Microbiological Ointments

(Polyantimicrobial ointment PNB) has reduced the bacterial flora, but statistically increased *Candida*, and is not recommended around the insertion site [1–4].

41.5.5.1 Disinfection of Catheter Openings: Hubs, Cap (Top-Plug-Stopper)-Syringe Nozzles, Spigot, Connections, Etc.

Central catheter openings and all other openings to intravascular sets should be treated and covered with absolute sterility. This is done by sterile gloves, sterile forceps, disinfection and packaging of the catheter system with sterile gauze, etc. A new sterile cap is used every time when the system is opened and should not be reused, even after disinfection. Use of disinfectant or antibiotic ointments as a “lid” over the opening is attempted, but is usually not recommended [54, 55]. Needleless connection (needleless connector) is not problem-free with respect to contamination of catheters and must be considered individually [36–39].

41.5.6 Catheter Type

There are many catheter types for various applications and with different experiences [1–6, 56–56].

Silicon latex catheter or catheters made of polyvinyl chloride (PVC) have shown greater in vitro tendency to adhere bacteria like *S. aureus*, *S. epidermidis*, *E. coli* and *Pseudomonas aeruginosa* than Teflon, polyurethane and Vialon catheters. Multi-lumen catheters are more frequently associated with infections than single-lumen catheters [1–41]. Antiseptic catheters may have an uncertain cost-benefit effect at high rate of infections and in critically ill patients; however, it is different opinions on the effect [5, 56, 58, 59]. It is usually not recommended in normal CVC treatment. Urokinase rinses of catheters that have been in place for a long time, for example, in haematological cancer types, have been of value to reduce colonization of coagulase-negative staphylococci [57].

Studies show that prevention of catheter infection may be at least as good with unimpregnated catheter, where hygiene and sterility are in place [60].

41.5.7 Infusion Site

V. jugularis interna: greater motility of the vessel, more capillary action, nearer airways with a rich flora, higher temperature, not easy to attach the bandage and greater risk.

V. subclavia: lower risk, better to keep the vessel still, bandaging, etc.

V. femoralis: more gram-negative flora, more motility of the vessel, moisture, heat, higher rate regarding deep vein thrombosis and greater risk.

A study of 440 critically ill patients showed that among 780 catheter tips grown was 19% colonized with bacteria [61]. The lowest rate of bacteria was found in vena subclavia, 15%, and the highest rate was in the femoral vein, 34%. The colonization of catheters increased over time and was related to the development of bacteraemia in approximately 10% of the colonized catheters [61].

Another study of 3150 CVCs in surgical patients was partially analysed retrospectively and prospectively [62]. There were significantly higher infection rates using vena jugularis interna than vena subclavia [62].

Tunneled CVC may reduce risk and also good fixation of the catheter may reduce the risk.

PICC—peripheral inserted central catheter—is increasingly in use outside the ICU, especially if there is lack of intravenous team and expertise to insert CVK [63]. If incorrect positioning of the PICC end, this can be corrected with no increased risk of CLABSI [64]. PICC may be associated with a lower incidence of CLABSI than inserted CVC outside hospitals, but these findings are uncertain [63–65].

41.5.7.1 Symptoms/Diagnosis—Catheter Infection

- Fever episodes; CVC is the cause until otherwise proven.
- Tenderness and erythema along the insertion site/tunnel.
- May be few symptoms, especially concerning Hickman and Broviac catheters.
- Bacteraemia without a known cause.
- Persistent fever, but negative blood culture.
- Should be suspected in all cases of fever and reduced general condition with no known other focus of infection.
- Fever fall after catheter removal [61, 62].

41.5.7.2 Treatment of Catheter Infection

- Tunneled CVC infections may generally not respond to local therapy; remove the catheter set.
- CVC infections caused by fungi; remove the catheter set.
- Short-term catheter should be removed immediately if possible.
- Long-term catheter; if not vital indications, it should be removed as soon as possible when suspected catheter sepsis.
- Difficult CVC access to critically ill patient with uncertain diagnosis; tentatively await removal of the catheter. Blood culture from the CVC + peripheral vein for microbial examination and empiric treatment—if necessary—until microbial results.
- If there has been a catheter change over guidewire, remove the new CVC if the old turned out to be infected.

41.5.8 Cultivating CVC

Indication for culture of CVCs is a clinical suspicion of catheter-related infections. Routine cultures of CVC are not recommended. Distal 5 cm tip of central venous catheter and ca. 5 cm segment of tunneled catheter section (subcutaneous area) is

cut aseptically into sterile containers and sent immediately to the laboratory for growth of semi-quantitative culture. Considering treatment if CVC tip is colonized with *S. aureus* [7].

41.5.9 Knowledge, Technology, Time and Control

Control, use and care of central venous catheters require competent and experienced personnel in a stable work situation at the department. Education and training are central, but may be of limited effect if it is a large consumption of temporary personnel and temporary workers [66]. High turnover of staff, temporary staff and high workload and work tempo, etc. are strongly associated with increased intravascular infections. Additionally, it can be difficult to follow guidelines and manuals even if they exist, and studies show considerable variation with regard to local practices [67–70].

Studies of immediate help patients in clinical anaesthesia show increased contamination of intravascular sets, contaminated syringes, lack of wearing gloves and lack of sterile covering of open syringe nozzles [71]. The culture of external and internal (liquid) portions of the syringe placed in the three-way connector showed bacterial growth in 46% surface samples and 15% of internal samples [71]. The same bacteria were also cultured from the ventilator and syringes in 13% of cases and in intravenous liquid from two IV-sets [71].

The aim is “zero”, which probably can be reached by combining useful measures, “bundles”, caused both with regard to CLABSI and VAP [72]. However, clusters of bacteraemia caused by the same microbe in hospitals may also be controlled for illicit drug use by healthcare workers [73].

CDC recommendations [3] for reducing catheter-associated bloodstream infections are shown in Tables 41.1 and 41.2. The recommendations are shortened and adapted by the author.

Table 41.1 Recommendations for infection control, divided into categories from CDC/HICPAC

According to research, theory, feasibility and if possible financial solution. Publications, etc.

Category IA	Strongly recommended for implementation and strongly supported by well-designed experimental, clinical or epidemiological studies
Category IB	Strongly recommended for implementation and supported by some experimental, clinical or epidemiological studies and a strong theoretical rationale or an accepted practice (e.g. aseptic technique) supported by limited evidence
Category IC	Required by state or federal regulations, rules or standards
Category II	Suggested for implementation and supported by suggestive clinical or epidemiological studies or a theoretical rationale
No recommendation	Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists

CDC system for categorizing recommendations [3]

Table 41.2 Key recommendations to reduce intravascular (IV) catheter infections. CDC 2011 [3]

	Recommendation selected, shortened and adapted by the author	Category
Education	Educate healthcare personnel in insertion and care of intravascular catheters. Periodically assess knowledge, adherence to guideline and practice regarding the use of IV catheter	IA
Training	Only competent and trained personnel are working with IV catheter techniques	IA
Staffing	Ensure appropriate nursing staff levels in ICUs; patient to nurse ratio. Avoid deputyship	IB
CVC		
1	Consider the risks and necessity of the catheter	IA
2	Do not use the femoral vein for central venous catheter in adults	IA
3	Use vena subclavia by non-tunneled placement of central venous catheter in adults	IB
4	Avoid vena subclavia in haemodialysis patients/kidney patients to avoid vein stenosis	IA
5	Use fistula or graft instead of CVC for permanent access for haemodialysis	IA
6	Ultrasound-guided placement of central venous catheter (if available) with trained personnel (<i>Ultrasound cream: remember infection risk!—author</i>)	IB
7	Use CVC with minimum number of lumens/ports—essential for the patient	IB
8	Remove IV catheter as soon as possible	IA
9	Replace catheter after emergency insertion and uncertain sterility conditions. Preferably within 48 h	IB
10	Maximum sterile barrier—precautions when inserting catheters in large vessels; CVC, PICC or guidewire exchange	IB
Hand hygiene	Hand hygiene before and after all activities around the catheter treatment	IB
Sterile technique	Aseptic technique for insertion, treating and handling intravascular catheter	IB
Disinfection	Skin disinfection with chlorhexidine (>0.5%) with alcohol by insertion and care of the catheter	IA
Bandage	Sterile gauze or sterile, transparent, semipermeable dressing to cover the catheter site	IA
	Not dressing in water—avoid shower water on the bandage Replace bandage for short-term CVC within 7 days, dependent on dressing	IB
IV set	Change IV-sets from every 96 h to within 7 days, if continuous infusion with clear liquids	IA
	Change tubing sets used to administer propofol infusion after 6 or 12 h	IA
	The access port for infusions should be disinfected before use and only be in contact with sterile equipment	IA

O'Grady et al. CDC. 2011, up-dated 2017, selected, shortened and adapted by the author

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Central Implanted Venous Access Port

42

Abstract

Venous port system allows for repeated accesses to the bloodstream over time, if treated with caution, up to 5 years with more than 2000 injections. Venous port is located beneath the skin and consists of a capsule commonly made of titanium with one or two injection chambers covered by a thick silicone rubber membrane which is self-sealing. The injection chamber is connected to a radiopaque catheter and should only be perforated by special venous port needles (“noncoring needles”). Training of personnel and patient/family is essential to keep the venous port over a long time. Only trained personnel should carry out the treatment and the procedure should be written and implemented.

Studies from CDC show that up to 70% of all nosocomial bloodstream infections may be prevented and that includes venous port infections. The following chapter focuses on practical measures to control and prevent bloodstream infections from implanted port for prolonged intravascular access.

Keywords

Venous port · Implantable venous access port · Port-a-Cath · InfusaPort · PassPort · Subclavian port · Medi-port · Bloodstream infection · BSI · Catheter-associated bloodstream infection · Infection control · Hygiene

42.1 Purpose

- To protect the patient from severe catheter-associated invasion of bloodstream microbes and other complications, such as thrombophlebitis, bleeding or air embolism.

42.2 Comprise

- Everyone who inform about, insert, control, work with, treat and remove central venous access port (CVAP).
-

42.3 Responsibility

Hospital management should ensure that all procedures for indication, placement and control of central venous access port are performed in a proper manner.

Department management is responsible for implementing and training current procedures concerning the use of CVAP.

Health professionals, who insert, check and take care of CVAP, should follow the actual procedures in a hygienic and safe manner [1–11].

42.4 Practical Measures

42.4.1 Definitions and Short Description

- Implanted port for prolonged intravascular access (implantable venous access port, Port-a-Cath; InfusaPort; PassPort; Subclavian port; Medi-port).
- Implanted ports are central venous catheters (CVCs), where the entire system is placed under the skin. It comprises an injection chamber implant under the skin, connected to a catheter that is commonly placed in vena cava superior [1–13].
- The venous port should be treated with the same high sterility and hygiene level as other central intravascular catheter described before. See CVC.
- The advantage of venous port is that it can be used for several years; mostly free of catheter infections, if treated properly.
- When it is not in use and the insertion site has healed, it is not an obstacle for shower or swimming, after consulting with responsible physician [3, 6, 7].

42.4.2 Information

The patient and family members should be informed of the indication and the special circumstances surrounding the treatment of venous port system, as well as good hand hygiene and individual infection control during long-term treatment [1–3, 6, 7]. It is important to ask the patient to tell healthcare providers if they do not implement good hand hygiene before care of venous port.

42.4.3 Indication for Venous Port

- Long-term treatment over weeks, months and years and intermittent therapy.
- Often several drugs used simultaneously.

- Repeated and prolonged infusion therapy.
- Blood tests—frequently—in susceptible individuals.
- Parenteral nutrition.
- Chemotherapy during periods and over time.
- Drugs that can damage the skin or muscle or if leakage outside blood vessels (vesicants).
- Poor vein status and insertion of a peripheral line is difficult.
- Haemodialysis—but brief—until established common system.
- Home treatment.

42.4.4 Contraindication

- Infection or suspected infection locally in the relevant area of the skin.
- Suspected allergies to materials venous port is made of.
- Note coagulation disorders and oedema formation!
- Others: fragile vessels, tachycardia, etc.

42.4.5 Equipment

Venous port and venous port needles—special needles (“noncoring needles”)—regular size 22 gauge (0.7 mm diameter) to the low viscosity liquid (e.g. cytostatic) and size 19G–20G (diameter 1.1–0.9 mm) for high viscosity liquids (nutrition solutions, blood products).

42.4.6 Sterile Procedures in Operating Theatre

- Performed in local anaesthesia + intravenous analgesia/sedation in the operating room with optionally X-ray examination.
- The area for insertion of the venous port is selected and is implemented as with the tunneled central venous catheter, is placed on a stable area and does not interfere with movement or pressure or with clothes. Should be placed against the bone structure for easy access, for example, close to the sternum. The location also depends on if the patient is to handle venous port even with injections, etc. [6]. The pocket or container is placed 0.5–2 cm below the skin and sutured firmly to a deep fascia [6]. The catheter tip should be on the transition between the superior vena cava and the right atrium [6].
- *Sterile drapes, perform surgical handwashing, and sterile dressing as by surgery!*
- Venous port can usually be used immediately after evaluated X-ray thorax.
- *Note—separate routines for very young children with regard to quantity of liquid, etc.!*
- If external sutures, cover the wound with sterile, and dry dressing for 2 weeks or until the sutures are removed after 7–10 days.

- Sterile gauze dressing or transparent, semipermeable polyurethane dressings are applied on the wound.
1. General information for care of venous port:
 - Only trained personnel (or personnel under supervision of trained personnel) can work with venous port system in the hospital. Two persons for inserting the needle and for other manipulation that can result in contamination of the catheter.
 - *Aseptic technique* by all types of manipulation and opening of the system.
 - *Use only sterile tape around the vein port!*
 - Hand hygiene, wear gown, use surgical mask/visor/cap, and sterile gloves by direct contact with the venous port area when the system is open. Sterile gloves and face protection is recommended by CDC [3, 4].
 - Check daily venous port—catheter area for signs of swelling/tenderness/redness that may be due to infection or leakage.
 - Observe the same area under flushing with 20 ml NaCl 0.9% (before the start of the infusion/injection). When signs of extravasation/discomfort/pain are present is the infusion immediately stopped. Note! Special procedures for small children!
 - Prevent catheter damage by *not* using syringes less than *10 ml* and by not using excessive force during the injection; pressures lower than 25 psi are not going to destroy blood vessels [6]. If using 3 ml syringes, the pressure may be too high.
 - Infusion of nutrition solutions should not exceed 24 h, and infusion of blood products should not exceed 4 h.
 - Check infusion solutions for suspicious-looking and the date.
 - Use only new opened vials and single-dose containers. If multi-dose is used once, it should be discarded immediately after use.
 - Careful observation of the infusion, especially when using chemotherapy.
 - Close the hose clamps on the needle extension tube under all switching operations (couplings) and when the needle is not in use.
 - Instruct the patient to report discomfort or changes in the venous port area.
 - Patient's face is turned away from the site during work. If not, or if the patient coughs, put on the patient a surgical mask.
 - *Note—own routines for very young children with regard to quantity of liquid, etc.!!*
 - The patient lies with the *lowered head end* during manipulations *where there is a risk of air leakage* into the system. Contact the physician if there is uncertainty!
 2. Equipment for insertion of the needle into vein port:
 - *Note—own routines for very young children with regard to quantity of liquid, etc.!!*
 - Sterile gloves, clean gown, surgical mask/visor/cap.
 - Shift set for wounds.

- Sterile drape.
- Chlorhexidine-alcohol solution 5 mg/ml.
- Venous port needle (e.g. Gripps needle) having a diameter adapted for infusion and the Y-line and extension tubing.
- Syringe (20 ml).
- Sterile NaCl 0.9%.
- Sterile compresses 5 × 5 cm to stabilization of the venous port needle (between needle and the skin).
- Sterile dressing 10 × 10 cm (e.g. Tegaderm).
- Sterile compresses 10 × 10 cm to the packing of the couplings.
- Optionally, sterile tape/strips (Steri-Strips) for fixing venous port needle with wings.
- Optionally xylocaine 5% cream or Emla cream—obs—clean, new tube, if needed for local anaesthesia (kids). Wipe off the cream thoroughly afterwards and wash with mild soap and water to remove a biofilm-like surface which may increase the growth of the bacteria. Then wipe thoroughly dry the area before disinfection of the skin before inserting the needle [6].
- Instruct patient to report discomfort or changes in venous port area.
- The lies with the *head lowered end* during the manipulation where there may be risk of air leakage into the system.

3. Inserting the needle to infusions, etc., a *sterile* procedure:

Only trained personnel, preferably two persons, are working with the venous port.

Hand hygiene, wear clean gown, use surgical mask/visor/cap, and sterile gloves.

Do not touch the vein port area without the use of sterile gloves!

If required local anaesthesia, add a thick layer of *sterile* xylocaine® or *sterile* Emla at injection site (Tegaderm dressing cover), and leave it briefly (1 h with Emla cream). Wash with soap and water and dry. Then disinfect the skin over and around the port with chlorhexidine-alcohol, and let it work minimum of 1 min.

- Disinfect the table to be used with 70% alcohol.
 - Disinfect hands.
 - Place the equipment on the table.
 - Wear surgical mask/visor/cap and clean gown and disinfect hands.
- (a) Inspect venous port area before the procedure to evaluate skin status and the chamber depth so that the needle length is selected right.
- (b) Hand hygiene.
- (c) Shift set for wounds is opened and can be used as sterile area for placing the other sterile equipment.
- (d) Lay out the sterile cover dressing on the patient with the edge a few centimetres below the venous port. Use sterile gloves to avoid unsterile accidents.

- (e) Disinfect the skin from the centre of the port and round and round outwards. The skin area over the port and a relatively wide field around the port are washed with chlorhexidine-alcohol with duration of at least 1 min. Disinfect three times.
- (f) Needle and the extension tube are filled with sterile saline from freshly opened bottle—hold the vial with sterile compresses.
- (g) Palpate forward—with sterile glove—to the top, where the port membrane sits. Disinfect with chlorhexidine-alcohol—let dry on the skin for 1 min.
- (h) Stabilize the port gently with one hand while the needle is inserted with the other. Punctate the skin and the membrane. The needle (e.g. non-coring needle—Huber needle) is passed vertically, slowly and gently to the bottom of the port chamber.
- (i) With the syringe (20 ml) prefilled with sterile saline, check the “backflow” (reflux) of blood, and flush gently through the system. Observe the venous port area.
- (j) The needle is connected to the infusion set with three-way stopcock and the links are packed in sterile packs. If the venous port is not used immediately, it should be flushed.
- (k) Place a special compress—transparent—over the site. If there is a large gap between the skin and needle angle, place a small sterile pad under the needle to stabilize. Optionally use Steri-Strips for needles with wings.

4. Various medicaments for infusion/injection:

If there are continuous infusions, rinse the venous port with 5 ml sterile NaCl 0.9% between different drugs to avoid interactions or precipitations.

Handwash, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment at all manipulations of the venous port.

5. Infusion pump:

The infusion pump is started before opening the three-way valve. When infusion is completed is the three-way/Y-line closed first, to prevent backflow of blood into the catheter. Do not exceed 2068 mm Hg pressure in the pump.

Handwash, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.

6. After use of the venous port:

Hand hygiene, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.

Upon completion of the infusion, rinse the venous port with sterile NaCl 0.9% and then with 5 ml heparin 100 IU/ml. Use new, unopened heparin vial. Before opening, disinfect the rubber membrane of the vial!

Close the tube clamp or three-way/Y-line under *pressure*, i.e. while injecting heparin (“heparin lock”) to prevent the backflow of blood in the catheter. See point 9.

7. Removal of the needle:

- Handwash, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.
- Disinfect the skin around and over the venous port with chlorhexidine-alcohol—let dry for 1 min.
- After adding “heparin lock”, remove the needle carefully while the skin is held down with sterile gauze.
- Stabilize the venous port with one hand while the needle is removed with the other [4].
- Compress the insertion site.
- Then disinfect the skin again.
- Cover with sterile compress.

8. Change of needle and three-way valve/Y-line—when the system is in use:

- The needle is changed once a week when the system is in use.
- Three-way valve/Y-line is replaced three times a week—aseptic procedure—and always after nutrition solutions (except glucose and amino acid solutions) and blood products. The bandage is changed every time.
- Disinfect with chlorhexidine-alcohol 0.5% over the links, before Y-line is replaced. Cover with sterile compresses.
- Hand hygiene, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.

9. Venous port is not used for a while:

- Hand hygiene, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.
- *Venous port must be rinsed regularly* about every 4 weeks with sterile saline 20 ml and heparin 100 IU/ml (5 ml). Always use a new, unopened heparin vial, and disinfect always the rubber membrane on the vial. The skin over the vein port is disinfected with chlorhexidine-alcohol 0.5% before heparin and saline flush. See also points 2, 3 and 6, 7.
- If the patient is not admitted to hospital, a plan for regular flushing of the venous port must be made for as outpatient and with equal need for a high level of sterility, as in the hospital.

10. Venous port used for parenteral nutrition:

- Hand hygiene, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.
- Disinfect the skin around and over the link.

- After the infusion is the venous port rinsed with:
 - 20 ml NaCl 0.9%
 - 2 ml ethanol 45% (leave for 2 min!!)
 - 40 ml NaCl 0.9%
 - 5 ml heparin 100 IU/ml (“heparin lock” under gauge pressure).
- Always use new solutions (previously unopened). This routine should be assessed by the local medical specialist.
- *Note! Separate procedures for small children! Ask the medical specialist.*

11. Blood sampling for examinations:

- Hand hygiene, wear clean gown, use surgical mask/visor/cap, and sterile gloves and aseptic treatment of venous port at all manipulations.
- Disinfect the skin around and over the venous port—let dry for 1 min.
- Recommended needle size: 19–20 G. Follow points 2 and 3a–h, if there is no needle in place from before.
- Aspirate at least 3 ml of blood and discard it before the desired volume of blood is aspirated. Note the volume has to be adjusted to the patient’s size, weight and age! (“Vacutainer” can be used.)
- Immediately rinse with 20 ml NaCl 0.9% and finally with 5 ml heparin 100 IU/ml. See point 6. Optionally change Y-line; see step 7. Upon removal of the needle, see point 6.

42.4.7 Complications

Consult a physician if there is increased resistance/complete blockage in the venous port or problems with aspirating blood.

- Check that the needle is correctly positioned. Check the hoses, clamps and couplings.
- Ask the patient to change position (lie flat, lift arms, cough, breathe deeply, raise your legs).
- If it is still not possible to rinse with NaCl 0.9%, there may be chest X-ray to confirm catheter position. If the catheter is correctly located, the problem may be thrombus or fibrin debris at catheter tip or precipitation. The physician considers the use of rtPA (e.g. Actilyse).
- Risk of catheter occlusion or thrombosis can occur by negative pressure which draws blood into the chamber [1, 2].

Subcutaneous or extravascular infusion—contact physician immediately:

- Note: Swelling, skin reaction, pain, discomfort or burning sensation in the venous port area.
- Infusion should be discontinued and the doctor contacted immediately. It must be checked whether the venous port system is damaged.
- To avoid subcutaneous infusion, it is important that the venous port needle reaches the bottom of the port and the needle is inserted without sloping (inclin-

ing), to prevent damage to the port membrane and subsequent leakage. Extravasation may occur due to catheter injury or damage to the catheter connector, which, for example, may happen with a too high pressure during use.

Infection/sepsis—contact physician immediately:

Note: Fever, chills, malaise. The cause may be contamination, catheter colonization and/or leukopenia. Measures in case of suspicion:

1. Blood cultures (peripheral vein) $\times 2$.
2. Blood cultures taken from venous port on suspicion that the primary focus lies in venous port.
3. If signs of local infection at the insertion site, remove the needle and take bacteriological sample from the site.
4. Bacteriological test of other possible infection foci.
5. Infection parameters.
6. Consider removal of the venous port.

Air embolism is rarely observed due to the use of thin needles—contact doctor immediately:

- The cause is air leakage in the system.
- May cause symptoms such as cyanosis, neck vein swelling and blood pressure fall.
- Check all connections and hoses for possible leaks.
- Upon suspicion of air embolism, the patient is placed in the left lateral side, making it easier for the air to leave the heart and move into the vena cava.

The patient and family should be well informed:

- The patient/family follows—if home treatment—a written, clear routine that has been reviewed and trained by the department. The same procedures as in the hospital.
- Patients and caregivers should be trained in proper hand hygiene and access to sufficient sterile equipment that are appropriate to use.
- Consult a doctor if [10]:
 - If the port seems to have moved.
 - It is hot, red and/or swollen around the venous port or fluid exits.
 - There is pain around the venous port.
 - Fever—elevated temperature—typically 38 °C or more.

42.5 Background Information

Venous port system allows for repeated accesses to the bloodstream over time, if treated with caution; up to 5 years with more than 2000 injections [6].

Venous port is located beneath the skin and consists of a capsule commonly made of titanium with one or two injection chambers covered by a thick silicone

rubber membrane which is self-sealing. The injection chamber is connected to a radiopaque catheter (silicone rubber or polyurethane). Venous port should only be perforated by special venous port needles (“non-coring needles”) [3, 4].

Training of personnel and patient/family (control of practice) is essential to keep the venous port over a long time [11]. Only trained personnel should carry out the treatment and the procedure should be written and implemented [2, 3]. Complication-free insertion of venous port is associated with good routines and well-trained surgeon.

Infections are most frequently caused by coagulase-negative staphylococci (50–70%) from the patient or the personnel’s skin or environment [12]. Gram-negative bacteria may come from infected solutions, non-sterile handling of the venous port, etc. (15–25%); there is a poly-microbial flora in a few cases, and *Candida* is a growing problem, particularly in cancer patients [12]. Underlying disease is important for the development of catheter sepsis [13]. Sometimes, *Staphylococcus aureus* is the microbial agent, often with a rapidly evolving sepsis.

Contamination is introduced into the venous port through needle contaminated by exposure to room air (sometimes high bacterial levels in the air—CFU/m³) or if non-sterile plaster tape is used for fixing the venous port area [1–3].

Control and use and care of venous port require competent personnel who have a good time during the procedure and who has a stable work situation at the department. A high staff turnover, temporary personnel, high speed, “efficiency”, etc. have been shown to be strongly associated with an increased number of intravascular infections [1].

Long-term catheter and risks Catheter-related bacteraemia when using long-term catheter is 5.1/100 totally implanted catheters (venous port) versus 20.9% for partially implanted catheter (Hickman or Broviac catheters); 0.2/1000 catheter days with venous port versus 1.2/1000 catheter days with partially implanted catheter [14].

In one study, the mean of the incidence of bacteraemia was 11.2% for venous port versus 36.7% for Hickman/Broviac catheter and, respectively, 0.059/1000 days versus 3.9/1000 days [15]. Exit site/tunnel pocket infections were 7% compared to 15.8%, respectively [15].

There are particular problems for cancer patients who need long-term therapy [16]. In a longitudinal study of 966 implanted venous ports in cancer patients, the infection rate decreased over time from 2.2 to 0.24 infections per 1000 catheter days [17]. Multivariate analysis showed higher risk in neutropenic patients and when using venous port for non-chemotherapy indication. A multidisciplinary team for venous port-treatment reduced infection rate [17].

New types of venous port infections are introduced with new infectious agents in food and beverage and commercial products thereof. An example is the non-typhoid *Salmonella*, NTS, which can cause bacteraemia that may come from infected venous port [18].

Other complications of long-term catheter include superior vena cava syndrome and ventricular tachycardia from embolism of the venous port [1, 19, 20].

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Part IX

Special Patient Groups



Urinary Tract Infections: Prevention

43

Abstract

Urinary tract infection (UTI) affects one in five women one or more times during their lifetime. Among elderly is asymptomatic infection common both in men and women. In hospitals, 2.6–8% of admitted patients may get nosocomial UTI, which prolongs their stay (2–4 days), is costly and may be deadly. UTI is also an important source of resistant bacteria that may be transmitted between healthcare institutions. Serious UTIs are frequent causes of (re-) hospitalization from nursing homes. Most nosocomial UTIs may be prevented by a good hygiene and by avoiding the use of catheters. The following chapter is focused on practical measures to reduce the incidence of urinary tract infections in general and the use of urinary tract catheters in particular.

Keywords

Urinary tract infections · UTI · Nosocomial infections · Urinary tract catheters
Catheter-associated UTI · Infection control · Hygiene · Prevention

43.1 Purpose

Reduce the incidence of urinary tract infections in general and use of urinary tract catheters in particular [1–8].

43.2 Comprise

- All patients with urinary tract infections and where drainage of urinary tract is relevant.
- All personnel treating patients should have knowledge about how to prevent urinary tract infections.

43.3 Responsibility

The hospital management should ensure that written, updated procedures for the prevention of urinary tract infections and necessary resources for this work are available.

The department's management should ensure that appropriate routines are implemented in the daily work with patients and procedures for catheterization of urinary tract exist and followed.

Staff should follow procedures and ensure that urinary tract infections can be prevented.

Urinary catheters are prescribed and discontinued by a physician. Healthcare personnel handling urinary tract catheters should know the procedure for insertion of catheters, aseptic technique and catheter care.

43.4 Practical Measures

Urinary tract infection affects ca. 20% of women one or more times during their lifetime, and one out of five elderly has asymptomatic UTI, equally common in men and women [1–3]. Symptomatic UTI is a very frequent complication in hospitals [1–8]. Many international and national guidelines are focused on the prevention of nosocomial urinary tract infection, especially on the use of urinary tract catheters and other urinary tract drainages, with variable effects [9–24].

Preventative measures must be directed generally against UTI/relapsing of UTI (see Part I below). In particular, measures must be taken against UTI associated with inserted urinary tract catheter or other urinary tract drainages (see Part II below).

43.4.1 Part I: Prevention of Urinary Tract Infections

A large proportion of hospital patients are elderly and people with a severe impaired general condition who need care and assistance for the most part. Many patients have asymptomatic UTI (bacteria in urine without symptoms), which sometimes flares up to a symptomatic infection, particularly within healthcare institutions [1–3]. In general, UTI may be prevented by good liquid supply, regularly emptying the bladder and intestines, mobility and good environmental hygiene and personal hygiene [1–3].

43.4.1.1 General Prevention: If There Is Tendency for Frequent UTIs

- Drink enough fluid—citrus substances can inhibit some bacteria.
- Disposal for kidney stones—ask the doctor concerning the use of cranberry juice or tablets.
- Frequent urination reduces the risk of cystitis, especially in females.

- Shower instead of bathing in a bath tub—avoid bath oils and perfumes below.
- Wipe/wash the genitalia and rectum from front to back, since the bacteria usually come from the rectum area.
- Use sanitary towels instead of tampon and change it for each toilet visit.
- Good hygiene in the genital region, especially if you have urinary or faecal incontinence.
- Good hygiene in the genital region—also before and after sexual activity.
- Urinate before and after sexual activity.
- Use loose-wearing lingerie, preferably cotton, and change daily.
- Do not drink fluids that may irritate the bladder, such as alcohol or coffee.
- If there are cystitis symptoms, take samples for laboratory cultivation and resistance studies. Have a treatment in accordance with resistance patterns and always after-check.
- Treat relapses and possibly chronic UTI with urine controls and cultivation/resistance patterns, to avoid infection of the kidneys.
- Use appropriate antibacterial agents in the right dose and in the correct treatment length [25].
- Asymptomatic UTI is usually not treated in the elderly (but with some exceptions) [26].

43.4.1.2 Fluid Intake

- Ample fluid intake can prevent urinary tract infection (at least 1500 ml/day).
- Record amount, especially in vulnerable, bedridden patients who have difficulties concerning intake of fluid/nutrition.
- Supply of citrus-containing juices may acidify the urine and inhibit bacterial growth.

43.4.1.3 Bladder Emptying

- Toilet routines should not be forgotten even if the patient is in the hospital.
- If possible, avoid using the bedpan (patient should preferably be placed in a sitting position).
- Help the patient to get to the toilet.
- Use sufficient time; try repeatedly to empty the bladder.
- Gentle massage/pressure over the symphysis to empty the bladder. Rest urine may promote growth of bacteria.

43.4.1.4 Hand Hygiene

- Properly performed hand hygiene is important to prevent urinary tract infection.
- Glove use (good gloves) should always be linked to specific tasks, such as direct contact with potentially infectious material, like blood, body fluids, secretions, urine, stools, wounds and mucous membranes.

43.4.1.5 Intimate Care (Genitalia and Rectum)

- Gown, patient-bound, changed daily and more often when needed.
- Hand hygiene before and after care.
- Wear gloves when doing intimate care.
- Intimate care is performed morning and evening—with lukewarm water and soap, rinse and dry well.
- Wash backwards (from genitalia to rectum).
- Patients who themselves are doing intimate care are instructed with correct care and hand hygiene.

43.4.1.6 Proper Use of Incontinence Diapers

- Selection of incontinence diapers is adjusted to each patient.
- The diaper is checked and replaced regularly, several times during the day. The skin is cleaned every time. Register change of incontinence diaper in bedridden patients.
- The diaper is placed directly in a plastic bag and disposed of in a sack of bags.

43.4.1.7 Disinfecting the Bedpan and Urine Bottles

- Disinfected in the decontaminator at 85 °C.
- Since particularly bedpans fail in decontamination, it is important to inspect the equipment after each disinfection.
- Regular and weekly temperature control of decontaminator and regular service according to product.

43.4.1.8 Cross Infection

- Staff must be aware of contact transmission and reduce risk of cross infection.
- Patients with urinary catheters should not share bedrooms because of risk of cross-contamination.

43.4.1.9 Medical Prevention—Not Well Evidence-Based

- Hiprex and vitamin C are often used.
- Oestrogen is used at recurrent urinary tract infections.
- Constipation may trigger urinary tract infection. Lactulose and other constipation-removing agents may be used.
- Patients with relapsing urinary tract infections may in some cases need antibacterial prophylaxis.

43.4.1.10 Urine Examination [2, 4, 12, 24, 27, 28]

- If suspecting UTI, take samples for examination and culture.
- Urine samples should preferably be taken prior to initiation of antibacterial treatment, [28]

- If there are symptoms like fever, dysuria, frequent urination, pain over the symphysis, flank pain and the like [1–4].
- If there are acute agitation, confusion, delirium and malaise as a part of differential diagnosis, especially in the elderly and young children [1–4, 18–20].
- Preferably morning urine, wash (midstream if possible) or sample from disposable catheters.
- In case of positive test results, contact a physician who administers examination and cultivation and possible treatment.
- The sample must be taken by using sterile glass obtained from the microbiological laboratory.
- Test strips must not be used in urine that is sent for microbiological examination, because of contamination from unsterile strips. Check the expiration date of test strips.
- In order to prevent microbial proliferation, the urine sample should be taken in a sterile test tube containing boric acid or immediately placed in a refrigerator before transport to a microbiological laboratory within a maximum of 24 h. Dipstick cultures can also be used.

43.4.1.11 Wash Before Sample Urine

- Equipment for genital wash—good disposable gloves, sterile shift set with cotton swabs and sterile 0.9% NaCl or sterile water.
- Steps: Wear disposable gloves.
 - In men: Slide the foreskin back and wash, only once with each swab, a total of five times. Ask the patient to urinate, if possible, first a small portion on the toilet and then into the sterile glass.
 - In women: Wash the urethra five times and ask the patient to urinate, if possible, first in the toilet and then into the sterile bedpan/glass.

43.4.1.12 Diagnosis of UTI [2, 3, 11, 18, 24, 29]

Minimum two of three of the following *diagnostic criteria* should be met:

1. *Clinical symptoms/signs*: Pain when urinating, frequent urination, increased incontinence, pain/tenderness over symphysis, fever, backache and turbid, bloody and/or foul-smelling urine. *Atypical symptoms in the elderly*: impaired general condition and level of functioning, fatigue, agitation, decreased appetite, nausea/vomiting, stomach pain, confusion and delirium. *Urinary incontinence* is most common in patients with asymptomatic UTI.
2. Pus in urine, detected by microscopy or test strip. Direct urine microscopy is a quick, easy and inexpensive examination for detecting UTI [2, 4, 30].

3. Bacteria in urine—more than 10,000/ml of one or at maximum two types of bacteria.

43.4.1.13 Significant Finding of Bacteria in Urine

- >100,000 bacteria/ml; gram-negative rods, one type (for instance, *E. coli*).
- >10,000 bacteria/ml; gram-positive, one type (for instance, group B streptococci).

43.4.1.14 Uncertain Result

- Two types of bacteria. If more than two, probably leading to contamination. Repeat sampling.
- Very resistant or unusual bacteria: repeat sampling.
- A lower number of bacteria/ml may be found in the following: urethral syndromes, ongoing antibacterial treatment and interstitial cystitis and/or occult pyelonephritis.

43.4.1.15 Treatment

- Asymptomatic bacteria in urine should not be treated in the elderly without symptoms [2–4, 26].
- Asymptomatic bacteria in urine should be treated before and during pregnancy in certain elective, surgical procedures.
- Patients with bladder catheters should be evaluated for treatment only if there is a clear indication, general symptoms and fever. Consider whether the catheter is necessary!
- Choice of antibacterial agents is preferably made after resistance determination [25]. In acute cases where treatment with antibiotics is indicated, start with a narrow-spectrum drug. To avoid the development of resistance, it is advisable to alternate use among several narrow-spectrum antibacterial agents, if necessary, and in accordance with resistance profiles.
- The use of broad-spectrum antibiotics should be restrictive and reserved for cases with complicated UTI.
- Duration of treatment is 7–14 days, depending on the severity of the infection.
- In patients with *Proteus*, *Klebsiella*, *Pseudomonas* or *Enterobacter* in urine samples, antibacterial therapy should be withheld until the diagnosis/indication is clear, because of risk of resistance development (ESBL, CRE) and development of *Clostridium difficile* infections [31].
- Control of urine by test strips, culture and microscopy is recommended [4, 24, 27, 30].
- Nosocomial UTI microbes often follow the patient home from the hospital. Symptoms of UTI can occur after the hospital stay as “community-onset, health-care-associated” urinary tract infection (CO-HCA UTI). This type of UTI affects the same patient group and has the same microbial resistance pattern and same risk of death as nosocomial UTI [32].

43.4.2 Part II: Prevention of Catheter-Associated Urinary Tract Infection

Urinary catheter is the most commonly used foreign body during hospital stays both in Europe and in the United States. Among admitted patients in 66 European hospitals, 17.5% had urinary catheter [33]. Among patients in 183 US hospitals, the proportion of catheter use was 23.6%, with the highest rate in ICUs (45–80%), surgical wards (23%) and medical units (17%) [20].

43.4.2.1 Note

- Urinary catheters or other drainage systems are prescribed by a physician and discontinued by a physician.
- Patients and eventually relatives are informed in advance.
- *Stop order* is important to reduce catheter time—set a date for withdrawal of the catheter [13].
- Short-term catheter is removed within 30 days [14, 20].
- Long-term catheter may lie 30 days or more [14, 20].

43.4.2.2 Closed Drain System

Closed drainage system is recommended for all. The system comes in *sterile packaging* and contains urine collection bag with tap, valve, hose and sealing.

- The sealing tape is attached between the catheter and hose. If this is opened, it cannot be retightened.
- Urine is emptied via a tap at the bottom of the bag, or the collection bag is changed.
- By properly handling of a closed system, the same drainage system can be used beyond 2 weeks.

43.4.3 Permanent Catheterization (KAD—Catheter a Demeure)

A catheter that is not removed immediately after the bladder is emptied. It is prescribed by a doctor and it is always used as a sterile procedure. Two trained persons should participate in the catheterization because of sterility.

Stop order is a time-decided use of catheter.

43.4.3.1 Indication

Continuous monitoring of urine output (hour diuresis), acute obstruction, surgery, neurogenic bladder disorders or injuries that affect the bladder, active UTI combined with widespread wounds in the perineum area and non-neurogenic bladder disorders in which the use of intermittent catheterization is not feasible [14, 18–20]. Options are intermittent catheterization or “condom” use (uridome) on men [11, 18–20].

43.4.3.2 Equipment for Catheter Insertion

- Catheterization kit (low friction catheter), container for collecting urine, wipes, aqueous chlorhexidine 0.5 mg/ml, sterile water or sterile saline.
- Hydrogel catheter is used for short and long catheter treatment (not allergic reactions).
- Teflon- and silicone-coated catheter is used when expected treatment is longer than 14 days.
- Latex catheters are not used because of risk of latex allergy.
- Select a small size as possible: adults, ch. 12–16; children: ch. 6–10. If bleeding from the urinary tract in adults: triple lumen catheter size until ch. 24. Prescribed by the doctor.
- Local anaesthetics, e.g. xylocaine gel 2%. Local anaesthesia added with chlorhexidine is generally not recommended.
- Closed urine drainage system: urine collection bag with tap, check valve and sealing tape. The system is sterile and should be treated sterile.
- Suspension to the bag.
- Sterile gloves.
- To catheters not prefilled with liquid—20 ml syringe and sterile water for filling the balloon. Check the balloon and follow the procedure. Make sure that the catheter is seated well before replenishing. Some catheter types shall not be filled up.

43.4.3.3 Insertion of Catheter

- Patient/relatives are informed.
- Hand hygiene before and after and use sterile gloves and clean gown with long sleeves and cuffs.
- Date is registered in the journal.
- In case of vaginal discharge (women), vaginal opening should be closed with sterile cotton/tampon.
- In bedridden/incontinent patients, wash the area around the urethra first with clean water—no soap. Wear gloves.
- Wash the urethra and the skin around a couple of times with sterile cotton swab moistened in sterile water.
- Open the catheterization kit sterile and make a sterile covered area. Moisten sterile swabs with sterile water/saline and chlorhexidine.
- Prepare catheter (ch. 12–16) in a sterile manner; if no liquid, add sterile water/ saline. Follow the instructions for the catheter selected!
- The syringe-sterile wrapped xylocaine is opened on sterile cover area.
- Prepare the urine drainage system as a sterile procedure.
- Use sterile gloves and cover with sterile cloth from the catheterization kit below the genitals.

- In women labia are kept well apart and in men the foreskin is pulled back. With a sterile compress, raise the penis towards the stomach with a slight drag.
- Disinfect around the urethra opening and the surrounding skin with chlorhexidine 0.5 mg/ml with at least five sterile swabs, from the urine opening and outwards, and afterwards with sterile saline with five sterile swabs.
- For conventional catheters the urethra is filled with xylocaine—local anaesthesia. Wait for 2 min for the effect.
- The catheter is then gently and without resistance conveyed sterile into the bladder. In men, lower the penis a little while the catheter is inserted. Do not contaminate the catheter during the procedure.
- *Do not use force when the catheter is inserted!*
- Contact a healthcare professional with greater expertise if the catheter is not easily inserted.
- Continue the catheter 3–5 cm further in after the urine comes and fill the balloon with salt water and put the clamp in place. Remove the balloon clamp and push in the fluid, if necessary, and enter the specified amount of fluid with syringe. Use the instructions for the specific catheter!
- Pull the catheter gently until the balloon meets resistance (towards the bladder neck).
- Connect the catheter sterile for drainage, fastening seal sterile over the link.
- Connect the catheter to the urine collection bag with the bottom crane and the non-return valve sterile.
- Secure the catheter so that it is stable.
- In men, secure the upwardly curving down (U-shape) to prevent tension on the urethra. Fix the catheter with tape in a bow on the thigh - obs. Break or drag!
- The urine collection bag should remain below the bladder level to ensure free drainage.
- Avoid contact with the floor!
- *The bag should never be placed on the patient's stomach or higher than the patient's bladder!*
- The catheter should go below the bladder level all the time while it's in!
- Clean contaminated material and remove gloves for good hand hygiene.
- Document date, type and size in the journal.
- Check the amount of fluid in the balloon.

43.4.3.4 Drainage

- Hand hygiene before and after the procedure and after using gloves and use a clean gown with long sleeves and cuffs to protect the uniform.
- Wear gloves.
- Closed drainage.
- The connection between catheter and drainage system is sealed with sterile tape following the package.

- Seal is broken *only* if rinsing is prescribed by a doctor.
- The urine collection bag must be below the bladder level in the lying, sitting and standing position.
- The urine is emptied from the collection bag through a tap at the bottom of the bag, in a separate container—aseptic method.
- Wipe the tap crane with sterile swab/cloth and cover with sterile, waterproof compress.
- Drainage of urine must be done aseptic so that the tap is not contaminated with bacteria with ascending growth to the urine bag and further up into the bladder.
- Replacement of urine collection bag may be done regularly, at least weekly.
- If other drainage systems are used, all openings must be treated and covered sterile to prevent retrograde microbial growth in the system.
- Replacement of the entire drain system should be avoided if possible. If change is required:
 - Disconnect used drainage system from the catheter—aseptically.
 - Disinfect catheter opening gently with chlorhexidine alcohol.
 - Connect new sterile drainage—aseptically.
 - Seal the connector with sterile tape.

Properly treated closed drainage can usually be maintained beyond 2 weeks. If permanent catheter is in place for more than 3 weeks, urinary tract is likely to have been colonized with bacteria. Closed drainage after 3 weeks does not have the same meaning in reducing the number of infections.

Urinary catheter is a risk to the patient. Therefore, good personal hygiene and good cleaning in the environment around the patient are very important measures to avoid contamination of the urine drainage system.

43.4.3.5 Intimate Care of Genitalia by Inserted Catheter

- Hand hygiene before and after the procedure and after using gloves and use a clean gown with long sleeves and cuffs to protect the uniform.
- Wear gloves.
- Wash around the urethra opening with lukewarm water and soap.
- Observe whether there is redness, soreness, secretion or blood around the urethral opening.
- Patients are instructed in the correct intimate care and hand wash.
- Chlorhexidine will not be used for intimate care.

43.4.3.6 Bladder Rinse

This procedure is rarely indicated with the exception of special operative treatment of urinary tracts and by large precipitation of slag that can quickly seal the catheter. Documented in the journal.

- *Hand* hygiene before and after work operation and use clean gown with long sleeves and cuffs.
- Use sterile gloves and sterile technique.
- When rinsing is required to prevent clogging, use continuous flushing with 0.9% NaCl saline—through triple-lumen, sterile catheter.
- The rinsing system should be handled sterile, like an intravenous infusion.
- When prescribing intermittent rinses, use sterile technique.
- Catheter opening is disinfected with chlorhexidine alcohol 0.5 mg/ml.

Chlorhexidine is generally not recommended to be used for rinsing due to uncertainty regarding the carcinogen effect. Bladder rinsing as a measure against infections is not indicated.

43.4.3.7 Sampling of Urine When Using Catheters

The test for microbial examination must be taken in the cleanest possible manner, otherwise worthless!

In case of infection symptoms, a urine test should be taken for bacteriological examination. The catheter is closed in 2 h prior to sampling. Please inform on the referral of urinary catheter use (due to colonization).

- Hand hygiene before and after the procedure. Use clean gown with long sleeves and cuffs.
- Wear gloves.
- The sample is taken through the catheter wall, distally in the catheter, or from a special sample-taking site if available.
- Disinfect the puncture site with 70% alcohol, optionally chlorhexidine alcohol for 60 s.
- Use sterile needle and syringe.
- The urine sample is collected in sterile container. Handle the glass and lid aseptically so that the urine is not contaminated by environmental microbes.
- In order to avoid microbial proliferation, urine samples that cannot be sent immediately to the microbiological laboratory should be stored in the refrigerator for transport within 24 h.

43.4.3.8 Removal of Catheter

- Hand hygiene before and after work operation. Use clean gown with long sleeves and cuffs.
- Wear gloves.
- The date of removal of the catheter is recorded.

- Aspirate the balloon fluid and check that the liquid withdrawal corresponds to the one that was inserted.
- Carefully pull the catheter out.
- If the catheter is stuck, call health professionals with greater expertise.
- Note that spontaneous water drainage is started. Until that happens, the bladder is emptied by intermittent catheterization.

43.4.3.9 Cross Infection

To reduce the risk of cross infection, staff must avoid contact transmission and exercise barrier care.

43.4.4 Sterile Intermittent Catheterization (SIC)

43.4.4.1 Note

SIC may be performed by a competent nurse after consultation with a doctor.

Catheter is removed after the bladder is emptied.

SIC is recommended for shorter treatment intervals in hospitals and in severely ill patients and in cases of chronic catheterization. If intermittent catheterization is used, the bladder must be emptied four to six times a day, until spontaneous urination is started.

SIC can be done by the patient himself, if he is well trained and instructed.

43.4.4.2 Indication

Temporary or permanent problems, concerning emptying the bladder.

43.4.4.3 Insertion of SIC

Equipment: Catheterization kit, sterile packaged catheter optionally beforehand moistened, container for collecting urine, wipes, aqueous chlorhexidine 0.5 mg/ml, sterile water or sterile saline to be poured into the catheter bag. Sterile low friction catheters, as small as possible; adults, ch. 12–16; children, ch. 6–10. Xylocaine gel 2% if a low friction catheter is not used.

- Hand hygiene before and after the procedure. Use patient-bound, clean gown with long sleeves and cuffs.
- Date and time are recorded.
- Performed by trained personnel, possibly under supervision.
- Wash the urethral opening and the surrounding skin by 0.9% NaCl and disinfect the region with chlorhexidine 0.5 mg/ml.
- Pour sterile water over the low friction catheter in the bag, and wait at least 30 s. Follow instructions or use a finished moistened catheter in a sterile bag.
- Use sterile gloves.

- Insert the catheter into the bladder; do not use force.
- Contact a healthcare professional with greater expertise if the catheter is not easily inserted.
- Empty the bladder completely, press eventually over the symphysis and help the patient to a sitting position if possible.
- The urinary bladder should not be dilated. The amount of urine should therefore not exceed 400 ml in adults.
- Always measure the amount of urine. Date, time and amount of urine are recorded.
- This means that the bladder must be emptied four to six times daily if only intermittent catheterization is used.

43.4.4.4 Intimate Care

- Use the same procedures under the insertion of permanent catheter.

43.4.4.5 Sampling of Urine During SIC Catheterization

In case of infection symptoms, a urine test should be taken for bacteriological examination; see earlier.

- Hand hygiene before and after the procedure. Use clean gown with long sleeves and cuffs and gloves.
- The first urine that comes after the catheter has entered the bladder is thrown away.
- Then the required amount of urine is collected in the sterile test tube. Do not contaminate the test tube or the inside of the lid!
- The urine sample is placed in a refrigerator before further transportation to the microbiological laboratory within a maximum of 24 h.

Note! When using SIC, never use tap water because of growth of gram-negative bacilli!

43.4.5 Suprapubic Catheterization (SPC)

43.4.5.1 Note

Always carried out by a doctor.

43.4.5.2 Indication for Suprapubic Catheterization

If there is serious or complete retention of urine, transurethral catheter is not possible or desirable to use or does not succeed when inserted into the bladder through the urethra. In a few instances, it is used for microbial sampling.

Equipment: Suprapubic catheter kit with trocar and catheter; choose such a small size as possible. Adults, ch. 10–12; children, ch. 5. Make sure that the catheter opening is adapted to the closed urine drainage system.

- Hand hygiene before and after the procedure and after using gloves, and use a clean gown with long sleeves and cuffs to protect the uniform.
- Sterile drapes; chlorhexidine alcohol 5 mg/ml; local anaesthesia, syringe and needle for withdrawal and injection; sterile knife; suture set; skin suture; sterile bandage and tape; sterile gloves; and closed urine drainage system, with drain valve at the bottom of the bag, as before, mounting for the bag, container and cellular material.

43.4.5.3 Insertion as an Operative Routine

Operating Room

- Surgical hand hygiene.
- Surgical mask, cap, sterile gown and sterile gloves.
- Sterile cover.
- Date of entry of SPC is registered.
- Sterile technique and sterile equipment as with other surgical procedures.
- Inserted in local anaesthesia after skin disinfection.
- The catheter is inserted through the skin just above the symphysis, usually using a trocar.
- The catheter should be sewn to the skin.
- Insert the catheter when the bladder is well filled.
- In patients operated in the lower part of the abdomen, the peritoneum may be pulled down behind the symphysis. Caution may be due to the possibility of perforation of the viscera, eventually insertion with the guidance of ultrasound.

43.4.5.4 Drainage

- See point earlier.

43.4.5.5 Catheter Care

- The catheter insertion point should be treated as sterile.
- Later on, normal wound care is performed (see wound care).
- Keep the bandages dry.

43.4.5.6 Bladder Rinse and Sampling

- See point earlier.

43.4.5.7 Removal of Catheter

- Hand hygiene before and after the procedure. Use clean gown with long sleeves and cuffs.
- Date of removal of catheter is recorded.
- Make sure that the patient has a spontaneous urination before removing the catheter.
- Remove the suture and gently pull the catheter out. See wound care.
- Press with sterile compress and apply a small bandage.

43.4.6 Pre- and Postoperative Urine Drainage

43.4.6.1 Note

The patient should empty the bladder immediately prior to surgery.

43.4.6.2 Permanent Catheter (CAD) Is Indicated

- If operations are to be performed that are associated with major blood loss.
- In cases where an operating technique wants an empty bladder.
- In situations where the procedure is so prolonged that the time exceeds 5 h from the patient urinated—until the operation is completed.
- If it is necessary to measure hour diuresis in severely ill patients.
- If possible, CAD should be removed at the end of surgery or before the patient leaves postoperatively.
- Postoperatively, monitor the bladder function. Symptoms of overfilled bladder are pain, unrest, blood pressure drop and possibly other shock symptoms.
- Spontaneous urination must be recorded by volume, number and time.
- Postoperative urinary retention is recommended treated with sterile, intermittent catheterization (SIC) approximately every 4 h.
- The urine volume should not exceed 3–400 ml.
- Spontaneous urination usually occurs after one to two SICs. All SICs with time and amount of urine must be recorded.
- A “bladder status” should be made on all patients before leaving postoperative/intensive.
- Urine retention after transurethral surgery should be handled by an experienced surgeon.

43.5 Background Information

Urinary tract infections (UTI) detected in the hospital can be a chronic, asymptomatic UTI that flourishes upon admission to hospital or other healthcare institutions [1–3]. Up to 20% of people over age 65 may have asymptomatic bacteria in urine

and are usually not treated with antibiotics [1–3, 26, 34]. Other causes are common recurrences during hospital stay in patients who earlier have been suffering from UTI, patients during pregnancy (1–10%, depends on sampling methods), patients who have urinary tract anomalies (particularly children) and patients who are infected with special microbiological agents or catheter or other urinary tract instrumentation [35–40].

Lower urinary tract infection includes the bladder, prostate and urethra, with cystitis, prostatitis and urethritis/urethral syndrome as the presenting symptoms [5, 11, 18].

Upper urinary tract infection includes ureters and kidneys, with pyelonephritis, pyelitis and nephritis as the presenting symptoms.

Nosocomial urinary tract infections are particularly associated with lack of fluid intake, inadequate emptying of the bladder and the use of urinary catheters or other urological procedures (70–90%) [9–20, 39]. Up to 15% of cases may be caused by cross-contamination in the ward by poor hand hygiene, contaminated bedding and environment. Microbes may alternate, but are in most cases 60–80% of *Escherichia coli*.

Catheter-associated UTI is prevented by reduction of the catheter use. Sterile intermittent catheterization (SIC) is preferred but may also entail risk of infection in about 1% [34]. When permanent catheter is used, the risk of infection can be reduced by measures such as sterile technique for catheter insertion, use of closed drainage and short treatment time.

43.5.1 Note!

Patients with catheters should preferably be in single rooms to avoid cross-contamination. Make sure *stop order* for catheter use! [13].

43.5.2 Symptoms and Infection Types

- *Cystitis*: infection of the urinary bladder, bladder inflammation.
 - Symptoms: dysuria, frequent urination, “urge incontinence”, suprapubic tenderness and fever ±.
 - Recurrent and often increasing throughout the life of women—unchanged for younger men.
 - Important with control and treatment, especially in children, pregnant women and diabetics to avoid pyelonephritis scar changes and sequelae [35–38, 40].
- *Interstitial cystitis*: Frequent occurring in women. Suprapubic tenderness, pain during sex, cystitis symptoms without microbiological findings. Microscopic

haematuria, bladder wall distended diverticulum. Chronic over many years. Most commonly around 40 years of age, but 25% is observed in women under 30 years (Note: bladder schistosomiasis after exposure in tropical setting) [41].

- *Pyelonephritis, acute* (pyelitis) infection in the renal pelvis [9, 11, 14–16, 18–20].
 - Symptoms: lower UTI symptoms ±, fever and flank pain (abscesses, oedema, pus in urine, “scarring”).
 - Occurred outside hospital: 15.7/100.000/year (United States).
 - Occurred in hospitals: 73.0/100.000/year (United States).
 - Age most frequently over 50 years, women significantly more frequent than men.
 - Pregnant in two trimesters—postpartum control and anomalies in the urinary tract.
 - Diabetes is very common and is complicated occasionally with necrotizing papillitis.
 - May develop to kidney failure.
 - Sepsis with pneumococci or group B streptococci.
 - *E. coli* and other gram-negative bacteria, staphylococci, enterococci, streptococci, mycoplasma and anaerobic bacteria.
- *Pyelonephritis*, chronic infection of the kidneys.
 - Symptoms: fever ±, flank pain ±, lower UTI symptoms ±. May be without symptoms.
 - Second most frequent endpoint of renal failure, following chronic glomerulonephritis.
 - Particularly related to vesicourethral reflux and other congenital anomalies/dysfunctions.
 - Most cases do not have proven bacteria in urine.
 - Prevented by treating and controlling cystitis and other types of UTI.
- Other infections of the urinary tract are kidney abscess (renal/perirenal—often *S. aureus*), glomerulonephritis (group A, C or G streptococci, endocarditis, leishmaniasis, malaria, etc.), infected kidney stones and infections elsewhere that damage the kidney (sepsis, septic shock, haemolytic uremic syndrome, epidemic nephropathy, etc.).

43.5.3 Microbes

Escherichia coli is the commonest cause of UTI both in and outside the hospital [1–4, 40, 42–45]. Gram-positive bacteria like enterococci and staphylococci are relatively frequent causes of infection. *Staphylococcus saprophyticus* is a relatively frequent cause of urinary tract infection in young women (Scandinavian phenomenon?) with seasonality, most often in summer and autumn, and has been linked to the consumption of raw vegetables and various other raw foods such as meat

products, poultry and eggs [46, 47]. *Staphylococci* (*S. epidermidis* and others and *S. aureus*) are most often hospital associated (older men with prostate complaints), and *Streptococcus agalactiae* (group B streptococcus) is detected occasionally, particularly in pregnant and older women. If there is a detection of *Klebsiella*, *Enterobacter* or *Proteus* species, check if this is caused by faecal contamination of the urine by control. *Serratia* and *Pseudomonas* species are not normal intestinal flora and generally transferred from an external source such as hands, equipment, etc. [45, 48]. Search for external source!

43.5.4 Some Important Bacteria [3, 11, 15, 16, 42–54]

- *Escherichia coli*—60–80% uncomplicated UTI [3, 11, 15, 16, 45].
 - “Uropathogenic *E. coli*” (serogroups: 04, 06, 075, 01, 02, 07) are primary pathogens in the urinary tract.
- *Staphylococcus saprophyticus*—5–10%; varies, mostly in women of childbearing age.
- *Staphylococcus epidermidis*—prostatitis in elderly men.
- Enterococci—nosocomial infection, especially during antimicrobial treatment. Can infect together with another bacteria like *E. coli* (synergistic).
- Streptococci (group B)—ca. 10%; more often among pregnant.
- *Proteus mirabilis*—recurrences and risk of pyelonephritis; control is important.
- *Pseudomonas aeruginosa*—resistant and can be contaminating; control is important.
- *Klebsiella/Enterobacter* and other gram-negative rods: often UTI with complications and should be controlled.
- *Candida species*: Note! Catheters and use of antibiotics!
- Other (*Gardnerella*, *Chlamydia*, *Trichomonas* mm)—often few symptoms.

43.5.5 Resistant Bacteria: The Patient Is Isolated

Antibiotic-resistant gram-positive and gram-negative bacteria increase in hospitals all over the world. Patients with recurrent antibiotic treatments for UTI are reservoirs of resistant bacteria, spread by patients through the different healthcare levels [32].

Resistant gram-negative bacteria are ESBL bacteria (extended-spectrum beta-lactamase) with extended resistance to all beta-lactam antibiotics (penicillins, cephalosporins) and may develop resistance to carbapenems. ESBL and CRE (carbapenemase-producing Enterobacteriaceae) were previously mostly related to increased travel and motility in the population [45, 49, 50]. Today, there is almost complete-resistant “import bacteria”, carrying super resistant genes (NDM = New Delhi metallo-beta-lactamase-1 and colistin resistance) [45, 50].

Such findings should be controlled with further samples and the patient should be isolated.

Methicillin-resistant *S. aureus* (MRSA, exposed to infection domestically or abroad) is related to use of indwelling catheter and intermittent catheterization, especially in long-term patients [51]. Enterococci are resistant and robust, causing UTI superinfections with a large potential of transmission. Note: vancomycin-resistant enterococci, VRE! [52].

Before any use of antibiotics in the hospital, a urine sample is recommended, especially in patients with risk factors and from abroad [50].

Bacterial characteristics promote ability of invasion and of ascending infection in the urinary tract, such as adherence to urinary lining (*E. coli*, *S. saprophyticus*, enterococci) and mobility (*E. coli*, *Proteus mirabilis*)—which both promotes upward transport of the bacteria in the urinary tract [53, 54]. Other properties are toxin effect (*E. coli* and other gram-negative bacteria) which destroys tissues of the urinary tract and urea decomposition (*Proteus*, *Klebsiella*, etc.) which promote bacterial growth.

Tuberculosis of the urinary tract is usually spread via blood from pulmonary tuberculosis, sometimes from tuberculosis in intestines, skin, tonsils, etc. where the primary focus can be healed. The infection is detected most frequently in the kidneys as small tubercles in the kidney interstitium (miliary tuberculosis) or solid conglomerates of caseous (cheese-like) necrosis (nodular tuberculosis) or cavernous with rejection of pyramids to the cortex (cavernous, renal tuberculosis). Eventually, the entire kidney may be destroyed to a “baglike” device with dense ureters and ligation of the kidney (autonephrectomy). The patient may always have cystitis symptoms because of bladder infection. Mycobacteria in urine can lead to the spread of infection if not handled properly. *Note! If there is pus in the urine without growth of bacteria, think always of renal tuberculosis!*

When travelling and staying in warmer climes with fresh water lakes should parasites like *Schistosomiasis* be a differential diagnosis [41].

43.5.6 Predisposing Factors

Patients with disease- or age-related changes in the urinary tract, malaise, decreased immune function, diabetes mellitus, prolonged bed rest/immobilization, etc. are susceptible to UTI. All patients with drainage of the urinary tract (catheterization and other instrumentation) will almost always have bacteria in the urine, introduced by contaminated catheter, other equipment, biofilm formation on equipment and with poor hygiene [11, 12, 18, 39, 40, 53–56]. These constitute a source of infection for other patients. Patients with asymptomatic UTI may be a source of infection by catheterization, when the microbes are transmitted to the staff’s hands [48]. Variation in types of microbes that cause UTI is greater in health institutions than outside.

Antibiotic-resistant microbes are mostly in hospitals and in patients who have been on repeated treatments with antibiotics. UTI caused by resistant bacteria implies a considerable nosocomial problem, and indiscriminate use of antibiotics promotes resistance.

Pathology that increases risks [11, 12]. Normal bladder walls eliminate approximately 90% of *E. coli* that infected cells fall off and take the microbes with them out. A quarter of the kidney is enough to maintain a normal renal function. Congenital anomalies of the kidney like hypoplasia, kidneys in the pelvis, horseshoe kidney, renal cysts, renal calculi, strictures, etc. may predispose to infection. Diseases in glomeruli as diffuse glomerulonephritis (group A and other streptococci), membranous glomerulonephritis, focal embolic glomerulonephritis, amyloidosis, lupus, eclampsia, etc. may eventually reduce the production of urine and are often combined with infections [11, 12]. Diseases of the tubules with nephrosis and shock kidneys for different reasons are also a risk. Diffuse interstitial nephritis (group A streptococcus, Clostridia, spirochetes, bacterial pneumonia, septicaemia, viral diseases, etc.) and various forms of pyelonephritis are participating infections.

All forms of urinary stasis predispose to pyelonephritis. In autopsy materials pyelonephritis is the second most frequent infection, after pneumonia. Pyelonephritis is detected in 15–20% of autopsies and one in three of these are the cause of death.

Urine is an excellent growth medium for bacteria [11]. Glucose and amino acids are nutrients for bacteria as urea and organic acids are growth retardant. Bacterial growth is optimum at pH 6.7 and the osmolality <200–1100 mosm/kg. Infections of the kidneys are associated with low osmolality. Once the infection is removed, the ability to urine concentration is corrected. Glucose in urine promotes maximum growth of bacteria, and diabetes patients have significantly more bacteria in the urine than nondiabetics. Urea is bactericidal at high osmolality. Congenital or acquired anomaly is associated with stasis or reflux of urine or residual urine with the risk of increased growth of bacteria.

43.5.6.1 Important Factors for Development of UTI [11]

- Too low intake of fluid and too seldom emptying the bladder.
- Women are most prone to UTIs because of a short urethra and close to the anal opening. Recent/frequent sexual activity (type of intercourse) is the most important release of UTI in young women—usually within 24 h afterwards, due to pressure over the bladder and reflux of urine.
- Urinary catheters, particularly if there is simultaneous asymptomatic bacteriuria or diarrhoea.
- Staying in healthcare facilities (nursing homes, hospitals). UTI infection in >40% of the elderly in institutions.
- Oestrogen deficiency in older women.
- Anatomical factors—enlarged prostate in men and/or cystocele in women.

- Stasis in the urinary tract due to pregnancy and other causes.
- *Pregnancy* with press on ureters can create stasis. Asymptomatic bacteria in urine (1–10%) may lead to acute urinary tract infection in 10–20% during pregnancy. These are relatively severe and can result in pyelonephritis, premature birth, abortion, mental retardation and delayed development of the child. Group B streptococcal infections in newborns are serious, and the cause may be urinary tract infection in the mothers.
- Recurrent UTI.
- Functional disorders like dementia, incontinence, parkinsonism, immobility, etc.
 - Kidney/bladder stones: relapsing infections, reinfection, often several microbes simultaneously and “chronic”.
 - Reflux nephropathy (intra-renal reflux + infection) in children and young adults—can be detected in utero (20-week pregnant) and can cause scarring which is common in adults; female >> male. Present in 0.3–0.7% of all women with bacteria in urine and one out of three develops renal impairment.
- Diabetes has three times more frequent UTI and increases with age, failure in blood sugar control, etc.
- Specific immunological disorders.
- Incorrect use of antibiotics which select for uropathogenic bacteria [25, 26].

Bacterial growth is inhibited by normal “washing effect” of urine at normal intake of fluid, normal renal function and normal urinary tract.

43.5.7 Prevalence, Costs, Severe Illness and Mortality

UTI represents the largest single cause of infections in the nursing home and is a frequent cause of hospital admissions. In a study among elderly in institutions from Sweden, asymptomatic bacteriuria in urine was shown in 26% of women and 16% of men [57]. Over 80 years of age, 50% of women and more than 30% of men had asymptomatic bacteriuria [57].

More than 60% of women will have a UTI at least one time during their lives, and already at 24 years of age, one in three women have had one or more infections. Among men, 20% will undergo UTI during their lifetime and they become more frequent hospital patients. For children, the risk is 2% in male and 5.8% in female children, most commonly associated with reflux of urine from the bladder up towards the kidneys (Table 43.1) [38].

In the United States, the estimated additional cost is 675 USD and, at uro-septicaemia, 2800 USD per patient [11, 58]. More than 380,000 infections and 9000 deaths from catheter-associated urinary tract infections can probably be prevented each year in the United States (more than 300 million inhabitants) [18].

Table 43.1 Presence of UTI between women (F) and men (M)

	F	M
Neonatal	0	2/1000
6 months–6 years	4.5%	<0.5%
School age	1–5%	<0.05%
21–65 years	5%	<0.1%
>65 years	10–20%	10–15%
Pregnancy	Ca. 5% (2.5–15%)	
Nosocomial	Ca. 3% (2.5–8%)	
Primary practice	2–5% of all consultations	

Source: Refs 5, 11, 18, 38, 57

Incidence and cost in Norway. Norwegian hospitals treat 600,000–900,000 patients a year. On average 2, 5% of these patients have nosocomial UTI and approximately 16,250/year—only when in hospitals. Each patient with UTI constitutes an extra length of stay of at least 2–3 days: 40,000–45,000 additional bed-days/year. The price per night is about NKR 5000 or 200–400 million per year, just in extra stay in hospitals. Additional cost per patient with nosocomial UTI is a minimum of 12,000 NKR (ca. 1715 USD) [5].

43.5.8 Urinary Catheters and Nosocomial UTIs

Catheterization involves bacteraemia (bacteria in blood) in 6, 5% of the cases, usually transient. There are five times more likely that bacteria pass into the blood by catheterization of a person with UTI than without UTI. Bacteraemia affects 0.5–3. 9% of patients with catheter-associated UTI. Up to 40% of patients with nosocomial UTI have also other nosocomial infections. Among 100 patients with UTI that are operated, 2–3% may get infection in the wound with the same agent.

Mortality is three times higher with nosocomial UTIs than without [59]. Among 2–4% of nosocomial UTIs that get bacteraemia, 10–15% may die. Nosocomial bacteraemia often starts from UTI, 15–20% [59]. In the United States, 31,000 patients die per year of catheter-related bacteraemia. Catheter-associated UTI results in a “crude” mortality between 4% and 14–30%, depending on the use of the closed system or not; corresponding 400–650 dead patients/year are associated with nosocomial UTI in Norway.

Permanent urinary catheter leads to bacterial growth from the outside inwards both on the outside and inside of the catheter, with several types of bacteria and often in large quantities [18]. Catheters may damage the mucosa and promote local infections and cause turbulent flow of urine, which can

promote growth of microbes. Mucosa of the bladder can be damaged and become more adhesive for bacteria with mixture of bacteria types protected by glycocalyx (Tamm-Horsfall protein, fibrin) [54]. A total of 20–30% catheter infections are asymptomatic.

E. coli is the most frequently cause of catheter colonization progressing to the bladder, but also other gram-negative rods like *Klebsiella*, *Enterobacter*, *Proteus*, *Pseudomonas*, *Serratia*, etc. cause colonization/infection and occasionally gram-positive cocci. An uncomplicated catheter infection/colonization should not be treated with antibiotics. Since there is a growing number of resistant gram-negative rods associated with catheter use in Europe, it is essential that the catheter usage is minimized [60]. A large study in Europe showed the following:

43.5.9 Risk Factors for Nosocomial UTI in 298 Patients with UTI [60]

- Catheter 62.8%.
- Intravenous catheter 48.3%.
- Previously received antibiotics 39.3%.
- Former UTI 25.2%.
- Surgery while hospitalized 21.0%.
- Faecal incontinence 14.8%.
- Steroids 11.7%.
- Recently intervention in the urinary tract 6.4%.
- Other invasive procedures 5.7%.
- Obstructive uropathy (catheter) 5.0%.
- *No predisposing factors* 22.8%.
- Simultaneously sepsis 35.9% [60].

43.5.10 Errors in Catheter Use in 187 Patients with UTI [60]

- Catheter indication uncertain 7.6%.
- Catheter unnecessary to continue with 31.3%.
- Catheter not indicated at all 36.7%.
- Closed drainage in only 78.5%.
- Serious fault with handling the catheter (procedure) 24.0%.
- Open drainage or opening of a closed system 36.8%.
- *Errors that could be prevented* 53.1% [60].

43.5.11 Other Errors/Problems That Need To Be Prevented

- Urine bag should never be at the level of the bladder because the urine—which can contain bacteria—then flows back towards the bladder.
- Securing against prolonged stasis in the hose.
- Hang the bag so that it does not drag along the floor when the patient walks.
- Sterile treatment of taps of urine bags, etc. and sterile closure of all openings.
- Do not place two catheter patients in the same room because of a risk of cross-contamination.

43.5.12 Prevention Particularly Addressed to Catheter Use

- Indication—consider more carefully—medical task.
- *Stop orders* [13, 61].
- Insertion and care—physician/nursing.
- Indication for to remove catheter—medical task.
- Indication for sampling and examination urine—medical task—usually not indicated when catheter.
- Indication for antibacterial treatment and choice of medicine—medical task.
- Catheter is not for care problems.
- No antibiotic prophylaxis for the use of catheter.
- The catheter is removed as quickly as possible.

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Abstract

At birth, most children are “sterile”, except for the amount and type of microbes that come in by the birth canal or by early amniotic rupture and retrograde invasion from the vagina. Susceptibility to infections is present especially among premature new-borns. An important start of life is to be protected against serious hospital infections. Premature and new-born babies that need medical assistance during the first period of life are often treated with invasive procedures which may include a risk of infections. Many neonatal intensive care units (NICUs) have few resources and are understaffed with a lack of competent personnel. This may increase risk of infection. The following chapter is focused on practical measures to reduce the incidence of infections among premature and new-borns in general and in the NICU, in particular.

Keywords

Premature · New-borns · Nosocomial infections · Infection control · Hygiene Prevention

44.1 Purpose

To prevent new-borns and premature against infections [1–22]. Several guidelines are focused on infection prevention in new-borns [1–6].

44.2 Comprise

All personnel who treat and manage this patient group and are in contact with patient-related equipment, medical equipment, incubators and textiles.

44.3 Responsibility

The hospital's management should provide resources and written guidelines regarding infection control work, proper patient care ratio, sufficient patient areas, isolation capacity and documented competence.

The department management should provide resources and skilled personnel and follow guidelines. In circumstances that expose patients to increased infection risk, this is reported to the Director immediately.

Staff should follow routines. Competence and practice in new-born medicine/new-born intensive care should be documented. Staff exposed to/infected with some types of microbes, for example, in work at other departments/countries, must report this to the management.

44.4 Practical Measures

44.4.1 Personal Hygiene and Infection Protection

All staff, including temporary workers, should be trained in hand hygiene, personal hygiene, use of clean work wear, no jewellery, piercing, etc. [1, 4, 5, 9, 22, 23] (see personal hygiene and infection protection). The manager should repeat such routines with employees [1–6, 9].

In many countries, employees, including temporary workers, etc., are submitting written questions about exposure to/infected with MRSA or tuberculosis. Information of recent illness/exposure to norovirus, other gastrointestinal infections or other serious or easily transmittable infections is also important.

44.4.2 Protective Intensive Care

Due to a very complicated treatment, there should always be two competent nurses present per patient.

The ward's burden of microbes and dust, are major strains for low-birth-weight premature with immature immune systems. Premature in incubators are protected from the environmental particle and microbial waste from the skin and the hair of personnel and visitors.

The environmental burden of microbes and particles in the room may be reduced by the following measures for staff and visitors:

- Before entering the room, disinfect or wash your hands. Remove wristwatch, jewellery or piercing.
- Use a cap, surgical mask and clean gown/clean outfit.
- Inside the room: disinfect or wash your hands up to the elbow.
- Before and after work in the unit: disinfect or wash your hands.

- Before planning work inside the incubator, disinfect the hands, wrists and forearms up to the elbow. Allow to dry. Or use clean gown with long arms, cuffs and sterile gloves.
- All contact with *sterile equipment* such as *central venous catheter, ventilator, tube set*, etc. that goes to the patient is carried out with *sterile gloves* that are changed between each handling.
- If the patient is taken out of the incubator, use clean gown with cuffs and sterile gloves, and the same does the parents.

44.4.3 Hygiene and Infection Protection for Parents and Other Relatives

Parents and other visitors are taught in personal hygiene like clean clothes and hand hygiene. The child is often admitted for a long time. Parents should learn how to behave in the department to not cause spread of infections within the department.

Parents and visitors should follow guidelines like:

- Hand hygiene on arrival; change outfit or wear gown, and ensure new hand hygiene before entering the department.
- Outerwear and bags are placed in own wardrobe designed for relatives, before entering the ward. The wardrobe is cleaned between each family period or more often during longer stay.
- Use protective clean clothing, and carry out good hand hygiene before and after visiting the department and before and after care of the child and other contacts.
- Go directly to the child's room by appointment with the responsible nurse, and do not use a common room without prior agreement.
- Do not enter the service room for textiles, equipment, milk kitchens, garbage, waste rooms, etc. or in other service rooms.
- Visits and the number of people present—ask the responsible manager. Ensure adequate space around the child to prevent spread of contamination, especially if there is more than one child in each room.
- Children infected with certain types of bacteria or viruses are placed in isolates to prevent spread of infections. A separate wardrobe for visitors to the child with infection is used. An agreement is made with parents about how to deal with infection.
- Tracing of certain infections is important to prevent spread of the infection in the children's department. Visitors and personnel are included in the tracing programme. It is currently useful to ask if visitors have recently been ill/exposed to norovirus or other gastrointestinal infections or respiratory infections or been recently exposed to special resistant bacteria.
- Toilet with hand wash/shower for visitors should be connected to the actual wardrobe unit.

44.4.4 Handwash and Hand Disinfectant Readily Available

Washbasins and disinfectants should be readily available in all patient rooms, disinfection rooms, ward office and at the entrance to premature/new-borns.

- The washbasin should be designed and placed so that spray from the basin is not reaching patients, equipment or glove boxes.
- In the washbasin and around the crane opening, gram-negative bacteria grow well. They are spreading and contaminating the environment by aerosol and splashes, causing infections [23]. Therefore, there should be plenty of space around all washbasins. The closest patient space/bed/incubator must be at least 2 m from the sink to avoid aerosols and splashes.
- Hand hygiene should be carried out in a calm manner without spraying water on the clothes and environment.
- Hand disinfectants—preferably dispensers—are placed at all entrances, service rooms, patient rooms and ward offices, with posters for information and encouragement for hand hygiene.
- Good daily cleaning is carried out around and in the washbasin and also supervision of paper towels, soap, disinfectants and trash can.
- There should be no equipment placed on the sink.
- Hand cream can spread infection. Microbes may grow well in cream/ointment. Avoid common hand cream boxes; use small disposable tubes.

44.4.5 Cleanliness and Tidiness

Good daily cleaning is carried out so that transient flora is removed quickly. Ensure good space and good routines for order and cleaning.

- Skin cells, the hair and microbes are released continuously from persons in the room—and fall down as a grey “dust” on all surfaces after a shorter or longer stay in the air. This “dust” often carries large amounts of bacteria but is nearly invisible. It is not enough to inspect the floors and surfaces to say that “it’s clean”.
- Large amounts of particles from disposable devices that open in the patient’s room will also cause dust.
- Even “harmless bacteria” are at risk for premature.
- The quality of cleaning should therefore be at the level of an operating department.
 - All patient rooms, service rooms, ward office, wardrobes, etc. must be cleaned at least once a day with soap and water.
 - All horizontal surfaces in patient rooms are washed daily.
 - To clean surfaces, shelves and cabinets properly, only necessary equipment, clothes, etc. should be present on open surfaces.
 - All cabinets in the patient room/intensive room are cleaned weekly.

- There should be no stockholding in patient rooms, except for what is needed for today's use.
- Toilets are cleaned $\times 2$. See chap. 65 on cleaning.
- When a patient leaves the room, everything in the cabinets must be discarded, and the cabinet should be thoroughly washed.
- Cabinets and shelves in service rooms must be cleaned once a month.
- All equipment must be cleaned after each use and before placed in a clean storage room.
- PCs, telephones, data in the patient room and the like should be washed over after each shift; if necessary, put on a new plastic bag for each shift.
- Main cleaning of the complete department two times a year.
- *Disinfect* mobile phone, glasses and all other equipments *before* bringing it into the ward.
- *Note:* Persons who perform room cleaning should not work with children at the same time. This is to avoid cross infection.

44.4.6 Disinfection of Rooms and Surfaces

In case of infections like MRSA, VRE, ESBL, norovirus, etc., follow routines for disinfection; see chapter on isolation routines. All rooms exposed to the infectious agent are disinfected. Disinfectants often used are peracetic acid, chlorines and chloramine 5%; they are effective against all agents with exception of prions, if following the guidelines. For rooms with a lot of disposable single-use equipment and other equipment difficult to disinfect and/or many rooms to be disinfected, gas disinfection may be practical [24, 25].

Hydrogen peroxide gas disinfection inactivates most bacteria and viruses, except for tuberculosis [25, 26]. Gas disinfection requires control measures to verify removal of gas from the room (<1 ppm hydrogen peroxide gas) before it is opened and spore quality control to assure the disinfecting effect [24, 25]. If problems exist, contact the hospital hygiene unit.

44.4.7 Ventilation and Cooling

Frequent air exchange (8–14/h) and fresh air supply to all rooms reduce the load of bacteria and particles. Bacterial volume in air in patient rooms should be low (<100 CFU/m³). Temperature of the air should take place in the ventilation system outside the ward. Cooling systems inside rooms are risky with germination of bacteria and fungi on dust particles and droplets that may blow into the room. Humidifier systems may also contain *Legionella*.

New-borns and premature should be shielded against building activities in or near the ward since dust particles loosened during the construction process may contain bacteria and fungi [27]. Contact the hospital hygiene unit for guidance.

44.4.8 Purchase, Storage and Maintenance of Medical Technical Equipment and Disposable Equipment

NICU need advanced medical equipment, larger reusable equipment and disposable equipment, which may be a challenge for hygiene and infection protection.

Note! Hospital hygiene unit and medical technical units should be contacted when purchasing new medical equipment to ensure proper cleaning procedures.

- All equipment that should be in contact with (directly or indirectly) sterile mucosa/sterile tissue must be sterile. Check if it has “sterile” mark on disposable packs.
- All equipment that should be in contact with (directly/indirectly) skin and normally colonized mucous membranes (oral cavity, gut) must at least be disinfected; not live microbes but spores may occur. In most cases, only sterile equipment should be used, such as equipment/probes, etc. to the upper respiratory and the gastrointestinal tract.
- Packages marked with “antiseptic” or “aseptic”. This requires documentation for production and microbiological control. Experience has shown that such declarations are not valid.
- Medical devices such as ultrasound apparatus, ECG, X-ray, etc. should be washed after use and disinfected before use. The equipment must be stored in a clean storage with a disposable plastic chapel over and disinfected with wipe just before the next use. In case of infection, the equipment must be disinfected completely (also inside) before the next patient.
- Before and after repair and maintenance, the equipment must be cleaned and disinfected. If the equipment has been used for a patient with infection and has not been cleaned inside afterwards, it is packaged and notified to the technical department as infected equipment.
- Medical technical equipment should be assigned to a defined section/department and not shared between multiple departments, due to infection risk.

44.4.9 Intravascular Access

Sterile procedures for establishing and managing intravascular access are central to successful treatment (see chapter on intravascular infections) [1, 4, 7–10]. Opening and closing of such systems must be done *sterile* [8].

44.4.10 Ventilation Treatment

All equipment entering the oral cavity/respiratory system should be sterile and later not contaminated by other than the patient’s own flora (see chapter on prevention of respiratory tract infections and respiratory/ventilator use) [1, 4]. In all suction procedures, sterile, new disposable equipment should be used every time and sterile

gloves (non-sterile gloves are often loaded with bacteria and fungi). Recycling of “airflow sensor”, unsatisfactorily disinfected, is associated with multiple infections in new-born [28, 29]. Change of ventilator circuit in neonates must be performed according to good routines to avoid pneumonia [30].

44.4.11 Tube Feeding or by Syringe

All equipment entering the nasal/oral cavity/ventricle should be *sterile* (check that the device is labelled sterile). Feeding through the tube should take place *without* environmental bacteria or flora from the hands of the staff being fed to the child. *The probe should be sterile every time it is put down; syringes for nutrition should be sterile, packed and used only once, that is, one feeding!*

Outbreaks of infection are occasionally linked to industrial ready meals—powders, etc. for premature/new-borns—with serious consequences for patients [1, 31, 32].

44.4.12 Antibiotics: Handling

An often too large and continuous consumption of antibacterial agents in neonatal intensive care units must be minimized, and resistance-driving agents must be avoided [2, 4, 14, 15]. Microbiological findings must be followed up with resistance pattern regarding the current drug used [15]. Antibiotics for infusion must be prepared in clean medicine rooms, and residues after completion of infusion should be immediately removed to reduce the selective pressure antibiotics may have on environmental microbes [15].

44.4.13 Care of the Patient

Follow the department’s guidelines for bodily care and hygiene [4]. The skin of the smallest premature is thin and easy to damage. Small damages to the skin can be a gateway to bacteria. Therefore, use only sterile or recently decontaminated equipment or textiles directly from clean storage to the very smallest and poorest patients. It is discussed what would be the best for the child’s skin [1, 2, 4]. Creams/ointments/oils and the like should be tested beforehand and should be sterile and preferably in single-dose units. Any means for the skin should be sterile, in single doses and discarded after each use.

Note! Bacteria grow easily in creams and ointments and even in soaps!

44.4.14 Examination of the Patient

All equipment in the patient’s incubator should be sterile or recently thoroughly disinfected. This applies to stethoscopes and other equipment such as ECG, X-ray,

ultrasound probes, etc. The ultrasonic cream must be in single doses (good growth medium) and disinfected before opening.

44.4.15 Milk Bottles and Food Preparation

Nutrition supplied must satisfy requirements corresponding to milk kitchen production [33, 34]. Good hand hygiene, clean clothes, clean surfaces and clean storage are important. The milk bottles with accessories should be thoroughly cleaned and boiled, eventually treated in a special washing machine at a minimum of 85 °C. Then the equipment must be stored in clean plastic bags in clean cabinets as clean equipment until use. All equipment for the pumping of breast milk should be treated in the same way. Mother should be advised of good hand hygiene and personal hygiene in order to avoid contamination of breast milk [34]. Mother should have equipment delivered, not pick it up in cabinets, etc., herself.

Note! In case of infection in a child or mother (resistant bacteria, virus, blood-borne infection), there should be a separate and isolated system that prevents infection through milk and food.

44.4.16 Incubators: Cleaning and Disinfection

Cleaning and disinfection procedures for incubators are complicated, due to the incubator's varying design and construction, water-containing parts and all the different materials it is made of. Strict hygiene requirements must be made when purchasing new incubators. Also contact the hospital hygiene unit.

- The use of chemical disinfectants for disinfecting the incubator should not expose children or personnel to toxic or allergic side effects.
- *Plexiglas* can withstand normal detergent and water, but not a variety of disinfectants such as alcohol and chloramine (blurred and opaque). Peracetic acid may be used. Gaskets can be decontaminated.
- *Sensor module* suspended in the ceiling, inside at the “foot end” of the incubator, has a number of openings into a technical unit that cannot be cleaned or disinfected. It should be taken out and disinfected over outer parts, daily. In cases of serious contamination with environmentally resistant contaminants, gas sterilization must be considered/replacing the module. Single-use module is preferable.
- *Water container* with connection to heating element: the temperature of the water vapour is approximately 100 °C and is passed through a short hose to the heating element at the bottom of the incubator. The water container is run in the decontaminator daily and then filled with sterile, distilled water. The space where the water container is in the incubator is washed with soap and water—daily. Gaskets are changed as needed.

- *The heating element at the bottom of the incubator* has a temperature of 100 °C and can be decontaminated in the usual manner, as well as a carousel for air mixing. Water vapour and room air + eventually oxygen are mixed in the cavity of the heater.
- *The air filter on the underside* should be changed every 2 months—and always by infection. Filter quality should preferably be hepafiltered.
- *Inner mechanical/electronic parts in the lower part.* The entire incubator, including heating element, can be cleaned, except for the lower part. Here service is carried out annually with cleaning, control of electronics, etc. (medical technical department). After special and unusual infection, the incubator is sent to service for gas sterilization of internal mechanical/electronic parts.

44.4.16.1 General Guidelines

1. *The incubator* should be cleaned with regular detergent, *daily* and *between* each patient. Clean cloth and clean bucket that have been decontaminated at 85 °C should be used for each incubator. Stains and spills that come during use should be washed with soap and water immediately. For long-term incubation, the patient should be transferred to a clean incubator *every week*.

Parts and equipment that are used in the incubator must be cleaned and disinfected *daily and between each patient*. All loose equipment that can withstand decontamination (prewash, disinfection and rinse) at 85 °C should be decontaminated (see chapter on technical disinfection).

2. *Disinfection* of the incubator should be performed after each patient with *infection*. Disinfection of incubators and accompanying equipment should be carried out with means such as heat, peracetic acid, optionally chlorine or chloramine 5%.
3. *Incubator washing room.* The incubator must be disassembled, cleaned or disinfected in the laundry room for incubators—not in the patient room after use, except after termination of infection isolation.

44.4.16.2 Special Guidelines

1. *Daily cleaning of incubator in use:*
 - (a) Wash hands, and put on gown/apron.
 - (b) Fill soapy water in a washbowl. Use liquid soap (tested for cleanliness) and clean cloth.
 - (c) Wash ceilings, walls and mattress. Pull out the tray and wash well below this.
 - (d) Sensor module is disinfected daily. In case of serious contamination with environmentally resistant contaminants, gas sterilization must be considered/replacing the module.
 - (e) Wipe dry with a dry, clean cloth.
 - (f) Replace clean laundry in the incubator. The mattress cover is protected, for example, with diaper with plastic coating.
 - (g) The plastic cuffs are removed and boiled in water daily.
 - (h) Close the incubator.
 - (i) Wash the outside in the same way.
 - (j) Wash the cabinet on the chassis inside and outside.

- (k) Remove the water container with equipment for decontamination, and wash the cavity. Disinfect hands before inserting new decontaminated water can. Fill with sterile, distilled water.
 - (l) Decontaminate the washbowl at 85 °C.
 - (m) Move the child to a clean incubator after 1 week.
2. Cleaning and disinfecting incubators once a week and between each patient:
 - (a) Wash hands, and put on gown/apron.
 - (b) Fill soapy water in a washbowl. Use liquid soap (tested for cleanliness) and clean cloth.
 - (c) Remove the water boiler, funnel and eventually icebox that are decontaminated, and wash the cavity.
 - (d) Take out and heat disinfectant: mattress and cuffs. The equipment must be replaced when it becomes stiff.
 - (e) Clean and disinfect with alcohol 70%: apnoe mattress and other technical equipment that cannot withstand heat.
 - (f) *Sensor module* is taken out and disinfected with alcohol.
 - (g) *Heat elements in the bottom of the incubator are* decontaminated together with the carousel for air mixing. The cavity is cleaned.
 - (h) *Check the air filter on the underside*—replace every 2 months. The air filter compartment is washed, disinfected and dried before new filter is inserted.
 - (i) Wash the incubator well inside.
 - (j) Wipe clean with dry clean cloth.
 - (k) Close the incubator.
 - (l) Wash the outside in the same way.
 - (m) Wash the cabinet on the chassis inside and outside.
 - (n) Hand hygiene before inserting new decontaminated water can. Do not add sterile water before use!
 - (o) Decontaminate the washbasin at 85 °C.
 - (p) Fit the incubator when it is *completely dry*. It is an advantage if it can stand unused for a day.
 - (q) Cleaned incubators must *be stored and covered* in the room for clean equipment.
 - (r) *Only immediately before use* should the incubator water container be filled with sterile distilled water.
3. *Disinfection* and washing incubators after infections or suspected infection.
Apply disinfection of the incubator, regardless of the type of infection. This is to ensure a safe and simple procedure. Disinfection takes place on the infection isolate—or where the patient has been treated. After the incubator has been disinfected, it can be transported and covered to the cleaning room for incubators for regular cleaning.
Use gown, cap, surgical mask and gloves.
 - (a) Insert all parts with peracetic acid, chlorine or chloramine 5%. Chloramine 5% should be used and *undiluted*. Wear gloves; disinfectants are strong! Allow effect time of 15 min for peracetic acid (tbc 30 min) and 1 h for chloramine 5%.

- (b) All heat-resistant parts/equipment are heat treated at 85 °C, are taken directly in the decontaminator (prewash, main cleaning, rinse) at temperature >85 °C (see technical disinfection).
 - (c) *Sensor module* suspended in the ceiling has a number of openings into a technical unit that cannot be cleaned or disinfected. In case of serious contamination with environmentally resistant contaminants, gas sterilization must be considered/replacing the module.
 - (d) *Air filter* on the lower part is replaced. The air filter compartment is disinfected, washed and dried before new filter is inserted.
 - (e) *Inner mechanical/electronic parts in the lower part.* The entire incubator, including heating element, can be decontaminated and cleaned except for the lower part. After special and unusual infection, the incubator is sent to service for gas sterilization of internal mechanical/electronic parts.
 - (f) After disinfection, wash the incubator with soap and water.
 - (g) Wipe all parts thoroughly before reassembling.
 - (h) The entire incubator is finally disinfected with wipes (not necessary with the parts that have been in the decontaminator). This is to remove the last residue of chloramine.
 - (i) Assemble the incubator, replace clean laundry, and store it, covered on a clean room.
4. Incubator: technical service
- Inform service personnel about the possibility of infection from incubator.
 - Regular service once a year where the entire incubator, including the lower part, is opened, cleaned and decontaminated. Cleaning and rinsing of electronics, etc. (medical technical department).
 - After special and unusual infection, the incubator is sent to service for gas sterilization of internal mechanical/electronic parts. Consider special service after serious infection.
 - The air filter is changed after 2 months and always after infection.

44.4.17 Disinfection Room

Good space and clear distinction between clean and unclean areas. See chapter on disinfection room. Routine control of machines, concerning temperature and quality of cleaning. The room should not be storage space for clean equipment.

44.4.18 Textile, Room and Clean Laundry

Limited access, no through passage, good daily cleaning, no unauthorized storage, the door closed. Refill of new laundry from corridor. Good space to avoid pollution of laundry when working in the room and no storage on the floor. Wash/disinfect hands before handling laundry. Repeated infections have been reported among newborns, associated with “clean” textiles contaminated with bacteria or fungi [35, 36].

44.4.19 Sterile Store Room

Sterile disposables are stored in cabinets with glass door for the overview, with limited access. The room should be cleaned daily.

44.4.20 Clean Store Room for Clean Equipment

Limited access, no through passage, good daily cleaning, no unauthorized storage, the door closed. Unclean equipment should not be stored here.

44.4.21 Clean Store Room for Large Equipment

For storage of clean incubators, cleaned equipment for intravenous treatment, respirator treatment, ultrasonic devices, etc. All equipments should be thoroughly cleaned between each patient and stored clean, preferably covered. Do not use store rooms for unauthorized items or as “office”.

44.4.22 Isolates for Infectious Agents

The department must have isolates for contact and air isolation, 10–25% of the bed capacity. In case of insufficient isolation systems, this must be solved by isolation at other departments. Isolation reduces the infection pressure in the ward. The infected patient is taken care of by a separate team that preferably are not in contact with other patients (which increases the risk of cross infection in the department) [1, 14]. Isolation is required for MRSA, VRE, EHEC, ESBL and other resistant bacteria, salmonella and other intestinal pathogens, norovirus, rotavirus, RSV, influenza virus, CMV, varicella, etc. and blood-borne viruses (hepatitis A, B, C, E, HIV, HTLV, etc.).

See chapter on isolation regimes.

44.4.23 Infection Protection and Vaccines for Personnel

See separate chapter.

44.4.24 Need for Personnel in Relation to the Number of Patients: Patient/Nurse Ratio

New-born intensive patients have a minimum need for two competent nurses per patient. The patient is continuously monitored—in place—at the incubator (not via a ward office) on a 24-h basis, by two nurses [1, 14]. Small changes in the patient

can lead to a dramatic worsening of the condition; if not, measures are done immediately.

Understaffing leads to overcrowding and mixing of patient categories, less skilled personnel, temporary workers, increased work stress, reduced hand hygiene and failing infection control [1, 14–20, 37]. In such situations, the risk of serious nosocomial infections may increase up to 16 times (!); and the risk of death increases markedly [1, 9, 14–20].

44.4.25 Needs for Areal in NICUs

Single patient room is recommended. Today, the pressure of infections is high, the visitor pressure is as large/increasing, and the ward most often lacks an overview of the infection of the visitors. Good area space and single rooms are therefore important for each patient.

- *Overcrowding and concentration of beds* on small common areas are not consistent with good infection protection or safe treatment [1, 14, 16]. It increases the risk of infection via air and contacts with more patients in the same room, common equipment, etc. and leads to reduced infection control [1, 9, 14, 15, 37, 38].
- *Patient areal for new-born on intensive and intermediate rooms* should be 20–25 m². For each patient there is a need for good ventilation, room for bed/incubator, two personnel continuously present, two parents, mechanical examination equipment, respirator, intravascular equipment, surveillance equipment, closet space, drug table/cabinet, care table, treatment table, washbasin (2–3 m from incubator/clean equipment), space for waste and hanging upgowns, etc. There should be 2 m of free area around the bed/incubator to avoid unnecessary contact and to lower the load of contamination.
- “Growth area” room for larger, not directly intensive patients: 20 m² for each patient with the same area and content requirements as above. Each patient should have his room. In addition, there should be a handicap toilet attached to each room.
- *Medicine room:* 10–16 m².
- *Storage room:* approximately 16 m² large, separate rooms for sterile equipment, clean equipment, medical equipment, auxiliary equipment, incubators, beds, textiles, sterile liquids, milk kitchens, food storage, etc. Each storage room should be at least 16 m² to ensure free access without getting into or contaminating equipment.
- *Disinfection room:* approximately 16 m² or more, with machines for decontamination and instrument washing.
- *Disinfection room for incubators:* approximately 16 m² with special air outlet.
- *Storage room for equipment for incubators:* approximately 16 m².
- *Talk space room:* 12 m².
- *Examination/treatment room:* approximately 16 m².
- *Ward office for all employees*—adapted number.

- *Entrance and dressing rooms for employees with wardrobes, textile room and toilet/shower.*
 - *Wardrobes for family and visitors with toilet.*
 - *Toilet for the staff.*
-

44.5 Background Information

There are major advances in reducing infections in premature and new-borns. In the United States, the state-wide study of new-born-intensive departments (NICU and PICU) shows that in the period 2007–2012, blood-borne infections were reduced from 4.9 to 1.5 per 1000 central catheter days and VAP was reduced from 1.6 to 0, 6 per 1000 ventilator days, while catheter-associated UVI was unchanged [6].

44.5.1 Intrauterine and “Congenital” Infections

At birth, most children are “sterile” except for microbes in the birth canal or by too early amnion rupture with retrograde growth from the vagina. Premature has an “immature immune system” and therefore a reduced resistance to infections [1–6, 13].

Some have an intrauterine or “congenital” infection with or without symptoms such as group B streptococci, *Escherichia coli*, cytomegalovirus, herpes simplex, toxoplasmosis, varicella, etc., and some are treated because of hepatitis B and C or HIV in the mother [39–42]. Diagnostics in new-borns can be difficult [40, 41]. In Norway, intrauterine infectious disease is relatively rare.

An unusual early infection is a fatal course of legionella after water birth [43]. Legionella and other bacteria may be heat-tolerant (65–75 °C) and are found periodically or stationary in normal drinking water/bathing water. In hospitals and other healthcare institutions, a proper control of legionella is required to prevent legionella infection which can cause severe sepsis, pneumonia and fulminant disease, especially in susceptible cases like premature and new-borns.

44.5.2 Nosocomial Infections

Intensive treatment of new-borns and premature opens several pathways to sterile areas/sterile tissues/mucous membranes of the child as *intravascular* access for nutrition, fluid treatment and measurements, intubation of *airway* for ventilation assistance and probing in the *ventricle* for nutrition and measuring equipment. In addition, a variety of blood samples are taken outside catheter systems, and monitoring systems are established on the skin (temperature, oxygen saturation and more).

After birth, nosocomial, bacterial infections are of importance: *S aureus* and coagulase-negative staphylococci, enterococci, group B streptococci, *E coli* and a variety of other gram-negative rod bacteria, especially those that thrive in the environment or in water and liquids [41]. Among viruses, different enteroviruses may

cause minor epidemics, while RSV, influenza and rotavirus are rare in this patient group [40, 42].

Group B streptococci (GBS) have a special position since it may be “intrauterine” infection and a nosocomial infection, “early onset” from mother and “late onset” from environmental contamination [44–48]. It is tissue invasive and causes severe sepsis, pneumonia, meningitis, arthritis, osteomyelitis, etc. [44]. Screening for GBS colonization during pregnancy is often recommended in weeks 35–37, one sample from the vagina and one from the rectum [45–48]. CDC and others have made good algorithms for how to handle pregnant colonized with GBS [46–48].

About every fifth premature with low weight, less than 1500 g, are expected to develop neonatal sepsis more than 3 days after birth (“late onset”) [44, 49, 50]. More than half of these infections are caused by coagulase-negative staphylococci, with a mortality rate of 9% [49, 50]. Most strains are *S. epidermidis*, but many others of about 20 different types of staphylococci can cause fatal infections in the low-weight premature [49]. New-borns are rapidly colonized by resistant white staphylococci from the environment in NICUs, and these usually come from the staff and from the equipment, less often from mother. One study found that new-born sepsis was associated with identical staphylococci in the employees’ hands in over 60% and that such “endemic” strains might persist in the environment for many years [49–52].

Risks of infection after colonization with possible pathogenic microbes are low birth weight, central venous catheter, umbilical intravenous catheter, respirator and total parenteral nutrition—especially lipid-containing products [7, 9, 10, 30, 49]. Symptoms of bacteraemias are usually vague. Staphylococci are also cause of pneumonia, urinary tract infections, skin infections, meningitis and necrotizing gastroenteritis in new-borns and premature [49, 52, 53].

Coagulase-negative staphylococci are normal skin flora and abundant in all other age groups, including healthcare professionals, and may cause clinical disease [54]. Therefore, it is important that the premature, immature child is protected in the first difficult phase of life against the staff’s skin flora, environmental flora and equipment flora [49]. Proper and thorough hygiene and infection control at the level of an operation department are measures that can reduce contamination and severe infections.

44.5.3 Environmental Spread of Infection

Premature are exposed to many external agents from the environment by care and feeding, from the microenvironment in the incubator, from hands, equipment, cloth, exploration equipment, etc. [15, 55–57].

Mobile phones may be a substantial reservoir for neonatal pathogenic microbes. A study of 50 phones on a NICU ward in Italy showed that among 22 doctors, 19 nurses and 9 medical students, 86% of the phones were contaminated with 66 different bacteria and students had more microbes on their mobile phones than other healthcare professionals [55]. More than two thirds of the microbes were coagulase-negative staphylococci, 8% was MRSA and over 10% were gram-negative bacteria

[55]. This and many other studies show that it is necessary to disinfect personal equipment such as mobile phones and other equipment (stethoscope, tourniquet, ID card hanging around the neck, etc.) to reduce the infection pressure in the department [55].

In Belgium, there were 9900 patients in NICU wards followed up during a 20-year period, 1992–2011 [58]. Nosocomial sepsis was present in 6.9% of the cases with a mortality rate of 9.7%. More than 60% were caused by coagulase-negative staphylococci. There was a significant increase of nosocomial neonatal sepsis caused by *S. aureus* during the last 10 years [58].

During a 6-month period in 2008, the NICU ward at Ullevål University Hospital, Oslo, had at least 15 patients with serious infections (sepsis, pneumonia, wound infections) with *S. aureus* resistant to gentamicin, erythromycin and clindamycin [15]. The same strain was detected in a number of environmental samples from care tables, treatment tables, medicine cabinets, beds and equipment in the unit [15].

Gentamicin was the “standard therapy” in the department, given to most patients [15]. It became apparent that *S. aureus* isolates from the NICU were not tested for susceptibility to gentamicin—as “a routine” on the microbiological laboratory! [15]. No one on the NICU ward asked the laboratory concerning gentamicin susceptibility of this clinical strain of *S. aureus*. This “misunderstanding” on both sides resulted in a continuation of the outbreak over time. The physicians at the NICU were not aware that they treated a gentamicin-resistant *S. aureus* strain with gentamicin! The outbreak stopped immediately after infection control personnel were involved and made measures, like isolation of infected patients, disinfection of rooms and equipment, establishment of formal susceptibility testing of *S. aureus* by the microbiology laboratory and training and reviewing practices in hygiene and infection control for the staff at the NICU (Andersen BM, personal information).

MRSA is a recurring problem in neonatal units [14]. In the UK and Ireland, 46% of all MRSA-related sepsis cases are found among children in neonatal wards [59]. An Irish national study showed that all new-born intensive units had a MRSA screening policy [59]. All children were screened for multiple anatomical locations at admission and mostly also after 1 week, and all made attempts to isolate patients, in spite of lack of good isolation conditions [59]. In a study from NICU in Japan, all new-borns were isolated on admission, tested, and further isolated if MRSA was positive [60]. This resulted in a significant reduction of the spread of infection in the hospital (HA-MRSA) from 3.5/1000 to 1.3/1000 patient days ($p < 0.0001$) [60]. See the chapter on MRSA.

A number of infectious outbreaks have been described [11, 14, 15, 61–66]. A Swedish study revealed 11 neonatal sepsis patients and 47 colonized patients with *Serratia marcescens* [63]. Prematurity, low weight, using a catheter and some failure to carry out hygiene measures were probably related to the outbreak that was repeating over time [63]. A similar outbreak with probably more than ten deaths of *Serratia marcescens* infection during 2 days in Honduras resulted in that a neonatal unit was closed [64]. This shows how difficult it is often to prevent infections in new-born intensive care units if there is a lack of systematic routines for hygiene and infection control.

44.5.4 Overcrowding and Understaffing

Neonatal intensive departments have often few resources, are heavily understaffed with a high patient density and have often lack of competent personnel, which increases risk of infection [1, 9, 14–20, 52]. The trend today is increased number of part-time workers that work at several health locations during the same period and bring with them microbes between healthcare institutions. Part-time work may also result in lack of follow-up routines and guidelines in the NICU or using a mixture of routines from different hospitals. Understaffing leads to increased patient density, putting different patient categories with microbes/infections in smaller areas during nights and holidays, and understaffing increases work stress, reduces time for hand hygiene and develops lack of infection control [1, 14–20, 37]. The risk of serious nosocomial infections may increase up to 16 times, and the risk of death may increase markedly, during such situations [1, 9, 14–20, 37].

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Abstract

Intensive care units (ICUs) are treating hospital's poorest patients that need medical assistance during the most extreme period of their life. Intensive patients are treated with extensive invasive procedures, which may cause a risk of hospital infections in 10–30% of the cases. More than half of these infections can be prevented. The patients are often admitted directly from outside the hospital or from abroad with trauma after accidents, serious heart and lung conditions, sepsis and other life-threatening diseases. Infection or carrier state of microbes is often unknown on arrival and poses a risk of transmission to other patients, personnel and the environment. Patients that are transferred between different healthcare levels and institutions with unknown infection may be a particular risk for other patients. In spite of the serious state of the patients, many ICUs have few resources and are overcrowded and understaffed, with a lack of competent personnel. ICU should have a large enough area and be designed, furnished and staffed for a good, safe and effective infection control. The following chapter is focused on practical measures to reduce the incidence of infections among ICU patients.

Keywords

Intensive patient · ICU · Nosocomial infections · Infection control · Hygiene Prevention

45.1 Purpose

Prevent nosocomial infection during intensive patient care.

45.2 Comprise

All patients treated in intensive care units (ICUs) and personnel working in the intensive care units.

45.3 Responsibility

The hospital's management should provide resources and written guidelines regarding infection control work, proper patient/care ratio, sufficient patient areas, isolation capacity and documented competence.

The departmental management should provide competent personnel that follow guidelines. In circumstances that expose patients to increased infection risk, this is reported to the director immediately.

The staff follows routines. Expertise and practice in intensive medicine must be documented. It should be reported to the management if exposed to or infected by resistant or special microbes, for example, in work at other departments/countries.

The patient and relatives/visitors should be informed about the department's routines, hand hygiene and good personal hygiene and cleanliness.

45.4 Practical Measures

Intensive care unit (ICU) should have a large enough area and furnished for a good, safe and effective infection protection [1]. The state of infection or carrier state is often unknown on arrival and poses a risk of infection to other patients, personnel and the environment [2–15]. Patients transferred between healthcare levels and healthcare networks may spread infections [12–16].

Note! Comprehensive responsibility! There must be *one* responsible department/unit manager who has total responsibility for patients, personnel and the environment—in terms of infection control and patient protection. Fragmentary leadership means that no one has direct responsibility for the patient's security and prevention of infection.

1. *Hygienic standard* should correspond to an operation department—to reduce the number of infections, the use of antibacterial agents and resistance development. Employees should carry out a good personal hygiene (see personal hygiene and regimes for isolation, Chap. 6 and 6–14).
2. *Separate patient rooms are recommended.* This is due to the many direct openings into sterile tissues, via respirator, intravascular catheters, urinary tract catheter, surgical site and other wounds. All intensive patients should be protected against infections from other patients, personnel and the environment [1, 17]. When sharing a room with a fellow patient, the distance between the patients must be 3–4 m from bed edge to bed side, and no one must have infections.

3. *Medical technical equipment* associated with every intensive bed take a lot of space in the room, generates dust, particles and heat and are easily contaminated with skin particles and bacteria. Written cleaning procedures must be available for all equipment.
4. *The burden* of bacteria, particles and other organic materials from the use of respirators, cough/suctions and particles from opening single-use equipment needs good room ventilation, preferably more than ten air exchanges/hour and control of bacterial numbers in the air, <100 CFU/m³. The air should enter the ceiling level and be filtered by 99% effective filter with particle diameter max 5 µm. Exhaust air is extracted approximately 15 cm above floor level (opposite side). Avoid turbulence, shaking of clothes, abrupt removal of bandages, etc. that increase the amount of bacteria in the air [7].
5. *Hand hygiene* is routinely enjoined for all personnel. Proper use of hand disinfectants and gloves is important. Non-sterile gloves often have a rich growth of environmental flora and *do not* protect the patient. Jewellery, piercing and wristwatches are not allowed since this collects microbes and inhibits personal hygiene/hand hygiene. Patient and visitor's hand hygiene routines will usually be the same in the hospital [18].
6. *Coats and outerwear* are taken off outside the unit.
7. *Glove box* for each patient, set date, and throw the box when the treatment ends.
8. *Water control*. Avoid splashes and aerosols from the sinks that are often colonized with gram-negative rods, and check the water for *Legionella* and other gram-negative bacteria (see *Legionella* and water control) [8, 9, 19].
 - (a) *Cooling systems, water coolers and large water reservoirs* are linked to the outbreak of *Legionella* and resistant gram-negative rod bacteria [20]. Use sterile water for intensive care patients for oral hygiene.
 - (b) *Biofilm formation* in water systems, on surfaces, etc. is increasing. Preventative measures are good such as daily cleaning with soap and water and disinfecting with chlorine or peracetic acid [19–21]. Biofilm can be resistant to chlorine [21].
9. *Clean work uniform*; change every day or more often if necessary.
 - (a) Separate gown for each patient—long arms and cuffs. The gown is changed for each shift or more frequently if contaminated.
 - (b) Cap/surgical mask and visor are used by work with respiratory tract (respirator), intravascular catheter, surgical wound, drain, urinary tract catheter.
10. *Cleanliness and order* to reduce biological burden in the environment and to reduce the risk to the patient. Good daily cleaning removes possible pathogenic flora fairly quickly. Good cleaning depends on good space and order. Large amounts of skin waste, hair and microbes are released continuously from people in the room—and fall down as grey “dust” on all surfaces after the floating state in the air—and carry invisible amounts of bacteria. In addition, there may be huge amounts of particle release from all disposable devices that are opened.
 - (a) All patient rooms, service rooms, guard rooms, wardrobes, etc. must be cleaned at least once a day with soap and water.
 - (b) The washbasin is washed and disinfected daily [19].

- (c) All horizontal surfaces in patient rooms are washed daily.
- (d) In order to carry out proper cleaning on surfaces, shelves and cabinets, only necessary equipment, clothes, etc. should be present.
- (e) All cabinets in the patient room/intensive room are cleaned weekly.
- (f) There should be no stockholding in patient rooms, except for what is needed for today's use.
- (g) Toilets are cleaned $\times 2$. See cleaning chapter.
- (h) After use to a patient, everything in the closet must be discarded, and the cabinet should be thoroughly washed.
 - (i) Cabinets and shelves in service rooms must be cleaned once a month.
 - (j) All equipment must be cleaned after each use and before it is stored.
- (k) PCs, telephones, data in the patient room and the like should be washed over after each shift; if necessary put on a new plastic bag for each shift.
- (l) Main cleaning two times a year.

Disinfect mobile phones, glasses, etc. and all other equipment *before* being brought into the ICU.

Note! Persons who perform room cleaning should not work with patients at the same time. This is to avoid cross infection.

11. *Medical technical equipment* must be cleaned outside daily, when the treatment is completed and when it is going to enter or leave the department. It must also be cleaned inside after infection and after certain periods of use or after each use. All equipment is stored clean and dry, preferably with a clean chapel, on a separate clean storage.
12. *Sterile equipment* is stored clean and dry on a separate storage for sterile equipment with requirements of low bacterial numbers in the air.
13. *Respiratory treatment*: see separate chapters.
14. *Intravascular treatment*: see separate chapters [22–26].
15. *Urinary tract infection preventive treatment*: see separate chapter.
16. *All drains, catheters, surgical wounds, other wounds, etc.* should be treated sterile with closed drainage (if use of drainage); see separate chapters.
17. *Isolates*: the ICU must have sufficient number of good isolates for contact- and airborne infections. See isolation regimes Chaps. 14–21.
18. *Isolation* is performed if uncontrolled wound secretion (pus), or suspected contact- or air transmission; MRSA, VRE, GAS (Group A streptococci), meningococci, ESBL, EHEC, *Pseudomonas*, *Acinetobacter*, *Serratia* and other resistant bacteria, TBC, *Clostridium difficile*, gastrointestinal pathogenic bacteria and viruses (norovirus etc.) and airway pathogenic bacteria or - viruses (influenza virus, etc.); see isolation regimes.
19. *Define contaminated waste*, and review procedures for removing such waste.
20. *Disinfection room* with decontaminator and instrument washing machine is checked weekly.
21. *Patients* should be on a single room (25 m^2 per bed)/isolated from each other, for example, using “glass cages” (see point 2).

45.4.1 Need for Personnel:Patient/Nurse Ratio, 1:2

There is estimated at least two competent intensive care nurses per patient. The ICU patient is monitored continuously—in place—at the bed (not via ward room) on a 24-h basis. Small changes in the patient can lead to a dramatic worsening of the condition if not detected early enough.

Understaffing leads to less competent personnel and temporary workers, increased stress in the work situation, reduced hand hygiene and lack of infection control [5]. This increases the risk of serious nosocomial infection and fatal outcome. Understaffing and overcrowding will also expose personnel and visitors to increased risk of infection [5].

45.5 Background Information

The ICU should be large enough to cover demographic needs, operational activity and specialty in the coverage area [1, 10, 11]. The department should be functional with ample space for each patient, necessary number of isolates, good ventilation, service rooms and storage space. The department must be prepared for good infection control, hand hygiene and a thorough cleaning system [1, 10, 11].

45.5.1 Nosocomial Infections at Intensive

Patient groups vary according to type of intensive care unit: surgically intensive, medical intensive, child intensive or a blend of patient categories.

- In Germany, nosocomial infections were detected in 9.4% of 1860 ICU patients, and after discharge, the rate increased to 10.6% [27]. Without follow-up afterwards, 12% of ICU-associated infections were not recorded [27].
- In Belgium, there were 6500 ICU patients examined in 2010 [28]. Nosocomial pneumonia and ventilator-associated pneumonia (VAP) starting in the ICU were 13/1000 and 12/1000 patient days, respectively, and ICU-associated blood infections were 3.2/1000 patient days. During the period 1997–2010, ICU-associated infections increased, while infections related to equipment (respirator, catheter) were reduced [28]. In 2010, at least 31% of adult ICU patients had nosocomial infections [29].
- Later studies showed that more than 10% of ICU patients had infections like VAP and catheter-associated infections [30]. Among 78, 200 patients with more than 2 days of stay in 525 ICUs in 6 European countries from 2005 to 2008, it was estimated that 52% of the VAP cases and 69% of bloodstream infections could be prevented [30].
- Intensive studies in the United States show that 65–70% of catheter-associated blood and urinary tract infections can be prevented and 55% of cases of VAP and postoperative wound infections [31].

- The American network study (2013) of catheter-associated intravascular and urinary tract infections, VAP and postoperative wound infections showed that these four infection categories caused 70,000 hospital infections per year, and it was found at least 81,000 pathogenic microbes in these patients [32]. Nearly 20% of the microbes were multidrug-resistant organisms (MDRO) like MRSA, VRE, ESBL and CRE isolates [32].

45.5.2 Intensive Beds and Nosocomial Infections in Norway

- In 2010, ca. 300 general intensive beds were registered at 44 hospital ICUs in Norway (five million inhabitants) [33]. In 2013 it was about 15, 200 ICU treatments and approximately 60,300 days of intensive care in Norway are distributed between local hospitals 28.6%; central hospitals, 34.5%; and regional hospitals, 36.9% [34].
- More than half of the patients were on respiratory treatment, average stay in the ICU was 4 days, and 82.8% were discharged from hospital, while 11% died on the ICU and 6.2% on other wards [34].
- There is a calculated need for about 11 ICU beds per 100,000 inhabitants [35]. Calculated from today's approximately 350 intensive beds, this amounts to 5.8/100,000.
- In 2015, the prevalence of hospital infections in the Norwegian ICUs was 23% in surgical ICU/postoperative ward (218 beds) and 11.5% in medical ICU/ward of monitoring (192 beds) [36]. About the same results were recorded in 2013 [36].
- Hospital infections and mortality are high in Norwegian ICUs, especially in surgical ICUs. Since postoperative beds are included in the number registered for intensive, the real number of hospital infections is probably much higher. The costs are uncertain but probably amounts to at least 36,000 NKR per day for regular intensive care. The presence of resistant microbes in Norwegian ICUs is unknown but probably an increasing problem.
- There are still too few ICU beds in Norway—maybe only half of what is needed—and this can lead to unnecessary disease and death [35]. Every 6th (17%) ICU patient died on intensive or afterwards on ward in 2013 [34]. The risk of death in ICU is therefore very high.

45.5.3 General Risk Factors for Infection in ICU

- Many entry ports through skin/mucous membranes (trauma, surgical procedure, respirator, etc.).
- Flat bed rest over time.
- Reduced immunity to infections, impaired general condition.
- Many procedures and a lot of handling of the patient.
- Much instrumentation.
- Acute care procedures.

- H-2 blockers with gastric colonization of gram-negative bacteria from the gut.
- Aspiration of stomach contents.
- Short distance between patients—high patient density and overcrowded.
- Many patients in the same room, open care—“dormitory” [2, 3, 17].
- Mixing of potentially infected patients with non-infected patients.
- Lack of isolates/single rooms and cross infection [1–3, 37].
- Poor cleaning, lack of hygiene measures and lack of follow-up of hygiene guidelines [6, 38].
- Environmental contamination [4, 6].
 - Contaminated water [8, 9].
 - Biofilm formation with microbe growth in water, on surfaces and equipment [20, 21].
 - Contaminated textiles.
 - Contaminated/unsterile equipment and liquids [38].
 - Contaminated patient room [39].
- Large consumption of antibacterial agents.
 - The use of multi-dose vials instead of single-dose.
- Large nursing load on few nurses, patient/nurse ratio—understaffing [5].
 - Short-term employed and a high personnel turnover [5].
 - Lack of knowledge, experience and use of written routines, large number of part-time workers and many “leaders” in the system.
- Number of days in hospital > 7 days; transferral of the patient between several departments and undergone at least one invasive procedure.
- Transport between departments and hospitals [15].

45.5.4 Special Risk Factors/Procedures

- *Airborne-droplet-borne infection:*
 - Bacteria like *S. aureus* (including MRSA), tuberculosis, gram-negative bacteria, pneumococci, meningococci, etc.
 - Respiratory virus like influenza, RSV, metapneumovirus, parainfluenza virus, bocavirus, etc.
 - Exanthema virus like varicella, mumps, morbilli, rubella, enterovirus, parvovirus, etc.
 - Diarrhoea virus—special highly transmissible like noro-, sapo-, boca- and coronavirus, etc.
- Mechanical ventilation [40–42]. See separate chapter.
- *Aerosol* from contaminated nebulizer and other respiratory equipment.
- *Aerosol/re-aerosol* from change of bed linen, making the bed and other activities [7].
- *Tracheal suction/coughing.*
- Oral hygiene—lack of [43].
- Intravascular treatment, haemodialysis, peritoneal dialysis, etc. [22–26, 44].
- Drainages and urinary tract catheters.

- Prolonged use of antibiotics and increasing bacterial resistance [42, 45].
- Personnel with infection/carrier state—without knowing—“cloud” personnel [46].
- Lack of tuberculosis control.

The greatest risk of infection is the number of days in the ICU and respiratory treatment (see separate chapter concerning VAP). The ICU patients have often complicating infections that lead to increased use of broad-spectrum antibacterial agents, which in turn often lead to resistant microbes. The patients’ microbes become environmental, robust microbes that may be transmitted to the lungs, blood or wounds of room-mates. The accumulation of robust environmental microbes and bacterial-bearing dust (gram-negative rods, staphylococci and fungi), over time, is a great risk that may be removed only by good daily cleaning and environmental control.

45.5.5 Important Microbes in the ICU

Occasionally, patients bring serious infections or infectious agents to the hospital and the ICU; multi-drug resistant organisms (MDRO) such as MRSA, VRE, ESBL, EHEC (entero-haemorrhagic *E. coli*, may be ESBL at the same time), CRE (carbapenemase-producing/resistant *Enterobacteriaceae*). A number of others are introduced periodically in the department like norovirus and influenzae.

The most common infections in ICUs are caused by *S. aureus*, *E. coli*, *Enterobacter*, *Pseudomonas*, *Klebsiella*, *Serratia*, *Acinetobacter*, *Stenotrophomonas*, *Burkholderia cepacia*, *Enterococcus*, *Clostridium difficile*, coagulase-negative staphylococci and *Candida*. During the stay in the ICU, the early infections are often with “common” bacteria like staphylococci, and the later infections after longer stay in the ICU are caused by more resistant bacteria like *Pseudomonas* and fungi. In Sweden, an increased incidence of invasive *Haemophilus influenzae*, non-type b, has been reported, with more than one third being treated at the ICU for septic shock [47].

Group A streptococci (GAS) are epidemic in a number of countries and constitute an important intensive treatment and infection problem. In England, there was registered 14,000 GAS cases in 2014—the highest number of the past 50 years of scarlet fever [48]. Healthcare professionals can become carriers of GAS, and the infection can spread through air [46, 49, 50].

45.5.6 Most Microbes May Become Airborne

Bacteria that are transmitted via direct inhalation, swirling of dust or aerosols are GAS, staphylococci, MRSA, meningococci, pneumococci, pertussis bacteria, diphtheria bacteria, EHEC, *Acinetobacter*, *Legionella*, *Pseudomonas*, *Clostridium difficile* (spores), *Mycobacterium tuberculosis* and other mycobacteria, *Nocardia* and a variety of other bacteria [46, 49–53].

Virus that is nosocomial through the air is respiratory virus (RSV, influenza, parainfluenza, rhinovirus, corona-, adeno-, entero-, parecho-, metapneumovirus), varicella-zoster virus, rubella, morbilli, norovirus, sapovirus, etc. [51]. Spores of fungi from *Aspergillus* and similar fungus types are liberated easily into the air and causes severe systemic infections in immunosuppressed patients [51].

45.5.7 Antibiotics and Resistance in ICU

Antibiotic resistance has increased dramatically over the past 20 years, and a large proportion of these occur in ICU departments with severe infectious disease [54–58].

New types of resistance appear as CRE (carbapenem resistant), *Enterobacteriaceae*: XDR (extensive drug resistance), *Acinetobacter* species; and totally resistant (NDM-1 and colistin resistant) gram-negative rods, extremely to totally resistant tuberculosis bacteria, and others that can cause fatal nosocomial progress, also in almost immune-competent patients [59–62]. These patients are often associated with ICU, respiratory treatment, pulmonary disease, antibiotic use and a high bacterial burden in the environment [59].

A specific “clad B” (XDR) strain of *A. baumannii* is—in the United States—a recent cause of fatal outcome of nosocomial infection in six patients: it is a highly resistant and dangerous (hypervirulent) strain [61]. Another multiresistant *A. baumannii* caused nosocomial infections in more than 19 patients, of which five died in Germany [62].

In a study from Brazil, the consumption of piperacillin-tazobactam, fluoroquinolones and cephalosporins increased at the hospital [63]. At the ICU, multi-resistance was detected in more than 30% of the cases, with increasing meropenem-resistant *Klebsiella* and *Acinetobacter* species. A significant correlation was detected between the proportion of multiresistant bacteria and the consumption of cephalosporins and fluoroquinolones [63].

Among 400 hospitalized patients in Germany, 18.5% were colonized with fluoroquinolone-resistant *E. coli* (FQREC), and this was linked to poor clinical outcomes and high mortality [56]. Stay in hospital, cancer diagnosis and the use of first-generation cephalosporin or cefepime treatment increased the incidence of new colonization with FQREC [56]. Isolation, good hygienic measures and a better antibiotic policy reduce the spread of infection. Fluoroquinolone resistance is an increasing problem since these drugs are used extensively both inside and outside hospitals [55].

Multiresistant bacteria may increase when using antibiotics in food and beverage production. An alarming occurrence of carbapenemase-producing gram-negative bacteria has been detected in food, for example, in Canada [57]. Also in Norway there are significant problems with resistant bacteria and other unfortunate agents in some food products [64].

Resistant microbes in the health system will migrate between health levels, such as either silent colonization or with infection symptoms, “the top of the iceberg”.

The real problem (the entire iceberg) is only detected by general screening and mapping of the patients [12–15]. International studies show insufficient knowledge about how to use the testing of resistance against antibiotics, also shown in a Norwegian study [65, 66]. Today, active screening of faeces/rectum samples (CRE, ESBL, VRE, (MRSA)) may be used in combination with *C. difficile* detection [67]. This has proven cost effective in ICU departments with problems with *A. baumannii* [68].

Chlorhexidine “bathing” of ICU patients to reduce infections is discussed, both for adults and children [69]. This measure is probably not so successful concerning the development of resistance as long as it is done so little for general hygiene and infection control in ICUs.

In Norway, there is increasing resistance development and outbreaks of resistant microbes such as MRSA, VRE and ESBL in hospitals, especially in recent years, but is still thought to be a “limited problem” [70].

45.5.8 Location, Area and Physical Environment at the ICU

Many ICUs around the world, including Norway, have until recently appeared like large dormitories, with mix of patient categories, no isolates and a strong understaffing in old and run-down areas. The outmost sever ill patients have often had the poorest treatment offer in the ICU of the hospitals. “Bad design, bad practices, bad bugs” is the starting point for a number of serious infection outbreaks in ICUs [71].

- *Space around the patient* is needed for different intensive equipment, nursing staff and family. Each patient should have a separate room (approximately 25 m² patient) to be protected against infection/noise/stress from the environment and other patients. Recent studies indicate that patients in separate ICU rooms will have fewer hospital infections and thus a lower risk of fatal outcome [72, 73].
- *Isolates*. Twenty-five percent of the bed capacity at intensive should be isolates with negative air pressure (16–25 Pa). The size should be at least 35 m²/isolate which includes patient room, sluice and disinfection room/toilet/shower.
- *Service room*. The unit must have service rooms/store rooms adapted to the number of intensive beds. The service rooms should be store room for single-use equipment (16 m²), medicine room (16 m²), disinfection room (needed, cross-contamination danger, 16 m²), textile room (needed, danger of cross-contamination, 16 m²) for technical equipment (respirator, infusion pumps, surveillance equipment, racks, etc., 15–20 m²), shower room for patients (4 m²) and waste disposal room (large amounts of waste, 12 m²).
- *Entrance control*. A separate sluice for entrance to the ICU with wardrobes with washbasins and disinfectants.

Note: Washbasins/sinks/shower rooms. A number of studies have documented bacterial aerosols around the sink/washbasin/shower room. A French multicentre study of 185 washbasins in 13 ICUs showed that one of three washbasins was contaminated with multiresistant ESBL gram-negative bacteria [19]. It was

recommended that washbasins should only be used for hand washing and disinfected with chlorine agents daily [19]. Washbasins, with a small fall height from opening to bottom, should therefore be placed at least 2 m from the patient to avoid aerosols.

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Cystic Fibrosis: Infections and Prevention

46

Abstract

Cystic fibrosis is a hereditary disease with repeated and chronic pulmonary infections and with a number of other complications from other organs. Patients are, at the same time, infection prone, exposed to infections, and may undergo several lower respiratory tract infections treated with antibiotics. There is a risk of becoming carriers of antibiotic-resistant microbes. Resistant bacteria are more adherent, invasive, and slime producing, form more biofilm, are more robust and have longer life in the environment than sensitive isolates. A massive nosocomial spread of antibiotic-resistant bacteria between cystic fibrosis (CF) patients in healthcare has been observed over the last 50–60 years. Infection control measures have often been absent. The measures described here are just a part of the precautions that patients with CF and attending staff must take into account. Cystic fibrosis patients should be protected against infection in the healthcare system. A number of guidelines and routines have been made specifically for these patients over the past 15 years, increasingly targeting infection prevention. This chapter is focused on practical measures to reduce the incidence of infections among CF patients.

Keywords

Cystic fibrosis (CF) · Nosocomial infections · *Pseudomonas* · *Burkholderia* · MRSA · Resistant bacteria · Infection control · Hygiene · Prevention

46.1 Purpose

- To prevent nosocomial infections in patients with cystic fibrosis [1–10].
- To prevent the development of pulmonary infections and resistant microbes in patients with cystic fibrosis.
- To prevent the transmission of microbes between CF patients, other patients, personnel, visitors or to the hospital environment.

46.2 Comprise

All CF patients, patients, hospital staff, visitors, equipment, textiles and environment in connection with admission, examination and treatment.

46.3 Responsibility

The hospital's management provides resources and written procedures for the detection, isolation and control of patients infected with specific or resistant infectious agents and ensures that CF patients are protected against infections.

The department management ensures that specific guidelines are followed and that CF patients are protected against the spread of resistant microbes from other patients and from the environment. Patients with CF and infected with specific and/or resistant infectious microbes should be isolated from other patients.

Employees should provide a safe hospital environment for CF patients—without risk of infection.

46.4 Practical Measures [3, 10]

A number of routines have been made by supervisors specifically for these patients over the past 15 years, increasingly targeting infection prevention [1–4, 8–10].

46.4.1 Admission of CF Patients

Patients with possible CF should be placed in single bedrooms, preferably with anteroom. Exposure to infection in common waiting rooms, treatment rooms, living rooms, etc. must be avoided.

1. Patients without special bacteria in the airways and asymptomatic patients with and without common respiratory flora like *H. influenzae*, *S. aureus*, *Streptococcus pneumoniae* and common gram-negative bacteria such as *E. coli*, *Klebsiella* and non-resistant *P. aeruginosa* can be admitted to CF single rooms with good air exchange (see below).
2. Patients with special bacteria in the airways like resistant mucoid *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, *Acinetobacter*, *Serratia* and other resistant gram-negative bacteria should preferably be placed on an isolate for air-/droplet-borne infections with a negative air pressure but can also be placed on a contact isolate in case of space shortage [3, 4, 10].
3. Patients with methicillin-resistant *S. aureus* (MRSA), *Burkholderia cepacia* and mycobacteria are placed on airborne isolation [2, 3, 10].

46.4.2 Information

Patients and relatives should be informed of the infection and how to prevent infection during hospital stay.

- *Hand hygiene.* Offer training in hand hygiene as needed: before and after meals, after toilet visits, cough attacks and sputum and the like. Dispensers for hand disinfectants (preferably automatic) must be readily available. Wet wipes with alcohol are good disinfectants.
- *Container for spit and expectorate.* There should be training in the use of a disposable container or vial for spit and coughs to avoid the expectorate from spilling in the sink, the toilet and the shower (where the bacteria live long). The disposable container is changed three to four times per day and thrown in waste defined as infected.
- *Reusable equipment* is washed and disinfected in machine washers/decontaminators with temperature >85 °C.
- *Isolation routines* are followed by all. Visitors come directly to the department/isolate and do not stay elsewhere in the department (common living room, etc.).
- *No self-service and pick up of clothes and equipment.* The department's service rooms are not available for patients, family or visitors. The food is to be served by the hospital staff, and textiles and equipment must be collected by the staff.
- *Surgical mask* on the patient is recommended when staying in public areas in the hospital, in order not to be exposed to environmental infections [2, 3, 11, 12].

46.4.3 Patients Without Specific Bacteria in the Airways or Asymptomatic CF, not Colonized

46.4.3.1 On Ward or Day Treatment Ward

The patient is admitted to a single room with separate toilet and shower.

Children receive schooling and play opportunities from the first day.

46.4.3.2 Patient Rooms

The room should be a spacious single room, with direct access to own toilet/shower. Fixtures, walls and floors must be of solid, smooth material that is easy to clean and that withstands regular disinfection with different disinfectants and cleaning for up to several times/week. There should be a possibility to make a negative pressure in the room and the sluice. CF rooms should have their own decontaminator (eventually throughput to the sluice) in the toilet/shower room.

Fabric furniture is removed; use only dense surface furniture that can be washed with soap and water and withstand disinfectants.

46.4.3.3 For Aerosol-Generating Medical Devices, Do Not Use Water from Tap!

Guidance varies with regard to cleaning and disinfecting respiratory equipment for patients with CF [3, 13–17]. Medical devices should have a high hygiene level for infection protection [18].

46.4.3.4 Inhalation Equipment (IE)—Nebulizer [3, 10, 13, 15–18]

- Avoid bringing own equipment to the hospital, or contact the actual department.
- If it is necessary to bring it into the hospital, clean it daily in a dishwasher at 85 °C after each inhalation. The equipment should not be taken to rooms other than the patient's own room. It is defined as contaminated.
- IE is used only for one patient.
- IE is used with aseptic technique.
- Only single-dose sterile medications for the patient are recommended [3].
- Handheld disposable nebulizers—hospital [3]:
 - *After each use*, rinse the residue with sterile water, and wipe over the mask/mouthpiece with a disinfection (alcohol) wipe. Wash the hands thoroughly afterwards.
 - Discard the nebulizer after 24 h (or after each use).
 - Pressure hoses are replaced with the nebulizer.
- Handheld reusable nebulizer (home equipment) must have more sets to use:
 - *After each use*, wash well with soap and hot water, and brush the equipment which is then heat-infected, for example, in a dishwasher/decontaminator/instrument washing machine at a minimum of 85 °C.
 - Depending on the secretion, biofilm formation and types of bacteria, evaluate disposable equipment.
 - Wash the hands between the procedures.
 - The equipment is air-dried in clean cabinet at a good distance from the sink.
 - The cabinet is wiped daily with alcohol wipes and contains only disinfected equipment.
 - Pressure hoses are treated in the same manner as above once a week or are changed weekly.
- Mechanical equipment for airway treatment:
 - Wash with soap and water daily (in hospital), and wipe over afterwards with alcohol wipes.
 - The hospital's medical technical equipment used for patients must be decontaminated—also internal parts (gas disinfection and cleaning)—after each patient, for the infection not to transfer to other patients [18, 19].
 - Note that on suspicion of mycobacteria in the patient, there is no safe method for gas disinfection [20]. Chemical disinfectants like 5% chloramine, chlorine, peracetic acid and glutaraldehyde have disinfecting effect for mycobacteria, but motors/electrical wires, etc. do not tolerate immersion in fluids.
- *Tap water—at home and in healthcare*—can contain gram-negative rod bacteria and atypical mycobacteria and a variety of other agents. Therefore, only sterile water or sterile saline is used for respiratory equipment-inhalation equipment.

- *Automatic hand disinfection* must be placed inside and outside the room, optionally disposable alcohol wipes.

46.4.3.5 Cleaning and Environmental Management

Have a good daily cleaning of all horizontal surfaces with soap and water. Use clean mops and clean washing equipment for each patient room. The environment may be heavily contaminated due to cough, sputum, etc., and the microbes may live long, even on dry surfaces [3, 10, 21–24]. Decontaminate all washing equipment between the patients.

Wash/wipe over on-off knots and other areas that are frequently touched, and disinfect with disposable alcoholic wipes afterwards. Wash the washbasin, bathroom and shower room with soap and water, and rinse/shower afterwards with warm water (75 °C). The toilet can be heavily contaminated. Work carefully to prevent scattering of drops. Close the lid on the toilet bowl before pulling down to avoid aerosol. Follow the routines for cleaning and what to wash first, from the cleanest to the dirtiest. Separate the routines for cleaning and disinfection during/after contact and air/droplet isolation. See Chaps. 14–21 on isolation routines.

Hydrogen peroxide gas disinfection is suitable for final disinfection and followed by good cleaning but cannot be used for mycobacteria [18–20].

46.4.3.6 School in Hospital for Children and Youth with CF

This should be considered for each child and should be avoided in short-term admissions. It is important to have a good daily cleaning of the school room of all the horizontal surfaces, the washbasin, the wall around, etc. The room should have good ventilation (minimum of six to eight air changes per hour). Avoid the mix of patients with other CF patients in the school class. Adults and children must be encouraged to have good hand hygiene before and after the school time.

Automatic hand disinfection must be placed inside and outside the room, optionally disposable alcohol wipes.

46.4.3.7 Playing

Playing with other children should be considered for each child and should be avoided in short-term admission. It is important to have a good daily cleaning of all toys (decontaminator), of the playroom and of all horizontal surfaces, washing, etc., and the room must be well ventilated. Toys that do not tolerate decontamination should be avoided. Toys, books, etc. that are brought in are not taken out of the patient's room. Wash toys after each use, for example, in a washing machine at 85 °C, and keep them clean and dry. Adults and children must be encouraged to have a good hand hygiene before and after playing.

Automatic hand disinfection is placed inside and outside the room, optionally disposable alcohol wipes.

46.4.3.8 Food Service

Patients without known infection and asymptomatic patients without known infection can eat with others who have normal immune systems and do not have

infections that present a risk to CF patients. It is important to have good daily cleaning of the dining room and of all horizontal surfaces, washing, etc. The room should be well ventilated (minimum of six to eight air changes per hour). All food must be in a one-time package, and buffet service must not occur due to a risk of cross infection. Certain vegetables may be contaminated with resistant gram-negative rod bacteria [25]. Adults and children must be encouraged to have a good hand hygiene before and after the meal.

Automatic hand disinfection is placed inside and outside the room, optionally disposable alcohol wipes.

46.4.3.9 Physiotherapy

Patients without known infection and asymptomatic patients without known infection may have physiotherapy in a suitable room with the possibility of negative air pressure.

- All equipment, benches, balls, mats, trampolines, etc., are thoroughly cleaned with soap and water between and after each CF patient.
- It is important to have a good daily cleaning of the room and of all horizontal surfaces, washing, etc.
- The room should be well ventilated with a minimum of six to eight air changes per hour.
- *The physiotherapist is using gown with long arms and cuff* (over hospital uniform) or is changing uniform after each treatment. Wear gloves, and perform hand hygiene before and after glove use. This generally applies to all physiotherapy treatment of CF patients. Infection can be transferred from the physiotherapist to the patient, and vice versa [26].
- *Service rooms for cleaning equipment* and storage are established with nearby *disinfection* room and storage facilities for cleaned physiotherapy requisites.
- *Automatic hand disinfection* is placed inside and outside the training room, optionally disposable alcohol wipes. Adults and children must be encouraged to have a good hand hygiene before and after physiotherapy.

Patients with known infection or carrier state with special/resistant bacteria are treated in isolation/under isolation conditions. The personnel, including physiotherapists, are following isolation routines.

46.4.3.10 Personnel Attire When Caring for CF Patients

Have a good hand hygiene before and after care/treatment of patients with CF and before and after wearing gloves. Personnel's uniform must be clean. Use patient-bound gown closed on the back with long sleeves and cuffs. The gown is hanged up *inside* the patient's room (at the door) and *inside out* in the sluice. Replace it after each shift and more often when needed. This is to avoid cross infection between patients [26].

46.4.3.11 Transport, Examination, Treatment in Other Units: X-Ray, Etc.

The patient should change to clean clothes before examination/treatment, and the bed must be clean. Use a surgical mask if coughing. The porter should have clean clothes before transporting the patient and be using hand hygiene.

46.4.4 Patients with CF and Infected or Colonized with Special/ Resistant Microbes

Patients with unusual resistant bacteria such as resistant mucoid *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, *Acinetobacter* sp., *Serratia marcescens*, *Enterobacter*, *Alcaligenes*, *ESBL*-producing bacteria and other multidrug-resistant gram-negative rod bacteria, *Clostridium difficile*, vancomycin-resistant enterococci (VRE), MRSA, mycobacteria, etc. are isolated like contact and air/droplet infections with the use of gown, gloves, surgical mask/cap and possibly room-bound shoes/shoe covers [4, 10]. See isolation routines for each individual contaminant.

Patients infected or colonized with MRSA, *Burkholderia cepacia* or mycobacteria should be placed on air/droplet isolate with negative air pressure. Routines for air and contact isolation should be followed [3, 4, 10].

46.4.5 Outpatient Clinic: Examination and Treatment

Outpatient clinics are usually open areas with common waiting zones and examination rooms for all types of patients. Infection-vulnerable patients should not come into contact with patients with infections or carrier state. Many of these infection-prone patients may also have infections and are thus a risk to others. Two patient groups need special attention for all outpatient control and treatment: oncology/haematologic/transplanted patients and CF patients, because of the increased risk of nosocomial infection.

Automatic hand disinfection is placed at the entrance of the outpatient clinic and inside and outside of all rooms, optionally disposable alcohol wipes. Everybody is encouraged to have a good hand hygiene before and after they have been to the outpatient clinic.

46.4.5.1 Which Type of CF Patients Can Be Examined/ Treated—Where?

1. Patients without special resistant bacteria and asymptomatic patients without known infection (see previous definition) are examined/treated, etc. at the outpatient clinic's defined CF room.
2. Patients infected/colonized with special/resistant respiratory tract bacteria (see previous definition) are treated/examined, etc., as other infectious patients in

rooms with isolation quality, at defined wards (childhood medicine/adult medicine). All investigations should be carried out here, possibly with transportable equipment from other units (decontaminated after use).

46.4.5.2 CF Outpatient Clinic

- Ventilation and negative air pressure:
 - Good ventilation (minimum of six to eight air changes/hour) with fresh air.
 - Negative air pressure in rooms where pulmonary function testing should be performed.
 - Weak negative air pressure (-4 to 10 Pa) in CF examination rooms relative to corridors.
 - Pressure is measured by pressure gauge and can be switched off if necessary.
- Location of the outpatient clinic for CF patients:
 - Check the location of CF polyclinic in relation to other patient categories to avoid transmission of infections.
- Examination and treatment room:
 - Minimal equipment is present in treatment rooms/examination rooms.
 - Avoid waiting time, i.e. a good logistic and treatment flow. This must be organized by the outpatient clinic.
 - All rooms must have robust washable walls and are equipped with surfaces that can withstand repeated disinfection with strong disinfectants.
 - CF patients should be examined/treated in rooms with some negative air pressure, controlled by pressure gauge.
 - PC should be covered with washable/replaceable plastic on the keyboard.
 - Do not place examination table/bed with long side along the wall due to cleaning problems.
 - *Automatic hand disinfection* must be placed inside and outside the room, optionally disposable alcohol wipes.
- Waiting room:
 - Avoid contact between CF patients and others with infections/impaired immune system.
 - Be prepared; do not let the patient wait—preferably do not use a common waiting room.
 - *Automatic hand disinfection* must be placed inside and outside the room, optionally disposable alcohol wipes.
- Disinfection room:
 - Practically designed with clean and unclean side.
 - Air extraction for cleaning and disinfecting lung function equipment that cannot be disinfected with decontamination at heat of 85 °C.
 - Disinfection rooms should always have a negative air pressure.
 - *Automatic hand disinfection* must be placed inside and outside the room, optionally disposable alcohol wipes.
- Lung function laboratory for CF patients:

Good space for all equipment and the room should not be stocked for equipment that is not in use. Only needed equipment is brought in and removed

afterwards. Woodway treadmill and similar systems take up a large part of the floor area.

- Provide adequate area, and adapt this according to new examination methods and equipment.
- Divide the equipment into two examination rooms if the area becomes too small.
- PC knots and surfaces should be covered so that it is easy to keep clean/disinfect between patients.
- Check the date of measurement of air changes per hour, preferably 14–16/h, and log the result.
- Use manometer for measuring negative air pressure in the laboratory: –10 to 16 Pa.
- Inhalation therapy should take place in a separate room; see below.
- If more CF patients are being investigated on the same day, other not infected patients should come between to not overload the environment.
- Avoid accumulation of CF patients (that patients come after each other)—infectious agents can spread in the air for a while after coughing, etc.
- Patients with distinctly resistant microbes should not enter the laboratory, and microbial test results should preferably be available before testing (note, exceptions should be discussed with CF physician).
- Patients with distinctly resistant microbes should be tested with mobile spirometry equipment in their rooms (air/droplet isolate).
- All inhalation equipment should be cleaned and disinfected between each use or be single use. Larger equipment should be decontaminated by defined procedures, and internal parts that cannot be reached by normal disinfection can be decontaminated with gas.
- *Note!* There is no gas/vapour decontamination agent that has a safe killing effect on mycobacteria. If necessary, contact hygiene personnel.
- *Good personal hygiene is important.* In case of lung function testing, airway secretion may spread in the room. Use clean uniform, gown with long sleeve and cuffs, gloves and cap/surgical mask for pulmonary function testing.
- *Automatic hand disinfection* must be placed inside and outside the room, optionally disposable alcohol wipes.
- Sampling room for expectorate, inhalation test, etc.:
 - About 12–16 m² with few equipment and easily washable surfaces that can withstand disinfectants and through-put decontaminator.
 - Negative air pressure (–10 to 16 Pa), checked every day.
 - Inhalation hood with separate air extract and disinfection of the air, checked every day.
 - *Anteroom/sludge* with plenty of space for take on and off PPE.
 - *Automatic hand disinfection* must be placed inside and outside the room, optionally disposable alcohol wipes.
- Need for cleaning (at the outpatient clinic for CF patients):
 - Thorough daily cleaning and cleaning between CF patients—surfaces and contact points are wiped over with alcohol.

- Due to the amount of equipment and the use of the lung function room, main cleaning should be carried out approx. Three to four times a year.
 - Internal parts of the apparatus and medical devices collect dust and microbes and should be gas disinfected according to the defined routines always after infection such as MRSA, VRE, multidrug-resistant bacteria, etc. [18, 19]. In mycobacteria, there is no effect [20].
 - Consideration should be given to the need for a separate cleaning assistant at the outpatient clinic who can participate in the prevention/limitation of cleaning work at the outpatient clinic.
 - Cleaning work should be organized in such a way that the environment around infection-vulnerable patients and patients with infections or carrier state is safeguarded as best as possible.
 - The cleaner must have thorough training and insight into contamination, disinfection, infection barrier, waste management and hygiene requirements.
- Fabric furniture is removed.
 - Fabric furniture is removed from examination rooms/treatment rooms/laboratories/offices or waiting rooms because they cannot be cleaned.
 - Physiotherapy:

Pulmonary physiotherapy is an important part of the treatment to remove secretion in the respiratory tract. This is associated with the spread of airborne/droplets—containing particles and microbes—to the environment, equipment, textiles, surfaces and floors. Many resistant bacteria and fungi are long-living outside the body (hours, days, months, years) and may be transmitted to other patients. It is especially important to prevent the spread of infection among patients with CF.

 - The physiotherapy room should have the possibility to establish a negative air pressure (−10 to 16 Pa, manometer), checked daily.
 - Check the air change per hour, preferably 8–12/h.
 - Same quality and requirements as in the lung function test room since play and physiotherapy are often used in combination to make the child cough, etc.
 - In special cases (suspected of resistant microbes), physiotherapy is performed in an isolate (remember contamination afterwards).
 - It is important to clean the room and all the equipment between each patient.
 - Infectious agents can disperse in the air for hours to days after coughing, etc. [27].
 - The hospital's multi-dose equipment for inhalation should be decontaminated after each use.
1. *Patients without special/resistant bacteria in the airways and asymptomatic patients* without known infection may have physiotherapy in appropriate rooms with negative air pressure and good ventilation. All equipment, benches, baller, mats, trampoline, etc., must be thoroughly cleaned with soap and water between and after each CF patient. It is important to have a good daily cleaning of the room and of all horizontal surfaces, washing, etc. Gown with long sleeves and cuff (over uniform) or clothes are changed after each treatment of CF patient. Use surgical mask, cap and gloves and perform hand hygiene before and after glove use.

2. *Patients with special respiratory tract bacteria are treated as in other isolate patients in isolates (special solutions). See isolation routines.*

46.5 Background Information

Cystic fibrosis is a hereditary disease with repeated and chronic pulmonary infections and with a number of other complications from other organs [1–3, 5–7]. Patients are infection prone and at the same time undergo several lower respiratory tract infection treatments. There is a high risk of becoming carriers of highly therapy-resistant microbes. Resistant bacteria are more adherent, invasive and slime producing, form more biofilm, are more robust and have longer life in the environment more than sensitive isolates [21, 28, 29].

A massive nosocomial spread of antibiotic-resistant bacteria between CF patients in healthcare has been observed over the last 50–60 years (Fig. 46.1). Infection control measures have often been absent. The measures described here are just a part of the precautions that patients with CF and attending staff must take into account. Special literature concerning CF is recommended [1–3]. CF guidelines may also provide good guidance for patients and staff outside hospitals [3].

Risk of infection transmission around CF patients:

- Insufficient isolation measures and use of PPE.
- Lack of environmental hygiene.
- Lack of separation of infected/not infected CF patients in hospitals and at home.
- Lack of ventilation and disinfection of the air—eventually air exchange.

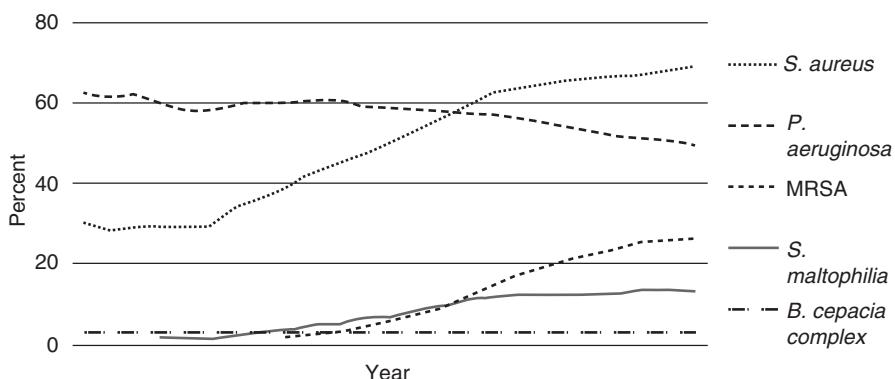


Fig. 46.1 The development of resistant microbes in samples from patients with CF in the United States in the period 1988–2012 [3]. Prevalence of *Staphylococcus aureus*, *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus* (MRSA), *Stenotrophomonas maltophilia* and *Burkholderia cepacia* complex among patients with cystic fibrosis in the United States of all ages from 1988 to 2012. These data reflect an analysis of the US Cystic Fibrosis Foundation Patient Registry. Source: Salman L, Siegel JD, LiPuma JJ et al. Infection prevention and control guideline for cystic fibrosis: 2013 update. *Infect Control Hosp Epidemiol* 2014;35: 1-67 [3]

- Water, sink, shower, drain-off, toilet; - gram-negative rods grow infinite.
- Nebulizer, other airway equipment and related medical devices are not well disinfected.
- Contact person to person: the hands, dinnerware, cups and carts are not well taken care of.
- Physiotherapy and examinations that create aerosols—droplets.
- Textiles, uniform and bedding are not hygienic treated.
- CF-associated bacteria are more environmentally robust than corresponding bacteria isolated from patients without CF [21].
- Infection with *B. cepacia* (BC) complex: serious pulmonary disease, relative with BC, epidemic strain, recent hospitalization and aerosol treatment.

Aggressive treatment of bacterial infections/lower respiratory colonization with antibacterial agents increases the quality of life and lifetime [30]. However, antibacterial treatment increases the risk of resistance development. During childhood, before antimicrobial treatments, *Staphylococcus aureus* and *Haemophilus influenzae* (non-typable) are the most current microbes. Especially, the mucoid type of *Pseudomonas aeruginosa* (PA) is associated with a progressive reduction in lung function [1, 31]. Later in life come often more resistant microorganisms, such as *Burkholderia cepacia*, *B. gladioli*, multiresistant *Pseudomonas* sp., *Klebsiella*, *Enterobacter*, *Acinetobacter*, *Serratia*, *Stenotrophomonas maltophilia* and atypical mycobacteria, *Aspergillus fumigatus* and others (fungus). The treatment must prevent infections with the least possible environmental impact.

46.5.1 Occurrence and Pathways

Pseudomonas aeruginosa (PA) poses a major environmental impact of infectious agents around CF and pulmonary infections [22, 31].

- An environmental study from 1983 showed that 51% of CF patients were infected with *Pseudomonas aeruginosa*, often the same strain throughout the CF clinic [22]. PA was detected in the air and on the hands when coughing. PA survived in dried sputum for weeks and was detected on soaps, sinks, baths, toys, tables, brushes, clothes and in the air at the CF clinic [22]. In units with isolation measures, there was a less environmental burden of PA [22].
- Elective antibacterial treatment of PA-infected CF patients in 1976–1980 led to significant *increases* of chronic *Pseudomonas* infections in CF patients, due to cross-contamination in the environment! [32].
- After the establishment of cohort isolation in 1981, the infection was significantly reduced in the period 1981–1989 and further decreased in the period 1989–1995 by the addition of early intensive treatment of PA infection [33].
- Isolation of PA patients as well as early intensive treatment postponed infections at least 7 years, reduced chronic PA courses and increased survival [32].

- A study from Norway in 2001 showed a large transmission of same type of PA between patients with CF [34].
- Staff may easily be contaminated with PA on the hands, uniforms and private clothes. Bacteria survive for more than 3 h (days and more) if hand hygiene is not well done [35].
- PA patients often have PA in the intestine—transmitted to the toilet—and may have significant environmental effect in terms of cleaning and the spread of infection [36].

Burkholderia cepacia (BC) infections are serious since the bacterium is a robust, resistant and typical long-life environmental bacterium [21]. Virulent strains have the greatest ability to invade and survive in the respiratory epithelium [28].

- Three courses are chronic asymptomatic, progressively worse over a long period or rapidly developing necrotizing pneumonia.
- Increasing incidence last 50–60 years is perhaps related to the use of *B. cepacia* as pesticides, etc. in agriculture! [11].
- BC *must* be contact- and air-isolated. Cohort with other patients with BC can make a more serious prognosis [37].
- More than 90% of BC strains found at five CF centres in the United States in 1997 were almost identical, showing a very large transmission between patients [38]. Similar studies are shown in England [39].
- Up to 40% of air samples during physiotherapy are BC-positive, i.e. airborne infection [27].
- Developing pan-resistant BC complex with at least 17 different types is an increasing problem, contaminates CF centres for many years and complicates therapy [40–42].

Stenotrophomonas maltophilia (SM) is usually found in the environment, vegetables, etc. and is seldom associated with infections [25]. It is usually “inborn” resistant to imipenem.

- SM was found in 211 of 773 CF patients; children, followed up in a year, a study from Ohio, USA [30]. Half of the patients had only one positive SM culture, while 11% were repeatedly SM positive and chronically infected with *S. maltophilia* that mostly (75–85%) were totally resistant to antibiotics. Five-year survival of SM-infected children with initial severe pulmonary status was 40%, compared to 72% for SM-negative patients. There were no defined isolation measures around these patients in 1998 [30].

Acinetobacter baumannii is an environmental bacterium. *Acinetobacter* spp. are unusually resistant and long-time survivors—months to year—in the environment even in dried state. The more resistant the strain, the greater the nosocomial risk [24].

- Pan-resistant *Acinetobacter baumannii* and other *Acinetobacter* types in patients are an increasing problem, including in Europe, and are a challenge for CF patients [43, 44].

Lung transplantation may often save these patients. Patients with totally resistant PA are optionally treated with aerosolized colistin when waiting for lung transplantation [45].

46.5.2 Infection Control

Until the middle of the 1990s, the CF disease has been treated with almost complete absence of infection protection. There has been a massive antibiotic therapy to “remedy” the many serious nosocomial infections that these patients were exposed to. Previous knowledge of infection-preventive measures around patients with tuberculosis from 1900 to beyond 1960 was completely forgotten for this group as for other weak and exposed patient groups.

Such patients should be prioritized with regard to infection protection. Also in non-CF patients, the specific CF-associated resistant bacteria can start significant epidemic outbreaks in hospitals, for example, caused by *B. cepacia* [11, 12, 46].

Strict environmental hygiene must include all medical devices for respiratory examination, treatment and other measures, as well as disinfection of internal mechanical parts that extract air, dust and microbes from the room and cannot be immersed in chemical disinfectants [18, 19].

Heat or chemical disinfection is recommended for all respiratory equipment or single use [3, 14, 17]. Tap water is not recommended due to bacterial growth. Air-drying of equipment is recommended because manual drying can lead to recontamination, and storage of equipment should have a high hygienic standard [3, 14, 17].

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Part X

Special Infections: Prevention



Abstract

Multidrug-resistant bacteria constitute a serious global threat—often as a result of dirty conditions treated with overuse of antibiotics. Dangerous microbes are easily transmitted when hygienic measures are inadequate, in the absence of isolation, and by overcrowding and understaffing. Extra costs and human suffering are related to the lack of consistency in the prevention and treatment of infections in the various levels of healthcare: poor and late diagnosis, lack of isolation measures and hygiene and incorrect use of antibacterial agents. Good infection control is linked to good hygiene, prosperity and security and breaks down quickly during disasters and chaos and when large crowds are on the move. Travelling to tropical areas is increasingly causing febrile diseases, by bacteria, viruses or parasites, depending on destination. More and more import-microbes are spread in healthcare and in society as a whole—and among animals by food and contact. Cross-infection occurs internally and between the different levels of healthcare, which can be avoided by good early information, good infectious protection and good disinfection and clearing of environmental contamination. Little by little new or emerging pathogenic microbes are becoming part of the regular human pathogenic flora in most countries and also in Scandinavia. These infections are creating carrier conditions and lead to increased mortality and costs in the healthcare. The following chapter is focused on practical measures to prevent early transmission of infections from patients before and at admittances in hospitals.

Keywords

Imported infections · Admittances in hospital · Pre-examination · Information Isolation · Nosocomial infections · Resistant bacteria · Dangerous virus Infection control · Hygiene · Prevention

47.1 Purpose

Prevent transmission of multidrug-resistant bacteria and other contagious agents to patients, visitors, staff, equipment and/or environment:

- By pre-examination and information concerning infection—in advance—before admittance.
 - By prepared procedures for early infection control [1–3].
-

47.2 Comprise

All patients to be admitted, examined as outpatient, day-treated or transported in ambulances and healthcare workers inside and outside hospitals—responsible for information of possible infectious patients.

47.3 Responsibility

The hospital's management provides guidelines for advanced information about the patients for early detection and control of import infection, multidrug-resistant agents, other serious infective agents and unknown types of infection, according to the country's infection control act or existing guidelines [1, 2]. The management should also provide resources for isolation and microbiological control of patients with possible infection to protect other patients and personnel.

The department's management implements preventive measures, ensures that employees follow the hospital's routines and reports to the Director in case of lack of resources (personnel, expertise, isolates) for necessary preventive measures.

The leaders of reception, outpatient clinics, day surgery, ambulance transport, emergency services and clinics should ensure that routines are followed and report to the Director regarding non-contraceptive measures that expose patients and personnel to infection.

Doctors and nurses who receive potentially infectious patients for admission or outpatient treatment should ensure satisfactory infection control measures. If relevant, they should inform actual referring doctor and healthcare institution, concerning detection of special infections that should be followed up.

Referring doctor (primary physician) or healthcare institutions who requests admission or outpatient examination/treatment is responsible for informing about possible infection [1, 2].

47.4 Practical Measures

47.4.1 Advanced Information About Infections: Before Admittances

- *Before* admission, day surgery, outpatient clinic, ambulance transport, etc.
- Applies to patient reception, primary care, emergency care, nursing homes and other healthcare institutions.

47.4.1.1 Before/During Admission/Treatment: Pre-Examination

Ask the referring doctor, emergency personnel, patient, etc. questions like: does the patient have:

- Diarrhoea and/or vomiting—now or recently?
- Respiratory infection?
- Influenza?
- Wound infection?
- Been abroad recently?—last year?
- Been in contact with healthcare abroad—last year?
- Previously been infected with MRSA, VRE, ESBL or other resistant bacteria?
- Been exposed to (direct contact with) persons infected/carriers of MRSA or VRE last year?
- Recently been infected with resistant bacteria?

If yes:

- Treat as possible contagious in a single room/isolate until infection has been clarified (see isolation regimens Chaps. 14–21).

47.4.2 Imported Microbes and Other Microbes That Can Be Spread in Hospitals

47.4.2.1 Information, Advice and Guidance: Contact Infection Control Personnel

1. *Multidrug-resistant bacteria* that cause skin/wound infections, respiratory infections, urinary tract infections, sepsis, gastrointestinal infections, etc.:
 - MRSA (methicillin-resistant *Staphylococcus aureus*) transmitted by contact and air, from infected wounds, hands, equipment and fixtures. All persons present in the room can become carriers if not using PPE, [4] globally a common bacterial infection.
 - MRSA with vancomycin resistance (VRSA) or vancomycin intermediate resistance (VISA) is unusual today [4].
 - VRE (vancomycin-resistant enterococci) is common in many countries (the United States, Canada, Europe). Particularly *Enterococcus faecium* is resistant against vancomycin. VRE outbreak at several hospitals and nursing homes increases in Norway [5].
 - ESBL (extended-spectrum beta-lactamase-producing). Resistant, gram-negative rod bacteria with ESBL activity are increasing rapidly also in Norway, especially concerning *Escherichia coli*, *Enterobacter cloacae*, *Citrobacter* sp., *Serratia marcescens* and *Klebsiella* sp. [6].
 - Multidrug-resistant, gram-negative bacteria increase. Resistance to carbapenem (CRE), gentamicin, ciprofloxacin, etc., individually or in combinations: *Acinetobacter baumannii*, *Klebsiella oxytoca*, *Pseudomonas* sp., *Pseudomonas aeruginosa*, *Xanthomonas*, *Burkholderia cepacia*, *Stenotrophomonas maltophilia*, etc. [6].

- Penicillin-resistant pneumococci, macrolide-resistant group A streptococci and multidrug-resistant *Haemophilus influenzae* [7, 8].
 - Multidrug-resistant, therapy-resistant *Mycobacterium tuberculosis* [9, 10].
2. *Intestinal infections* with bacteria [11]:
 - *Salmonella*, *Shigella*, *Campylobacter*, *Yersinia*.
 - Enteropathogenic *Escherichia coli*, entero-haemorrhagic *E. coli* (EHEC).
 - *Clostridium difficile*—CD (toxin producing and diarrhoea).
 - *Vibrio cholerae* and other vibrios.
 3. *Protozoans* that cause intestinal infections [12]:
 - *Giardia lamblia*.
 - Cryptosporidia.
 - *Entamoeba histolytica*.
 4. *Viruses* that cause liver infections, blood and/or other infections [13]:
 - Hepatitis A, B, C, D, E and HIV and HTLV.
 5. *Viruses* that cause gastrointestinal symptoms [14]:
 - Norovirus, rotavirus, sapovirus, etc.
 6. *Viruses* which cause respiratory symptoms [15]:
 - Influenza virus, parainfluenza virus, metapneumovirus, bocaviruses, enteroviruses, RSV, adenovirus.
 7. *Fungus infections*—invasive [16].

47.4.3 Definitions and Short Versions of Measures

1. Imported infection

Patients from abroad infected/carriers with resistant and/or virulent microbes, more frequently occurring abroad than in actual country:

- Directly in isolation if admitted—until known infection status (sampling and control). Use of personal protective equipment (PPE).
- Infection prevention measures for outpatient treatment.
- In case of negative tests—no more measures (no testing of personnel etc.)
- By positive tests—continued isolation, treatment and information.
 - Information concerning infection to the patient's next and possibly previous treatment unit.
 - If detecting MRSA, recommend testing of personnel who have had *unprotected* (without using PPE), direct contact with the patient. See *MRSA for further action, Chap. 49*.

2. Known infection

Patient admitted with a known infection such as MRSA, VRE, other multidrug-resistant bacteria (ESBL, CRE, TBC, CD), etc. For MRSA, this always applies (previously infected with MRSA,—ever).

- Directly in isolation if admitted. Check infection status.
 - Infection prevention measures for outpatient treatment. Check infection status.
 - In case of negative tests—no more measures.
 - For negative tests in previous MRSA-positive patients, See MRSA for further action, Chap. 49.
 - For positive tests—continued isolation and information to the patient and to the earlier and next treatment unit. *See Chap. 49 for further action.*
3. Unknown infection, detected randomly in clinical samples or by new information

In the event of unexpected discovery of resistant or special microbes and the patient has not been isolated:

- Directly in isolation if admitted.
- Infection prevention measures for outpatient treatment.
- Disinfection of relevant rooms and surfaces exposed to the infected patients.
- Infection control measures concerning exposed patients and personnel.
- Possible infection tracing (testing) and other measures, depending on the agent.
- Information to the patient and to previous and next treatment units.
- For detected MRSA and other special agents, *see the relevant chapter.*

NB! The isolation regime should not prevent necessary diagnostics and treatment!

47.4.4 Implementation of Measures

1. Preliminary assessment of infection risk:
 - *First contact:* Ask if the patient has been treated abroad or been a carrier/infected with resistant bacteria or other infectious agents. Risk of infection is addressed by telephone (postdoctor) or outpatient *before* admission/readmission.
 - In case of elective treatment, consider postponement until infection is resolved, possibly sanitized.
 - *In case of suspected highly infectious, severe import disease or other serious contagious disease (viral haemorrhagic fever, therapy-resistant pulmonary tuberculosis, diphtheria, pest, etc.),* contact infection control personnel. Such patients should directly be in strict isolation, not through reception. (See chapters on strict isolation, highly infectious and serious import disease—PPE, bioterrorism).
2. Outpatient assessment first—if possible:
 - Determine the risk of infection and take samples.
 - Minimal equipment available in the room so that it can easily be washed afterwards.

- Staff wears surgical mask/cap, gloves and gown at all examinations and treatments.
 - The room is disinfected and washed afterwards; inform cleaning staff!
 - Responsible physician provides microbial sampling of the patient.
3. Admission in hospital and ward and suspected imported or other known infection: *isolation*
- The ward/physician in charge provides isolation.
 - Not via patient reception but directly to current isolate.
 - Personnel who follow the patient to the hospital should not enter the ward. Exceptions are immediate help or when using PPE. If personnel accompany the patient from institutions abroad, see measures for healthcare professionals, Chap. 48.
 - Personnel/companions who have been MRSA-positive, have active tuberculosis infection, are infected with known resistant microbes, or have recently had symptoms of gastrointestinal infection, etc. should not enter the ward without agreement with the ward coordinator.
 - If suspected highly infectious, *severe import illness*, see point 1.
4. Isolate for imported infection, possible pulmonary tuberculosis or known MRSA—see *isolation routines*, Chaps. 14–21. Always wear gown, gloves and surgical mask/cap when receiving the patient! The following isolate types may be used for human pathogenic infectious agents:
- *Isolate for air-/droplet-borne infections with negative air pressure.* In case of suspected pulmonary tuberculosis and other dangerous airborne agents, use respiratory protection (P3 mask) instead of surgical mask.
 - *Isolate for mainly contact-borne infections.* In case of suspected pulmonary tuberculosis, use respiratory protection (P3 mask), and transfer patient as soon as possible to isolate with negative air pressure.
 - *Single-patient room with anteroom and separate toilet/shower*—so that the patient is not using common corridor, etc. with other patients is an emergency solution. In case of suspected pulmonary tuberculosis, use respiratory protection (P3 mask) and transfer patient as soon as possible to negative air pressure isolation.
 - *Single-patient room without anteroom and/or without a separate toilet/shower* is a short-term emergency solution, but should not be used in suspected pulmonary tuberculosis. The patient should not enter the common hallway and must therefore use the mobile toilet seat in the room.
 - The *isolation* should continue until the microbiological control is negative.
 - Further *isolation* level (contact/air droplet) is determined when the infectious agent is known.
5. Immediate-help patient:
- The *isolation* regime should not prevent necessary diagnostics and treatment.
 - Other patients and personnel should not be exposed to infection.

6. Treatment, transport, operation and other activities *outside* of the isolate—*see isolation routines*:
 - Inform relevant departments that had been or should be in contact with the patient.
 - Avoid unnecessary transport, examination and treatment of the patient before a negative test response exists.
 - Put on PPE before entering the patients' room.
 - Transport (if needed) the patient in a clean, new bed with clean clothes and clean bandages. The patient uses surgical mask (optionally respiratory protection) if respiratory symptoms are present.
 - Disinfect and wash locally at the places the patient has been. Inform cleaning staff!
 - If *suspected* of high-risk infection (viral haemorrhagic fever or pulmonary tuberculosis, etc.) contact infection control personnel immediately.
 - See the *operation* department's procedures for surgical treatment of patients with infections.
7. Procedure for test sampling:
 - Wear *gloves*, surgical mask/cap and gown with cuffs, and follow routines for taking on and off the PPE.
 - Rapid *tests*, such as MRSA and flu, are used for rapid clearance of infection status and to reduce isolation time; answer after about 2 h.

7(a) *Clinical samples*

Samples from wounds/pus/tissue/blood/catheters and other relevant infectious sites. Fill out the referral and inform about “*import* infection”/resistant microbes so that the laboratory can check the profile of resistance.

- Use ordinary sterile pencil that is placed in transport medium.
- Wet the pencil in sterile water before each sampling.
- Virus testing—follow routines; use virus transport medium.
- Rapid transport to the laboratory.
- Inform the laboratory of the need for quick response and if many tests will be done (infection tracing among other patients).

7(b) *Colonization or carrier state (import, MRSA, VRE, ESBL, CRE or other microbes)*.

MRSA detection usually consists of four brush samples that can also be used for other bacteria:

- Sterile pencil in transport medium.
- Wet the pencil in sterile water before each sampling:
- One nose sample (front part of the nose floor/and internal walls, both nostrils—roll around three times in each nostrils).

- One throat sample (over the soft palate and tonsils three times).
- One from both wrists and hands (“wash” both hands and wrists).
- One from the perineum (stretches the area between the urethra and rectal openings three times).
- One from wounds/eczema/rash/scars, etc.

Record clinical information and ask for resistance profile.

7(c) *Other microbes*

- Wound/pus/expectorated specimens and samples from other relevant infection sites.
- VRE: perirectal/rectal samples.
- Imported intestinal infections or occurring in the actual country.
 - Faeces samples, possibly samples from vomiting, are sent for microbiological examination (bacteria, Clostridium difficile—toxins, viruses, parasites).
- *Mycobacterium tuberculosis*—expectorate samples for microscopy, rapid test and cultivation on suspicion of pulmonary tuberculosis.

8. Microbiological department

- Remember clinical information and ask for resistance pattern.
- In case of infection tracing, contact the microbiologist for the extent, shipment, rapid tests (MRSA, influenza, other respiratory tract infection, etc.) and rapid response procedures (by telephone).

9. Measures if detected infection

- *See routines for isolation of MRSA and other resistant bacteria, tuberculosis, gastrointestinal infections, respiratory tract infections, etc.*
- *Infection exposure?* Patient with proven infection/carrier state—not isolated from admission on—and with defined risk of transmission to the environment, personnel and other patients.
 - Infection tracing and eventually microbial screening of exposed patients and personnel (MRSA, tbc, etc.).
 - Exposed patients who have been in the same room as the infectious patients are isolated in a separate room until infection status has been clarified (norovirus, MRSA, VRE, *C difficile*, etc.).
 - Disinfection and washing are carried out in all rooms where the infectious patient has stayed.
 - Other measures are followed up by the department’s management in consultation with hygiene nurses and according to proven agents and isolation routines.

10. Isolation is lifted

- See isolation routines and chapters of special microbes.

11. Information and registering of critical infections
 - Patients with detected *MRSA* or *other resistant bacteria* may periodically be carriers/infected for one or more years (especially MRSA, resistant enterococci and gram-negative rod bacteria in the intestine).
 - Patients with proven *tuberculosis* may experience relapse if treatment is not followed up/completed and control fails.
 - The patient is advised to inform—about infective status—health professionals at the next contact or hospitalization/healthcare/primary care service.
 - Information and registration in the journal, by “flagging out” important information and good, written information to the next and possible previous treatment.
12. Follow-up and treatment of carrier status/infection

It may take some time for the patient to get rid of the infection/cARRIER status, and a few will be carriers. Continuous environmental sanitation reduces microbial load and risk of reinfection.

The carrier status is less important for the patient’s own health if in a general good condition but can affect disease progression in disease and cause infection risk to personnel and exposed patients if no effective preventive measures are taken.

- *MRSA* (see separate Chap. 49) is the only *carrier state* that is practically followed up, cleared and controlled in Norway and in some other countries in Europe. Follow up for at least 12 months after the first three test sets are negative, or according to national guidelines.
- *Other microbes*. VRE and ESBL are followed up and checked, but are not usually cleared for infection. It is recommended that multidrug-resistant gram-negative rod bacteria should be followed up as MRSA, with the exception of clearing. Many get rid of their carrier status after wound healing and completed treatment.
- *Tuberculosis*. Exposure to tuberculosis and infective status are followed up, treated and controlled according to national guidelines.

13. Marking of the journal, possibly “flagging out” of the infectious agent

47.5 Background Information

Multidrug-resistant bacteria are increasing problems [17]. Prevalence of MRSA increases both in- and outside hospitals in Norway and has also been introduced in food production [4, 17–24]. There is increasing tendency to find resistant, gram-negative rods with extended beta-lactamase resistance: ESBL and enterococci with enhanced resistance to vancomycin and similar agents, VRE [5, 6, 17, 25].

Multidrug resistance is associated with overuse of antibiotics and is easily transmitted when hygienic measures are inadequate, in the absence of isolation, and by

overcrowding and understaffing [18–30]. Unusual, multidrug-resistant/super-resistant *Acinetobacter baumannii*, *Klebsiella oxytoca*, *Pseudomonas aeruginosa*, *Burkholderia cepacia* and *Stenotrophomonas maltophilia* with infectious resistance genes (like New Delhi metallo-beta-lactamase 1, NDM-1) that spread to almost all types of gram-negative bacteria pose a serious global threat [6, 31–38]. From the 1990s on, and especially since the 2000s, resistant gram-negative bacteria have become a noticeable problem, also in Norway [6, 17, 39–41].

47.5.1 Import Increases

Good infection control is linked to good hygiene, prosperity and security and breaks down quickly during disasters and chaos and when large crowds are on the move [42].

Gastrointestinal infections often occur during international travel. Among 25,900 travellers examined after returning home, almost 30% had an infectious gastrointestinal disease, most commonly detected in women, younger travellers and regular tourists [43]. Among the clinically significant infectious agents were parasites, 65%; bacteria, 31%; and virus 3% [43].

Travelling to tropical areas is increasingly causing febrile diseases, by bacteria, viruses or parasites, depending on the destination [44]. Among 42,200 sick travellers studied in the period 2000–2010 came 26% from sub-Saharan Africa, 17% from Southeast Asia, 15% from South Central Asia and 10% from South America [45]. Intestinal infections and dengue fever increased, with clusters of malaria in Africa in 2000 and 2007, dengue fever in Thailand in 2002 and India in 2003 and salmonella infections in Nepal in 2009 [45].

In 2010, international travel activity was estimated at almost a billion tourists with a strong increase to visit developing countries [45]. More than half of those travelling to developing countries on vacation get sick, and 8–10% of these seek medical treatment during or after the trip [45].

The most serious infectious diseases are rarely imported to Norway, but an increase is recorded, especially for intestinal microbes [11, 46, 47].

47.5.2 Expenses

More and more import microbes are spread in healthcare and in the society as a whole—and among animals by food and contact. And little by little, they are becoming part of the regular human pathogenic flora in most countries and also in Scandinavia. These infections may be invalidating; they are creating carrier conditions and lead to increased mortality.

Costs—human and resources—are related to the lack of consistency in the prevention and treatment of infections in the various levels of healthcare: poor and late diagnosis, lack of isolation measures and hygiene and incorrect use of antibacterial agents [20, 24–32, 36–38, 48–51]. Cross-infection occurs internally in and between the different levels of healthcare, which can be avoided by good information, good

infectious protection and good disinfection and clearing of environmental contamination [33–39, 41, 52–59].

Good isolation measures and routines for screening and information may effectively reduce costs in all levels of healthcare, especially associated to reduce length of stay at intensive departments and fewer problems with transmission of infected patients to long-term institutions without isolates and non-competent personnel [21–25, 49–51].

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Abstract

Healthcare professionals may become sick or infected with human pathogenic microbes during travel, work and stay in other countries (imported infection) and at home. In some cases, the infection occurs nosocomial by direct or indirect work with infected patients, employees or the environment. Personnel can therefore be “sources, carriers and victims” of infection with a variety of different microbes, including MRSA. Most infections and carrier states among healthcare personnel are preventable and subclinical and may cause large outbreaks in hospitals and other healthcare institutions.

The following chapter is focused on practical measures to detect and prevent transmission of infections from healthcare personnel before and during work in healthcare institutions.

Keywords

Imported infections · Work in hospital · Pre-examination · Information
Nosocomial infections · Resistant bacteria · Dangerous virus · Infection control
Hygiene · Prevention

48.1 Purpose

Control of personnel after contact with healthcare abroad or after work in war areas, refugee camps or otherwise exposed to particularly infectious microbes:

- By pre-examination and information—in advance.
- By preparing procedures for early infection control.

48.2 Comprise

- All personnel, including students, temporary workers, visitors, etc., after contact with healthcare abroad or after work in war areas, refugee camps or otherwise exposed to particularly infectious microbes at other departments, healthcare institutions or other known infectious contacts.
 - All personnel that has direct or indirect contact with patients, examination, treatment and care, textiles, equipment, cleaning, transportation, handling food, etc.
 - Check for blood-borne virus infection (see also section on employees with infectious/carrier status).
-

48.3 Responsibility

The National Board of Health decides issues concerning preliminary examination of workers after possible exposure to antibiotic-resistant bacteria [1–9]. Practice today, for instance, in Norway, is the examination of MRSA and tuberculosis [1–9].

The hospital's management provides a control system for employment via agency and other offering personnel to the hospital and for students, temporary workers and other visitors—at the resource—and recruitment centre, corporate health service centre or otherwise.

The department management checks when recruiting/reinstating the position. This applies to all employees, temporary staff, assistants or students and visitors.

The personnel are required to provide information about exposure/illness prior to entry/reinstatement of the work and to perform current routine examinations (including students, guests, etc.).

48.4 Practical Measures

Requirement for microbial testing after healthcare contact abroad.

These routines may vary between countries. In Norway it is required testing after international stays in connection with *healthcare* or *being a patient* [1]. Only the county governor can exempt from testing [1]. All personnel, including temporary staff, short-term employees and hospitals, are tested prior to work at hospitals and at other healthcare institutions following healthcare or as a patient abroad—or in areas at home and abroad where multidrug resistance is a problem. This applies especially to the *last 12 months before employment* and *always* if previously been MRSA-positive.

1. The recruitment centre/department management verifies that documents relating to infection exposure are understood and signed by employee, student, guest, etc.
2. The head of department asks the employee to contact the hospital's medical officer/general practitioner for the relevant microbial tests *before* work.

3. Await test result (2–4 days for MRSA), or use quickest (approximately 2 h). Avoid clinical work during this period.
4. In case of *suspicion* of positive test answers, the microbiological laboratory contacts the hospital's medical officer/general practitioner and infection control staff.
5. The medical officer/general practitioner contacts eventually the carrier personnel, and the infection control staff contacts the head of the department if the employee is at work.
6. MRSA testing during the last 14 days before starting work at the hospital is approved, also if satisfactory testing has been carried out abroad. The test results must be documented in writing.
7. The medical officer/general practitioner will provide further follow-up on suspicion of tuberculosis or other specific infections/carriers.

48.4.1 Sampling/Treatment/Post-Control in MRSA Suspicion

See Chap. 49 on MRSA infection detection and control.

48.4.2 Suspected Tuberculosis

See Chap. 56 on tuberculosis and tuberculosis control.

48.4.3 Suspected Gastrointestinal Infections

See Chaps. 52–54 on gastrointestinal infection and norovirus.

48.5 Background Information

Healthcare professionals may become sick or infected with human pathogenic microbes during travel, work and stay in other countries (imported infection) and at home [10–13]. In some cases, the infection occurs nosocomial by direct or indirect work with infected patients, employees or the environment. The personnel can therefore be “sources, carriers and victims” of infection with a variety of different microbes, including MRSA [10–13].

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**Abstract**

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a serious and increasing global problem. MRSA infection is linked to patients from abroad (imported infection), war injuries, high antibiotic consumption, lack of environmental hygiene and infection control, understaffing, overcrowding and absence of isolation procedures. MRSA is a *S. aureus* bacterium that has developed resistance to several good antibiotics and that may harbour special dangerous virulence genes. *S. aureus* is causing infections in two out of seven billion peoples in the world each year, and 10–50% of the most serious types are caused by MRSA. MRSA is causing one of the largest infectious diseases in the world with a rather high death rate. It is easily spread by contact, droplets, air, equipment and dust and may survive in dry state outside the body for up to 1 year.

Everyone should be protected against infection with MRSA since it is a highly preventable infectious disease. In countries with strict infection control, like in Scandinavia, high standards (like “Ullevål standard”) have been used with rather good experiences. Still, the infections are increasing because of a high mobility in the population and spread of MRSA in the environment, in the community and among animals and via food chains. Healthcare professionals may become infected with MRSA and may be the “source, carriers and victims of infection”. Carrier states are preventable, subclinical and may cause large outbreaks in hospitals and other healthcare institutions. The following chapter is focused on practical measures to detect and prevent transmission of MRSA in healthcare institutions.

Keywords

MRSA in and outside hospitals · Imported from abroad · CA-MRSA · HA-MRSA · Resistance genes *MecA*, *MecB*, *MecC* · Admission to hospital · Pre-examination Information · Screening · Testing · Isolation · PPE · Sanitation · Decontamination · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

49.1 Purpose

Prevent the introduction and spread of MRSA in the hospital by information, testing and isolation of suspected MRSA-infected persons.

Control of personnel and patients after contact with healthcare abroad or after work in war areas and refugee camps or otherwise exposed to MRSA—or earlier tested as MRSA positive—at home or abroad.

- By pre-examination and information—in advance.
 - By implemented procedures for early infection control.
-

49.2 Comprise

Close contact of MRSA-infected patient or personnel, patients in the same room and others who have been in direct contact with the source of infection without personal protective equipment (PPE).

Environmental contamination: patient room, toilet/bathroom, ward office, living room, disinfection room (cleaning room), etc.

Outbreak: one single case (or more) of MRSA if the infection/colonization has occurred after admission and is not known positive on or beforehand or not previously exposed to known infection.

49.3 Responsibility

The hospital's management provides routines and guidelines regarding MRSA and of infection detection and control [1–12].

The department management implements routines, following up outbreaks in collaboration with the infection control unit, provides for testing after possible exposure and contacts the Director at increased risk of infection for patients and personnel.

Personnel follow routines and measures.

49.4 Practical Measures

All patients, visitors and personnel should be protected against infection with MRSA which is a highly preventable disease [1–24].

49.4.1 Coordination of Outbreaks of MRSA

Infection control personnel coordinate infection control measures, give hygienic advices, guidance and information during outbreaks and inform the Director of

larger outbreaks, extensive use of resources and possible deaths in connection with MRSA.

49.4.1.1 Department/Ward Manager—Where the Problem Occur—Coordinates

- Preventive measures (patient isolation, testing of contacts, use of PPE, disinfection, etc.).
- Information to exposed personnel to not work elsewhere because of risk of transmission (extras, etc.).
- Establish overview of patients/employees/environment that have been exposed (direct contact).
- “Flagging out” MRSA into patient journal—critical information.
- Information to other departments/personnel exposed to the infection.
- Follow-up of MRSA-infected persons in cooperation with the hospital’s medical officer (personnel) and the infection control unit.

The MRSA responsible physician of the ward requests samples from patients and personnel and informs the microbiological department of the number of samples in case of outbreaks. Employees with proven MRSA are referred to the medical officer/infection control doctor/general practitioner for possible disinfection and follow-up. Test responses (from staff) are administered in hospital archives.

49.4.2 Pre-Examination: Before Entering Hospital

Preliminary examinations of patients and personnel should be conducted *prior to* hospitalization.

49.4.2.1 Patients

- Presurvey (telephone, formal letter and information to the patient, etc.): was there any contact with healthcare abroad or exposure to resistant bacteria? Determine infection risks by telephone (referring doctor) or outpatient for elective patients and for immediate help.
- The preliminary examination can be carried out with the GP. The patient receives information from the hospital and is asked to contact the GP if exposed to MRSA infection for the past 12 months or earlier, or MRSA infected—if ever. The patient is tested at the GP in the same way as in the hospital.
- *Critical information.* Check if the patient’s journal is flagged out under critical information.

49.4.2.2 Personnel (Including Temporary Staff, Guest Visitors, Students)

- Possible exposure (last 12 months), or previously infected with MRSA; tested prior to employment/re-entry, etc. at the hospital.
- The preliminary examination can be carried out by own GP.
- Personnel from healthcare abroad can be pretested abroad 14 days prior to arrival at the hospital. The test result is brought and delivered to the department manager. Patient is tested in the same way as in the hospital.
- Personnel with chronic wounds or eczema should not work with MRSA patients.
- Exposed personnel, pre-examined before employment, should not work in the healthcare system before a test response is available.

49.4.3 Testing/Screening of Patients and Personnel Suspected of MRSA

49.4.3.1 Ullevål—Standard for Detection, Isolation and Follow-Up on Suspicion of MRSA (Tables 49.1 and 49.2)

Table 49.1 Who should be MRSA screened?

Ask patient/personnel	If yes
<i>Import?</i> Have you been in contact with healthcare abroad for the last 12 months? ^a	<ul style="list-style-type: none"> • Directly take the patient in an isolated/single room and conduct the test (outpatient or inpatient); isolate the patient until the test result is completed • PPE: Surgical mask/cap, gloves, gown for the one who is testing/entering the room • <i>Patient:</i> Isolated until test results are clear • <i>Personnel:</i> Should not work with patients before the test result is complete
<i>Earlier MRSA positive?</i> Have you ever been infected with MRSA? (no matter how far back in time)	<ul style="list-style-type: none"> • As above
<i>MRSA exposed last 12 months?</i> Have you been in contact with people infected with MRSA infection in nursing homes, home care, primary healthcare, hospitals, etc. during the past 12 months? ^b	<ul style="list-style-type: none"> • As above

^aExamined/treated/worked at hospital, outpatient clinic, primary care, nursing home, abroad, etc. exceptions are the consultation, prescription or attestation of a doctor

^bExcept for protected contact with MRSA (use of PPE and patient isolated)

Table 49.2 Testing for MRSA

Test sampling equipment	<ul style="list-style-type: none"> • Sterile pencils and transport medium (from microbiological department) • Sterile water/saline. The pencil is always wetted before sampling
Sample locations (anatomical)	<ul style="list-style-type: none"> • Nose—inside, outer part of inside • Throat—tonsils and soft palate • Hands and wrists • Perineum—between the urethral opening and rectum • Wounds, eczema, scarring, catheter and drainage • A common test kit for patients and personnel: nose, throat, hands, perineum
Remisse	<ul style="list-style-type: none"> • Information per test kit (nose, throat, hands, perineum, event elsewhere) from a patient/person • Record the name, date and test mark of the referral and the samples • Note remarks of MRSA (import, exposed, etc.)
Sample vials and test answers	<ul style="list-style-type: none"> • A test kit (per patient) is bundled together • Test kit and referral will be delivered to the microbiological department directly and as soon as possible • Go and get test answers or use telephone—with the post it is taking time

49.4.3.2 Procedure Description: Equal to Patients and Personnel

- Nose—both nostrils: wet the pencil. Roll the pencil three times around inside each nostrils—outermost.
- Throat: wet the pencil. Roll the pencil over tonsils and soft palate region three times.
- Hands and wrists: wet the pencil. Roll the pencil on both sides of the palm, between fingers, over fingertips and around wrist.
- Perineum: wet the pencil. Roll the pencil between the urethra opening and rectal opening three times back and forth. Employees take the sample themselves.
- Wounds/scars/eczema/skin lesions: wet the pencil. Roll the pencil over areas with wounds, eczema, etc.
- All types of catheter: wet the pencil. Roll the pencil and wipe it well around the insertion site/catheter/drain, etc. Take eventually, in addition, urine test, tracheal secret, drain secret, etc.

49.4.3.3 Testing of Staff at Outbreaks

- The department manager or delegated staff is responsible for screening of exposed personnel.
- In case of major outbreaks, a list of exposed patients and personnel is made, and the number of persons to be tested for microbiological laboratory is reported.
- Non-medical personnel (cleaning, technical or other service personnel) address the occupational health services or other defined units by appointment.

49.4.3.4 Important!

- Personnel in close contact with MRSA patient, equipment/bed, etc. are tested. During the period of the test (3–5 days), the personnel are using surgical mask/cap, gown and gloves for all patient care in the actual ward with outbreak. In rooms with more patient beds/cohort, change gloves between each patient.
- Personnel, temporary workers, students, etc. should not work elsewhere while infection tracing is in progress before the results are available (event sickness reports). Exposed personnel can still work in the particular ward, while infection tracing is in progress, but should use PPE; see above.

49.4.3.5 Interpretation of Test Answers

MRSA Test Negative: Previously Not Detected MRSA Positive and All Samples Taken Now Are Negative

- Patients/personnel are declared free of infection after a complete set of tests (nose, throat, hands, perineum and clinical samples).
- Prerequisite: MRSA testing is done properly, and the patient is not recently on antibiotics (last 14 days) or disinfection (last 10 days).

MRSA Test Positive

- Isolation of this patient is continued. In case of isolation measures started from the day of admission, infection tracing (testing of other patients, personnel, etc.) is unnecessary.
- In case of occasional discovery, the patient is isolated, and a number of preventive measures are taken (see below).
- Personnel who are diagnosed as MRSA positive should avail sick leave and submit an information concerning accident statement (infected on job), and adequate protection measures are taken for any close contacts and for the contaminated environment (see later).
- Check the findings of MRSA (repeat sample from nose, throat, hands, perineum, etc.) before taking disinfection measures to verify findings and map the infection sites.
- Written information on infection and disinfection measures.

49.4.4 Patients with Known MRSA at Admission/Outpatient Clinic

- The patient is isolated throughout the stay!
- Inform the patient about infection prevention measures.
- Always isolate—no matter how far back MRSA was detected.
- The department/responsible physician provides suitable isolation room and agrees with this before admission/outpatient clinic.

- Isolation for airborne infections with negative air pressure is recommended, especially if having respiratory symptoms, respiratory treatment and widespread skin ulcers.
- Contact isolation with separate toilet/shower/decontaminator can be used.
- Single room with anteroom and separate toilet/shower, attached room (not in common hallway), is a short-term emergency solution.
- The staff use surgical mask/gloves/cap/gown and follow routines for the removal and disposal of PPE.
- Check if the journal is flagged out under critical information.
- Examination and treatment at other units, etc. are carried out by appointment and with protective measures (patient in a clean bed, clean clothes and with a mask if coughing—to the actual unit).

49.4.5 Suspected MRSA—Not Been Isolated in the Ward

The patient or relatives may, for example, after a few days tell about contact with healthcare abroad or exposed to MRSA otherwise.

- Isolation due to MRSA status is clarified. MRSA is tested; rapid test + cultivation are recommended. Fastest possible clarification regarding infection status.
- *Await MRSA testing* of exposed patients and personnel until results from the index patient are available.
- Inform the patient about infection prevention measures.
- Treat MRSA infection until test results are negative.
- Hand hygiene and personal hygiene should be done.
- Patients in contact with the actual suspected patient are registered and isolated in their own room.
- Personnel with direct contact with the patient are registered.
- Disinfection and washing of important common rooms such as X-ray rooms, operating rooms, etc. where the index patient has been treated—contact infection control personnel for advices.
- The staff wear surgical masks/cap/gloves and gown when entering the room of index patient/exposed patients and follow the procedures for the removal and disposal of PPE afterwards.
- Examination and treatment by other units, etc. are carried out by appointment and with preventive measures (patient in a clean bed, clean clothes and with a surgical mask if coughing—to the unit responsible for examination/treatment).
- If the test result of the index patient is negative, the patient is considered to be not MRSA-infected if the samples are taken in a proper manner.
- No testing of patients or personnel if the patient's test result is negative.

49.4.6 Unexpected Discovery of Inpatient Patient with MRSA

Example: MRSA detected in clinical samples of a patient after some days in the ward. The patient has been in a four-bed room with other patients, used common living rooms and toilets and been on other units for X-ray, etc. Most nurses on the ward have been caring for this patient.

49.4.6.1 Isolation

The ward/physician in charge provides for isolation of the MRSA patient who is isolated throughout the stay and informed about infection control measures.

49.4.6.2 Personal Protective Equipment (PPE)

- Surgical mask put on outside the cap, gloves with long cuff and single-use gown. Check that the staff can use PPE—donning and doffing.
- PPE is used for the care of all patients in the ward until the test result is available—to prevent spread of infection.

49.4.6.3 Hand Hygiene

- Tighten up general personal hygiene and hand hygiene.
- Check hand disinfectant and procedures for hand disinfection.

49.4.6.4 Exposed Patients

- Patients on the same room may often be colonized or infected. Inform by writing about infection prevention measures.
- Exposed patients are transferred to a clean bed with clean clothes (the unclean is treated as infectious) and returned to the patient room after disinfection of the room has been completed (takes about 1–2 h)—or to another clean room—and isolated. They are MRSA tested and isolated until test results are negative.
- Cohort isolation (same room) may be used during large outbreaks (but should be avoided).
- Until test results are negative, patients are treated as MRSA positive in examination, treatment, care and transportation.
- Avoid relocation of MRSA-exposed patients to other wards or to nursing homes, home nursing, etc.
- Message is sent to departments and institutions that have received exposed patients before the current case was detected. They are isolated and tested where they are located.
- If necessary, transfer to other departments/hospitals/health institutions *before negative test response is available*; notify exposure to MRSA *prior* to transmission.

49.4.6.5 Exposed Personnel

- Tighten up general personal hygiene and hand hygiene.
- Register, test and use PPE for care of patients until the infection situation has been resolved.

- Inform about protective measures—written.
- Do not work elsewhere, at other departments/health institutions, before test results are present; contact infection control personnel if there are questions.
 - Exception: in special circumstances, be careful. Change clothes (gown) and disinfect hands when leaving the outbreak ward. At work elsewhere: clean gown, surgical mask/cap and gloves. This is carried out until infection status is clarified.

49.4.6.6 Visitors/Relatives

- Inform about infection prevention measures.
- Must follow isolation routines, hand hygiene, etc.
- Do not stay anywhere else in the ward (direct to and from).
- Close relatives (direct contact) are recommended to undergo MRSA testing at their own GP.

49.4.6.7 Disinfection and Cleaning of Exposed Rooms and Equipment

- Personnel in charge provide rapid disinfection and cleaning of contaminated rooms and objects (see contamination/room disinfection) in cooperation with cleaning and hygiene staff.
- The same procedures are done elsewhere in the hospital where the MRSA patient has been treated/examined.
- During disinfection, the room is emptied—the patient is moved to another room.
 - Exception: If the condition of the MRSA patient is such that he cannot be moved to isolation immediately (for instance, ICU patient), contact infection control personnel for advices. If there is shortage of rooms, a local disinfection around the patient may be done—as an exception. Then other patients on the same room may be moved to a new, clean bed with clean bedding/equipment and still considered to be exposed to MRSA infection.
- If there are problems with disinfection of rooms due to a lot of single-use or other equipment, fixtures, etc., assess decontamination by dry hydrogen peroxide gas—contact infection control staff.

49.4.6.8 Flagging-Out Journal

- Check if the patient's journal is flagged out under critical information.
- Flagging-out mark should not be removed even if the patient is disinfected!

49.4.6.9 Message Information

- Manager in charge at the relevant ward reports the MRSA result to other units/wards/departments that have been in direct, unprotected contact with the patient (X-ray, surgeons, anaesthesia, porters, bioengineers, transport staff, ambulance, etc.) and to other hospitals, nursing homes, home care services, etc. (see more later).

49.4.6.10 Screening of Whom?

- Close contacts and patients who have been in the same room (not necessary if the index patient has been isolated from hospitalization due to other infections).
- Other patients exposed due to local conditions (open units, e.g. intensive), less good hygienic conditions, use of common exposed personnel, common service space over time, etc. Ask for specific additional MRSA examination when sending microbial samples. Contact infection control personnel for advice.
- Exposed personnel: direct contact with the patient or patient's room/equipment or other patients in the same room.
- NB! Inform the microbiological department about the number of people to be tested!
- Infection control personnel provide advice on the extent of testing.

49.4.7 Unexpected Findings of MRSA in Several Inpatient Patients

If there is detected spread of infection among several patients or personnel, it may be necessary to repeat MRSA screening, disinfection of rooms, isolation and closing the ward for new intake until the situation is under control.

- If another patient in the same room as the MRSA patient (index) is detected of infection, have new control measures of patients in the same room and actual personnel and decontamination on actual rooms (measures as above).
- If one or more patients in *other* patient rooms (in addition to the index room) are infected, the entire ward (patients and personnel) may have been exposed and are tested. Evaluate stop for new intake (measures as above).
- If MRSA is detected in one or more personnel at the department, all (patients and personnel) are tested; stop for intake (measures as above).
- If MRSA is detected in personnel from other wards (been in contact with the outbreak ward), these contacts are followed up with measures in cooperation with infection control personnel (measures as above).
- Always check the findings of a positive MRSA result.

49.4.8 Unexpected Discovery of MRSA in a Healthcare Worker

- MRSA detected in one or more personnel at the department: test all (patients and personnel) and stop for intake (measures as above).
- Personnel with proven MRSA are on sick leave and followed up/treated by the GP or other doctors in collaboration with infection control personnel.
- MRSA is registered as occupational disease, and injury claim form is completed.

- In case of detected MRSA: no patient-related work as long as the person is infected/carrier.
- Infection tracing in the family of healthcare professionals with proven MRSA infection varies. It is most often required to remove carrier status. In case of recidiv of carrier status, and if others in the family are working in the healthcare system or are to be treated by the healthcare service, infection tracing and sanitation are especially important to be carried out.
- MRSA disappears in 10–40% of infected healthcare professionals within 14 days to 3 months and most within 12 months after adequate sanitation. Prolonged carrier status is less likely after adequate sanitation, with the exception of wounds/eczema. Best chance of successful treatment if it starts immediately.
- Personnel with chronic wounds or eczema should not work with MRSA patients because they are more vulnerable to become long-term carriers.
- Check the findings of MRSA before any treatment (nose, throat, hand-wrist, perineum, eczema, ulcers, scars, etc.).

49.4.9 Follow-Up of MRSA-Infected Person

Infected healthcare personnel should be followed up quickly and efficiently; they should be taken care of and come back to work as quickly as possible.

49.4.9.1 Follow-Up of MRSA Tests Concerning Infected Person: Patient or Personnel

- In the case of detected MRSA, three consecutive test sets taken at 3 days intervals must be negative before the person is defined as “low MRSA risk”. It is assumed that the sampling will start at least 10 days after completion of the sanitation/disinfection and at least 14 days after the end of the use of antibacterial agents.
- Then follow up for 12 months with frequent testing at the start—for instance, every week—and later on testing after 3, 6, 9 and 12 months. Each time three sets of tests are taken at 3 days intervals. After at least 15 consecutive negative test sets/(0, 3, 6, 9, 12 months) during 1 year and no positive findings in between, there is less chance of permanent MRSA status.
- In the event of residiv, a new sanitation period and follow-up over 1 year until the patient/personnel has been continuously negative for 1 year (*see sanitation*).
- Personnel are on sick leave and followed up by the GP (or infection control doctor in the community)—in cooperation with infection control personnel at the hospital.
- All expenditure on tracing of infections, sanitation and other treatment of MRSA-positive cases and exposed environment should be charged to the current institution/primary healthcare.

49.4.9.2 Patient

- Control samples from the nose, throat, hands, perineum, wounds, eczema, scars, catheters, drainages, secretions, pus, etc.
- Sanitation started early if not quickly negative (see sanitation).
- Considered as “low MRSA risk” if three consecutive test sets taken with 3-day intervals are negative at least 10 days after completion of sanitation and at least 14 days after the end of the antibiotic cure.
- Considered possible MRSA positive when readmitted/any contact with the healthcare, and the journal is “flagged out” under critical information.
- Sanitation and follow-up are carried out at different healthcare levels where the infected patient stays; at hospitals, nursing homes, home nursing and at home, in collaboration with the GP and in consultation with infection control personnel.
- If there’s a need for use of systemic antibacterial treatment, contact specialist in infection medicine.
- Reported as hospital-associated/healthcare-associated infection if encountered after contact with healthcare in and outside the country.

49.4.9.3 Personnel in Healthcare Institutions

- Sick leave when detected—not at work before MRSA negative and informed about further action.
- Mapped, reported, sanitation and followed-up as above.
- Considered as MRSA negative after 1 year with only negative control samples taken at certain intervals.
- Re-entry into work is planned as early as possible (see below).
- Carrier state and infection must be reported as occupational injury.

49.4.10 Sanitation for Patient and Personnel to Get Rid of MRSA Contamination

Sanitation is a combination of whole-body disinfection and effective disinfection and cleaning of the environment, equipment, textiles, etc. While the sanitation period is ongoing, the person is nearly not infectious, because of the daily effect of the disinfectant used. Written information is always included in sanitation measures. Contact infection control personnel for advice and guidance.

49.4.10.1 Sanitation Steps: Short Version

- Mapping MRSA status and requesting complete resistance form from microbiological laboratory, including mupirocin resistance.
- Patients and relatives are informed of the treatment.

- All sanitation take place at the same time; if more people live together, all of them are treated regardless of MRSA status (exceptions—contact infection control personnel).
- Disinfection, cleaning and environmental treatment to avoid recontamination from own environment: disinfect switches, door handles and other common touch points three times a day.
- Disinfect whole body and hair \times 1 per day (hibiscrub/stellisept/other recommended disinfectant) for 10–14 days. Soap in twice for 2 minutes each time with the disinfectant. Rinse off the disinfectant soap thoroughly afterwards—otherwise skin problems! *The disinfectant must be tolerated by the skin!*
- Switch to clean personal clothing and bedding—after each whole body's disinfection. The used laundry is washed at a temperature above 65 °C. (Eventually, textiles that does not withstand high temperature is washed 2 \times at 45 °C.)
- Disinfect the nasal cavity with Bactroban nasal (mupirocin) 3 \times per day for 10 days. Disinfect so much that the taste is felt in the throat.
- If mupirocin resistance is detected, use Naseptin® which contains 0.1% chlorhexidine and 0.5% neomycin/or other recommended disinfectants.
- Disinfect mouth with chlorhexidine mouthwash 3 \times per day for 10–14 days.
- Disinfect toothbrush, glass, toothpaste, denture, comb, etc. 2 \times per day for 10–14 days.
- Avoid using jewellery, piercing, makeup, lipstick, creams, etc. that may easily be contaminated.
- Hand hygiene with 70% alcohol-chlorhexidine with glycerol: 10–20 times per day, optionally using alcohol wipes.

49.4.10.2 Special Problems

- *Surface wounds/eczema:* The disinfectant (hibiscrub/stellisept) is usually tolerated on superficial wounds; possibly use diluted alcoholic-chlorhexidine 3–4 times a day—or chlorhexidine aqueous disinfectant (Note chlorhexidine—not in the ear!).
- *Alternatively by wound:* Chlorhexidine liniment/rinsing fluid for wounds/mucous membranes, Bactroban ointment 3 \times /day, Bacimycin wound powder/ointment, not fucidin.
- *Eczema:* Contact a skin specialist if widespread, superficial wounds/eczema.
- *Carrying MRSA in the throat, etc.* Contact specialist in infection medicine for assessment of antibacterial agent for systemic therapy in addition to sanitation. Current agents may be minocycline, trimethoprim-sulpha and linezolid—after resistance pattern.
- *Mupirocin resistance:* use Naseptin® containing 0.1% chlorhexidine and 0.5% neomycin or other recommended medicament.
- *Ointments and other skin care products*—Contact infection control personnel. A variety of skin ointments can inactivate chlorhexidine.

49.4.10.3 Sanitation Kit

- Sanitation kits for treatment of MRSA carrier state may be pre-packaged as cleaning kits—every set for 5 days of treatment.
- Contents may be disposable bed sets and towels, disposable vials and other personal hygiene equipment.

49.4.10.4 From the Pharmacy

- Disinfectants like hibiscrub/stellisept/hand disinfectants/mouth disinfectant, etc.
- Mupirocin ointments, bactroban, etc. after prescription by the responsible physician (Table 49.3).

49.4.11 Information and Registration

- Inform patient or relatives that MRSA may be present on the body periodically in 40–60% of the cases a time following infection (12 months or more), if the patient is not being sanitized. It may also disappear spontaneously. The infection is usually not dangerous for healthy people.
- The patient should inform about MRSA infection/carrier state to actual treating healthcare providers.
- Journal tagged and flagged out under critical information.
- The patient is monitored for MRSA carrier state in new contact with healthcare.
- In the United States, influenza vaccination is recommended in former or current MRSA-infected people to prevent serious respiratory infections and the spread of infection with MRSA.

49.4.12 Administrative Measures and Cancelling Restrictions

- MRSA patients and carriers are out of the hospital system/or isolated.
- Disinfection and cleaning are completed.
- Personal and general hygiene must be tightened up.

Table 49.3 Scheme for sanitation of MRSA in patients or personnel

NB. No investigation or treatment is postponed due to suspicion of MRSA

- Mapping MRSA prevalence on the body before sanitation—with one or more sets of tests
- Ask for complete resistance pattern from the microbiological department, including mupirocin
- Patients and relatives are informed of the treatment
- All sanitation should be carried out at the same time, possibly with the addition of antibacterial treatment
- Disinfection and cleaning—daily—are important in the process to avoid recontamination from own environment
- Follow-up with control tests starting 10 days after completion of sanitation and 14 days after antibiotic treatment

(continued)

Table 49.3 (continued)

<i>Sanitation measures for 10–14 days</i>	<i>Steps at the same time</i>
Contact infection control nurse for advice and guidance	<i>1. Soap in with disinfectant once for 10–14 days</i>
<i>1. Disinfect whole body and hair once per day for 10–14 days</i>	<ul style="list-style-type: none"> • Twice for 2 min each with rinsing between • Wash over the soap container surface with the disinfectant. Use disposable washcloth • Remember hair, ears, genitalia, between toes • Rinse off the disinfectant thoroughly afterwards—otherwise skin problems • Rinse the shower cubicle walls with warm water. Step out on a clean towel or in an area that is disinfected with alcohol and wipe yourself with another clean towel • Both towels are placed in yellow plastic bag for contaminated textiles after use
• Soap in twice for 2 min with the disinfectant, with thorough rinse between the washes afterwards	
• <i>The disinfectant (chlorhexidine, stellisept or another) must be tolerated!</i>	
• Switch to clean personal clothing and bedding—after each body's disinfection	
• The laundry must withstand washing, 65–85 °C	
<i>2. Disinfect the nasal cavity (mupirocin) 3× per day for 10–14 days</i>	<i>2. Disinfection of the nasal cavity: Bactroban/mupirocin 3× for 10–14 days</i>
<i>3. Disinfect mouth with chlorhexidine mouthwash 3× per day for 10–14 days</i>	<ul style="list-style-type: none"> • Disinfect hands and outside of the ointment box with hand disinfectant • Take ointment on a clean Q-tip and smear well in each nasal cavity or use disposable gloves for the procedure
<i>4. Disinfect the toothbrush, denture, prosthesis 2× for 10–14 days: Wash at temp >65 °C or chlorhexidine alcohol (70% alcohol, 5 mg/ml chlorhexidine)</i>	<i>3. Disinfect the mouth: Chlorhexidine mouthwash 3× for 10–14 days</i>
New glass/disposable cup for every mouth care	<ul style="list-style-type: none"> • Disinfect the hands and outside of the bottle/cup • New cup for every rinse • Rinse your mouth well, put your head back and “gurgle” mouth rinse in your throat for 2–3 min. Do not swallow
Do not contaminate the toothpaste (or small portions in single cups)	
<i>5. Disinfect all patient-related equipment (comb, jewellery, watch, glasses, etc.) and remove makeup</i>	<i>4. Brush your teeth, dentures, prosthesis 2× for 10–14 days and disinfect the equipment—see point 4, left</i>
<i>6. Hand hygiene with chlorhexidine alcohol (70% alcohol, 5 mg/ml chlorhexidine) or alcohol-based agents added glycerol, 10–20 times per day; in an event, use alcohol wipes</i>	
<i>7. Wipe (alcohol wipes) surfaces, switches and common touch points 3× for 10 days</i>	
<i>8. Ointments and other skin care products—</i>	
Contact infection control nurse for advice	

Special problems

- Surface wounds/eczema: body disinfectants (hibiscrub/stellisept/alcohol) are usually tolerated in superficial wounds or chlorhexidine 0.5–1 mg/ml in aqueous solution 3–4×/day (note chlorhexidine—not in the ear and has short durability after opened: 1 week). Optionally mupirocin ointment (should generally be avoided)
- Alternatively when wound: Chlorhexidine liniment/rinsing liquid to wounds/mucous membranes, Bactroban ointment 3×/day, Bacimycin wound powder/ointment, but do not use fucidin ointment. Request resistance pattern of the MRSA strain
- By mupirocin resistance, use Naseptin® containing 0.1% chlorhexidine and 0.5% neomycin
- Eczema: Contact dermatologist if there is widespread superficial wounds/eczema
- Carrier state in throat, etc. contact specialist in infection medicine for selecting antibacterial agent for systemic therapy if failure of the sanitation
- Infection with fever. Contact specialist in infection medicine

- Initial control of exposed personnel is mostly carried out, and no new infected persons are found.
- Activity is normalized after consulting with infection control personnel.

49.4.13 Discharge to Community Health Centres, Primary Health

Responsibility: management by relevant department in collaboration with infection control/hygiene nurse.

- When transferring to other health institutions, nursing homes and home care, notify MRSA infection in the actual ward, even if the patient has negative samples at discharge.
- Follow-up and sanitation can take place outside the hospital in consultation with the family doctor/responsible institution/infection control (see earlier).
- Good discharge procedures and information about MRSA control and infection control procedures to patients, relatives and receiving health unit *before* the patient is discharged.
- Good monitoring by nursing/retirement home/condominiums/home care, preventing the spread of infection.
- MSA patients in institutions, in home care or special living units must get patient-responsible doctor and nurse who follow up with the controls and treatment until the MRSA patient is negative in consecutive samples for 1 year after the last positive sample.

49.4.14 Outpatient Treatment and Examination When MRSA Is Infected

- Planned at the end of the day, prepared well.
- Clear away equipment, etc.—not fabric chairs or a lot of equipment.
- Use personal infection control equipment (gloves, face mask/hood, infection coat).
- Take the patient directly into the office—not in the waiting room.
- Let the patient sit on a chair or on an examining table—and do not touch the stuff in the room.
- Calm examination and treatment—have all the necessary equipment available—do not leave the room with PPE on.
- Afterwards disinfect relevant surfaces and contact points—including floors that the patient has been in direct contact with using disinfectant—alcohol, chloramine, chloricide, peracet acid, etc.
- Remove the PPE without contaminating hands, own clothes or the environment—and treat it as infectious waste.

49.4.15 Notification Responsibilities

- Microbiological laboratory reports telephonic identified/suspected MRSA to department/ward and infection control personnel.
- Department manager (event in charge) contacts infection control personnel and other departments where patients have been and sends nominative message.
- Nursing homes, home care and primary health service in general are notified if infected patient/employee has been in contact with these.
- Employees are obliged to inform about exposure to MRSA.
- Infection control doctor reports to the Director, National Institute of Public Health, the County and the State Board of Health during major outbreaks of MRSA. The Director is also notified by fatalities due to MRSA and/or particularly costly measures.

49.5 Background Information

MRSA is an increasing problem in healthcare worldwide and also in Scandinavia, including Norway [15, 18]. The largest hospital outbreak of MRSA in Norway occurred at the Regional Hospital of Trondheim during 1970–1974 with 144 cases, 48 (31.6%) deaths (direct or indirect), 15 infected employee (13 nursesassistants, one physiotherapist, one physician) and did not end before a separate isolation ward was established [15, 25]. The index case was a 59-year-old woman with postoperative wound infection (never been outside Norway), treated with cephalothin and ampicillin. The highly virulent strains of MRSA were found in environmental samples from air in several patient rooms, equipment, bed-lining, dust on floors under the beds and in the beds, etc. [25]. The entire hospital was nearly paralyzed during the endemic—because of lack of isolation units and qualified personnel, difficulties concerning information, disagreement concerning infection control and more or less follow-up of doctors that did not believe in the effect of infection control measures [15, 25]. The same problems are still present in many hospitals, also in Norway.

- *MRSA* is unusually robust with long survival in dry state in the environment—up to 10 months, and with ability to spread to animals and grazing land and to nutrients as food and drink [18, 24, 26].
- *MRSA* is resistant to all penicillins, cephalosporins and carbapenems; all types of beta-lactam antibiotics have resistance genes *MecA* and/or *MecC* and is often resistant to other good staphylococcal medicaments, especially import strains.
- *HA-MRSA* (*hospital-associated MRSA*) is nosocomial, often more antibiotic resistant than MRSA occurring outside healthcare: CA-MRSA [18, 24].
- *HACO-MRSA* (*hospital-associated community-onset MRSA*) is increasing in the United States and Europe where MRSA infection is discovered first after a few months after hospitalization. This is due to ever-shorter hospital stay.

- *CA-MRSA (community-associated MRSA)*—outside health institutions, often in young, healthy people—with no previous contact with the healthcare system [18, 24, 27]. Serious abscesses in the skin and other acute infections are associated with CA-MRSA. The MRSA is sensitive to other staphylococcal medicaments but may produce dangerous toxins that PVL (Panton-Valentine Leukocidin) and is associated with greater virulence than HA-MRSA [18, 28].
- *LA-MRSA (livestock-associated MRSA)* is a new type of MRSA (first occurring in Denmark, Netherland and USA) transmitted by a high production of animals, especially of pigs, and also found in bulk milk and other foodstuffs [18, 24, 26, 29].
- *Mixing of MRSA types:* MRSA transmission happens very fast. In hospitals today, there are both CA-MRSA and LA-MRSA—types, in addition to HA-MRSA, and vice versa [18, 24, 30]. In the United States, type USA300 is spread both outside and within the healthcare system [31].
- *VRSA* is vancomycin resistant (VRSA) or vancomycin intermediate resistant (VISA)—MRSA which are selected by the high prevalence of MRSA and VRE, combined with the use of vancomycin [32–34].
- *MRSA tracing:* sampling of close contacts of the MRSA case and/or the environment surrounding the source of infection. Typing of MRSA-genotyping (PFGE, sequencing of the entire genome etc.) show similarity between bacteria which indicates the pathways of infection and sources [18, 19, 21–23, 35, 36].
- *Mupirocin*—disinfectant of skin and mucous membranes and is used in ointments to kill MRSA during decontamination of MRSA [37].

49.5.1 Incidence, Cost and Mortality

Occurrence varies from 40–60% of *Staphylococcus aureus* in Southern Europe to 1–4% in Norway, Sweden, Finland and Denmark (Fig. 49.1) [38].

In the United States, the percentage of MRSA among *S. aureus* isolates was 55% from cases with catheter septicaemia, 60% from UVI catheters, ca 50% from VAP cases and 44% from postoperative wounds [12]. MRSA-type USA300 is spreading, and serious nosocomial pneumonia cases increase [31, 39]. Carrier state of MRSA in the population is high. In routine samples from 250 pregnant women in the United States, MRSA were detected in 10.4% of recto-vaginal swabs. Carrier state in pregnant women can lead to complications around birth and in the child [40].

From 2002 to 2009, MRSA increased significantly at Veterans Affairs Healthcare System (a large healthcare chain in the United States) at hospitals 14%, nursing homes 10% and outpatient clinics 37% [41]. Hospitals in the chain had during this period 44,668 MRSA-infected patients! Despite the increase in MRSA—cases, the clinical outcomes were better [41].

The risk of spread of MRSA is great in nursing homes, home care, day care, schools and among families of infected healthcare professionals. MRSA among pet, pig herds, in grazing land, recreation areas, foods, bulk milk, meat, etc. promotes the spread in the environment and in the population [18, 24, 26].

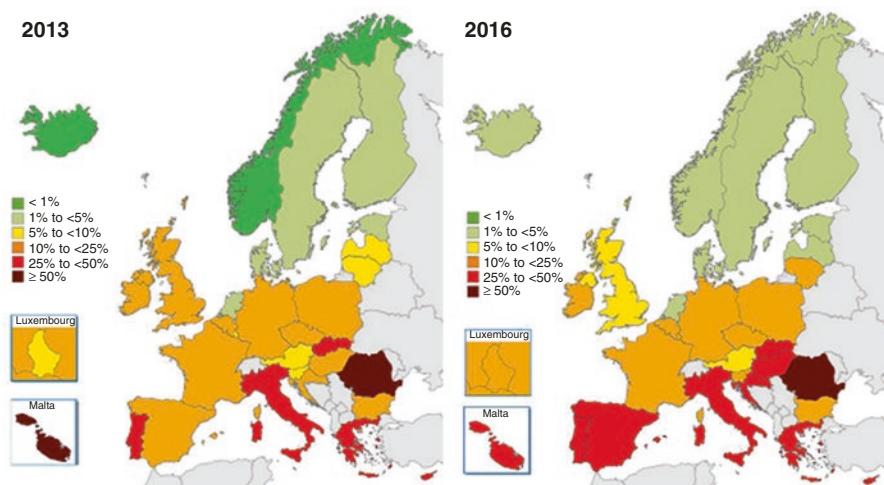


Fig. 49.1 Percentage (%) of invasive isolates resistant to methicillin (MRSA), by country, EU/EEA countries, 2013 and 2016. Source: ECDC, 2013, 2017 [38]

Attack rate of infection after colonization in hospitals is 26–33% and may even be almost 50% in infants [12, 18]. Attack rate of CA-MRSA can be up to 100% [18]. Certain epidemic clones, USA300 and USA400 is easily transmitted and harder to get rid of than others [12, 18].

In Norway, MRSA increased to 1867 cases in 2014, hence 832 with infections and 1035 carriers (Fig. 49.2, source: MSIS). MRSA has been out of control, with outbreaks in pig herds, much like in Denmark, but is now followed up by the Norwegian Veterinary Institute [18, 24].

Costs associated with MRSA infections are dependent on active infection control that prevent transmission of infections in hospitals. Good isolation measures and procedures for screening and decontamination is cost-efficient and leads to control [12, 18–24, 42–45]. There is less spread if the infected patient is diagnosed quickly [18, 23, 24, 46, 47]. Costs are associated with extra length of stay at the ICU, up to 20 extra days, and are significantly higher than for other infectious agents [12, 18].

At Ullevål University Hospital (UUH), one patient with MRSA was costing in 1997 526,000 NKR (ca. 75,150 USD), including extended length, transmission of MRSA to a hospital employee, screening tests, disinfection, sanitation and antibacterial treatment [19]. An outbreak of MRSA in the same hospital's neonatal intensive department in 1999 resulted in additional costs of 375, 000 NKR (53,600 USD) per MRSA positive patient, including isolation costs, disinfection, screening and extra days in hospital—a total of ca. three million NKR (ca. 429,000 USD) [21].

A rapid MRSA test within 2 h, combined with regular cultivation, may save huge costs for patients and personnel exposed to MRSA or suspected to be MRSA infected [23]. A rapid MRSA test is saving isolation measures, and exposed personnel can go directly to work without being on sick leave while waiting for the test result [23].

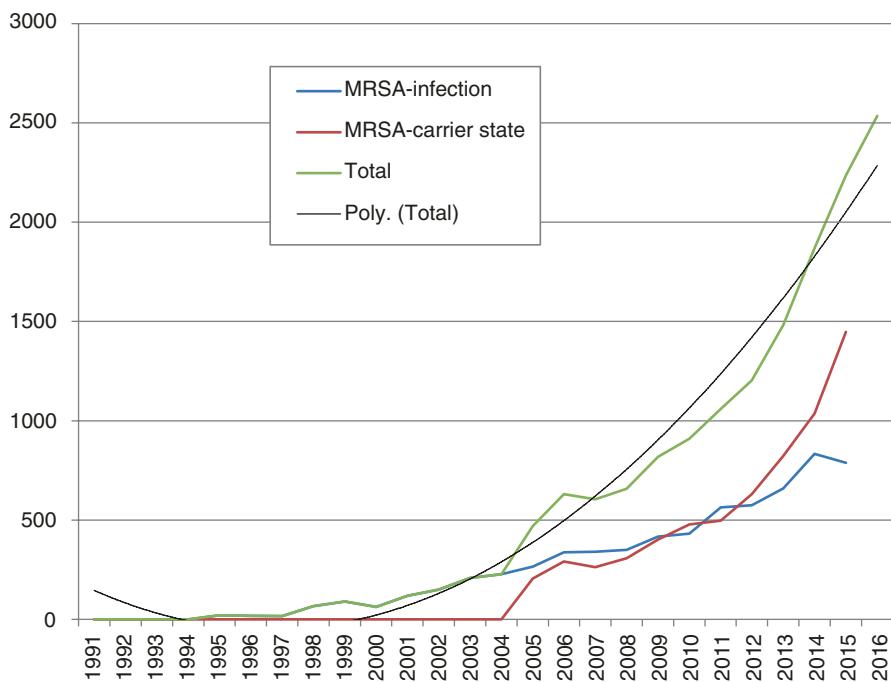


Fig. 49.2 Development of MRSA cases in Norway; 1991–2016 (source: MSIS, National Public Health)

Active screening and isolation is significantly cheaper for the healthcare than uncontrolled transmission of MRSA which can result in serious infection and death and lead to “hopeless” endemic conditions and even more antibacterial resistance problems!

Mortality among people over 65 years of MRSA bacteraemia is found to be ca. 36%, compared with 12% below 65 [15, 18, 48]. Among ca. 3400 cases of *S. aureus* bacteraemia in Europe and the United States (2006–2011), more than 20% of cases were caused by MRSA as an independent risk factor for death [49]. Survival period after MRSA bacteraemia was 14 months, compared to 54 months after MSSA (methicillin-sensitive *S. aureus*) bacteraemia [50]. Mortality associated with MRSA bacteraemia is evaluated to be more than three times higher than that of MSSA bacteraemia [12, 18].

49.5.2 Isolation and Testing Prevents the Spread of Infection

The presence of MRSA at hospital admission is usually applied to the patient in one or another prior to health-related situation [51].

49.5.2.1 Contact and Airborne Infection

Rooms, equipment, ventilation and other patients and personnel can be contaminated and infected with MRSA before test results are available [12, 18, 52–56]. Contamination and spread of MRSA may lead to carrier states: the nose, and sometimes the throat, in the perineum, around the wrists, hands, hair, ears and other parts of the body [18, 23, 24].

MRSA-infected patients are often contaminated on hands and therefore constitute major infectious sources for direct contact and the environment [18, 23, 57]. A study of 82 patients colonized with MRSA demonstrated that 82% had MRSA on hands and that hand disinfection was ineffective in 40% of the cases [57].

Carriers of MRSA on multiple anatomical sites on the body are more prone to infection than those with MRSA only on one place [58]. Large amounts of MRSA in the patient is more easily transmitted to the environment [46]. Contamination of environment and air in the room of MRSA patients happens very quickly—within 10 h [18, 52–55]. Therefore, personnel should use infection control equipment when entering the room, and patients should be isolated for suspected MRSA from admittance to hospital.

49.5.2.2 Contact Isolation (Contact Precaution = CP)

Contact isolation, defined by CDC (use of gloves, gown and the patient in isolate/private room), is used in high-endemic areas where 5–10% of hospitalized patients are infected [12]. Effect of CP is discussed [59–67]. Many studies are poor in terms of documentation and compliance [59]. Some studies are worth noting.

- Huang et al. found that CP led to significant reduction in bacteraemia in ICU (ICU): 75%, in non-ICU, 40%, and throughout the hospital, 67% reduction of MRSA cases [60].
- Robiscek et al. conducted PCR MRSA screening on admission and CP and eradication (sanitation) of MRSA positive patients, with significant reduction of MRSA disease during stay and 30 days after discharge [61]. MRSA was detected in 8.3% of 3300 patients admitted to the ICU and in 6.3% of the total of 62,000 patients tested, as is endemic conditions [61].
- Harris et al. showed significant reduction of MRSA under endemic conditions (10% MRSA infection among hospitalized patients), among 26, 200 patient admissions to 20 ICUs' [62]. Overall CP treatment of patients resulted in 40% reduction of MRSA, and a targeted isolation of only proven MRSA cases led to 15% reduction [62]. The more use of the CP, the less prevalence of MRSA in the units [62].
- A two-phase study from Australia was conducted at a medical ICU where prevalence of MRSA was 6.9%, and 60% became infected with MRSA during their stay [63]. In phase 1, MRSA patients were treated as other patients (no use of CP or isolation), although they were MRSA positive. In phase 2, CP was utilized for all MRSA positive patients, with use of a single room or cohort with other MRSA-infected patients [63]. All patients in the Phase 1 and 2 were MRSA screened on arrival (PCR), and in phase 2, all MRSA findings were reported

telephonic. There were about 2200 ICU patients in each phase. CP and isolation resulted in 60% reduction of MRSA infections acquired in the ICU [63]. *This is the only known “pure study” where the contact isolation are compared with no isolation.*

- Mangini et al. showed significant reduction of nosocomial MRSA when using CP and further reduction when using masks in addition to CP, for healthcare personnel working within 3 feet of the MRSA patient [64].
- A couple of large studies from the healthcare chain, Veterans Affairs, hospitals and long-term institutions in the United States, showed that with universal MRSA nose testing (96%) at admission, contact isolation of MRSA cases, hand hygiene and cultural changes in the institutions led to a sharp reduction of MRSA [65, 66].
 - In long-term institutions of Veterans Affairs (12,000 places), the reduction of MRSA cases was 36% [65].
 - In hospitals of Veterans Affairs (approximately two million admissions), 93–96% were nose tested at admission, and 13.6% were MRSA positive, an endemic situation [66]. During the period 2007–2010, a 62% reduction in MRSA infections in ICU's and 45% reduction in non-ICU's were found [66].
 - The large and robust studies showed significant effect of CP combined with hand hygiene and identification of MRSA positive patients.
- Good networking concerning infection control among hospitals may lead to less spread of infection [67].
- MRSA screening, isolation and eradication are important to reduce the spread of MRSA, even in hyperendemic areas [60–70].
- At the University Hospital of Basel, Switzerland, Widmer et al. (2015) described that the same procedures for strict isolation of MRSA cases had been used for 20 years [71]. There was targeted testing of patients and personnel and routine decontamination of infected persons. During a period of 20 years, approximately 540,700 blood cultures were studied. *S. aureus* was detected in blood cultures of 1200 patients, of which 34 were MRSA cases (2.7%). During the whole period, there had been a stable, low MRSA rate, without significant changes of the presence of MRSA in blood cultures [71].
- Similar experiences, with strict disease control measures and low rate of MRSA bacteraemia, have been recorded in Norway and other Scandinavian countries [18].

49.5.3 MRSA Testing and Screening

One single test is not good enough. Today, MRSA screening, only from a single anatomic site, the nose, is rather “bad medicine”. At least 50% of nasal samples may be negative, even if the patient is an infection disperser to the environment [18, 23, 52, 72–75]. The greater the number of MRSA colonizing the nose, the greater the chance of finding MRSA elsewhere on the body [74]. In case of MRSA patients with skin and soft tissue infections, which occur most often outside healthcare (CA-MRSA), samples from the nose are often negative for MRSA [52, 72]. Among

the 290 MRSA patients with skin and soft tissue infections, only 41% of nasal samples were positive [72].

Hands/wrist-testing MRSA patients often have contamination on hands and transmit the infection via contact to the environment [18, 23, 53, 57]. Among 82 patients colonized with MRSA, 82% had MRSA on hands, and hand disinfection was ineffective in 40% [57]. Therefore, hands/wrists should be included by MRSA testing of patients and personnel, as a routine used at United States during the past 20 years [13–24].

Universal test, targeted test, rapid test, universal decontamination without testing, etc. are different methods used to prevent the spread of MRSA. This is especially discussed in areas with endemic occurrence of MRSA [76–80]. The problem is that unstructured and half-hearted infection control measures over time have prepared the ground for serious endemic MRSA [59]. Under such conditions, it may pay to do universal testing, isolation and decontamination of MRSA cases, as shown by Jain et al. in the United States [66, 67]. Ireland, having one of the highest rates of MRSA both in Europe and compared to the United States, reports that MRSA screening—universal or targeted—is better than no screening because it results in fewer MRSA infections [79]. All measures that reduce MRSA lead to savings, not just MRSA but also with regard to other resistant microbes [79]. Targeted screening and isolation is probably most effective in countries with more stress on infection control over the MRSA situation.

Rapid tests are successful. A prerequisite for successful screening and savings is that rapid tests are used as real quick tests on a daily basis, combined with the culture and PCR response within a few hours [18, 23, 51, 61, 63]. Patient rooms may be contaminated within a few hours to a day and thus fellow patients are at risk for infection [45, 51]. MRSA are detected in the air in most hospital rooms where MRSA patients are staying [55]. Colonized persons are greater infection spreaders than patients with clinical infections [55]. Therefore it is important to isolate patients from the start and use rapid tests to quickly clarify infectious condition.

49.5.4 Sanitation and Eradication of MRSA in Patients and Personnel

Without sanitation measures, MRSA may disappear spontaneously in approximately 10% of the cases within 1 month. In a study of 365 patients with prolonged admission and infected or colonized with MRSA and/or VRE, MRSA disappeared spontaneously in 11% after a median of 23 days and VRE in 18% after a median of 26.5 days [81]. Many persons are carriers of MRSA for years if sanitation is not performed, documented by several studies [18].

Daily baths of patients in chlorhexidine, regardless of MRSA status, are becoming popular in the United States but miss good documentation [82–88]. The main study included 74,000 patients at 74 ICUs for adults and showed that daily chlorhexidine bath reduced sepsis in patients infected with MRSA by 23% [82, 83]. If all were sanitized with chlorhexidine bath, regardless of MRSA status, the MRSA

sepsis was reduced by 37% and all sepsis cases with 44% [82, 83]. There are a number of important objections to this survey with regard to quality and documentation [84, 85]. A good global used disinfectant which is also used as surgical handwashing may not be used indiscriminately as a substitute for good infection control. There is a documented risk of developing resistance to chlorhexidine.

Sanitation (disinfection of person and environment) and eradication of cases infected/colonized with MRSA may be difficult and need often to be repeated several times before effect. Among 351 MRSA carriers who got institutional clearance of MRSA, most 70% were negative after 2 years, while about 30% relapsed [89]. However, the carrier state was only controlled by nasal samples [89]. It is especially important to eradicate MRSA in healthcare personnel and in patients that is going to be treated in the healthcare [23]. Among 510 healthcare personnel with MRSA, 88% successful eradication was reported by Albrich and Harbarth [90].

Chlorhexidine sanitation for clearance of carrier state of MRSA may eradicate the risk of infectious attack and transmission and prevent the skin and soft tissue infections. Among 3090 military with MRSA skin infections, the reduction of infections was 64% after implementation of chlorhexidine gluconate wash/shower on arrival at training camp and with six consecutive repetitions with chlorhexidine during their stay, in addition to advice on personal hygiene [88]. During high-endemic conditions, eradication of MRSA in infected patients may be very effective [91, 92]. Screening and sanitation of healthcare workers are best utilized and targeted, especially when it comes to superspreaders [18, 71, 92].

It is often recommended to have 5 days of sanitation, but experience suggests 10–14 days to get rid of the microbe [13–18]. Patients and personnel are then monitored so that the “isolation time” can be minimized.

49.5.5 Contamination of Environment, Equipment and Textile Uniforms

49.5.5.1 Environmental Infection

It is often a very fast contamination of rooms via contact and air from patients with MRSA [45, 51, 55]. More than 80% of environmental samples from patient rooms of MRSA patients may be positive [45]. MRSA carriers are transmitting MRSA as much to the environment as patients with infections do [93]. MRSA-type USA300 has great ability to contaminate and survive in the hospital environment and in homes [94]. Therefore environmental sanitation is important. Gas disinfection is recommended in difficult local conditions with a lot of equipment and with medical devices that cannot be cleaned internally [18, 95–97].

49.5.5.2 Personnel Attire Is Contaminated

During all care, examination and treatment, personnel most often have a close contact with the patients, which may lead to the transmission of the patient’s flora to the uniform—especially on the front and sleeves of staff’s outfits. The use of private clothes

in healthcare entails increased carrying state of microbes [98–101]. Resistant bacteria are commonly detected in clothes and other textiles, particularly at high patient occupancy and high rates of bacterial resistance in the department [99, 100]. Universal gowning and gloving and good hand hygiene when caring for patients have shown a reduced transmission of the patient's microbes to the staff clothing by 70% [99].

MRSA is easily transmitted in intensive care with a respirator, a catheter and contact with the head/neck area of the patient [101]. Gloves used “everywhere” without change pose a serious source of infection [102]. The healthcare workers use and change of uniforms is considered as “the emerging frontier” in epidemiologically important environmental surfaces [103].

49.5.5.3 Healthcare Worker

Outbreaks in hospitals are often linked to overcrowding, understaffing and increased workloads for staff [18, 21]. Healthcare personnel is considered as “source, vector or victim” with regard to MRSA infections [90]. Up to 5% of personnel in Northern Europe may be infected with MRSA [90]. In Paris, MRSA was detected in 10% of healthcare providers, associated with a high incidence among patients. Nurses who were most in contact with the patients had the greatest risk of becoming infected [104]. Carrier state on hands is common in MRSA-colonized persons, and hand disinfectant may fail, which makes testing of the hands and wrists necessary also by healthcare professionals [18, 53, 57, 105, 106].

49.5.5.4 Hand Hygiene and Use of Gloves

Hand hygiene is a problem in busy departments with understaffing, overcrowding and many patients on the corridor without access to washing or other hygiene, as observed by Norwegian hospitals that generally have occupancy rate of more than 100%. Infection barrier is the first thing that falls in busy departments. This is expensive for the healthcare system. More and more new and dangerous nosocomial microbes are spread in the hospital, including MRSA. Hand disinfection with alcohol 70% v/v was ineffective against MRSA in 40% of the cases, also earlier documented [26, 105, 106]. Therefore, good disposable gloves should always be used for any suspected infection, hand hygiene before and after using gloves.

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Vancomycin-Resistant Enterococci Prevention

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Abstract

Multidrug-resistant enterococci are selected by antibiotics, combined with lack of hygiene and infectious barriers and promoted by infected patients and carriers. The most common and serious types today are vancomycin-resistant enterococci, VRE, most commonly associated with *Enterococcus faecium*. From a few imported cases each year, VRE has become a large global problem in healthcare institutions. VRE is more than conventionally resistant against antibiotics and disinfectants and can withstand high temperatures encapsulated in biological material. Some types may be harder to control than the other, can cause more problems and have a very long environmental survival—up to 4 years. The infection is transmitted via direct and indirect contact, via faecal oral infection, via equipment, environment and textiles and occasionally via air. Everyone should be protected against infection with VRE since it is a highly preventable infectious disease. The following chapter is focused on practical measures to detect and prevent transmission of VRE in healthcare institutions.

Keywords

VRE · Vancomycin-resistant enterococci · *Enterococcus faecium* · Imported from abroad · Admission control · Pre-examination · Information · Screening · Isolation PPE · Decontamination of environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

50.1 Purpose

To prevent transmission of VRE between patients, staff, visitors, equipment, textiles and the environment [1–9]. In accordance with international and national laws and guidelines, neither patients nor personnel shall be subjected to unnecessary risk of infection with resistant and potentially dangerous bacteria such as VRE [1, 6, 7, 10–24].

50.2 Comprise

All close contacts of patients (patients in the same room, personnel, visitors, etc.) and all patient-related equipment, textiles, waste, etc.

50.3 Responsibility

The hospital's management is ensuring appropriate testing, isolation, control and treatment of patients with suspected/detected VRE infection.

The department's management has overall responsibility for the follow-up of routines and to report to the Director if preventive routines are not followed up, such as lack of isolation, contaminated equipment, lack of expertise and personnel and the like [1, 8, 9].

Employees are responsible for following the department's routines in suspected VRE infection.

Information. Medical doctor or other healthcare provider/home care/hospital department/other healthcare institution is obliged to report known or suspected/exposed VRE (current or previously proven) to the recipient and to others who are going to treat/investigate the patient.

50.4 Practical Measures

Note: The treatment facilities (investigation, care) should not be weakened if infected with VRE.

Preliminary examination. Ask the patient, relatives or referring physician before admission/check, etc. if the patient has been infected or exposed to VRE [1, 6, 8].

If detected infection/exposed to infection, there are at least two possibilities: (a) wait for admission/treatment until the infection status is cleared; (b) isolate and treat the patient as infectious until infection status has been clarified.

50.4.1 The VRE-Infected Patient Is Isolated as for MRSA-Positive Patients

- Isolate as contact infection in a single room—immediately.
- Wear protective clothing, gloves and surgical mask/cap. Room-bound shoes or shoe covers are recommended. Learn to take on and off personal protective equipment (PPE).

50.4.2 Screening for VRE

- All import patients, patients who have been hospitalized/treated in the health service abroad for the last 12 months [1, 6, 8, 9, 12].
- All patients who have been admitted/treated at healthcare institution with ongoing VRE outbreaks for the last 12 months.
- All patients who have been exposed to VRE infection, i.e. been in the same room and/or used the same equipment as a VRE-infected person.
- Faeces test or perineal swab test.
- Rapid test for VRE is recommended.
- Inform the laboratory and ask for a telephone answer.
- For more quicker answer, do not send the sample by mail!

50.4.3 Proven VRE-Infected Patient

The VRE patient is isolated and treated as MRSA-positive patients [1, 6, 8, 9].

- If several cases of VRE in the ward, evaluate intake of new patients (like MRSA), and test all patients.
- Inform all healthcare institutions and departments that have been in contact with the patient.
- Avoid transport/transfer of VRE-positive patients between wards/departments/institutions.
- *Flagging and control.* VRE-positive patients should be isolated and checked for VRE when readmitted to health institutions.
- *The journal is labelled* VRE under critical information.
- *Cohort in a separate unit* with own services; store rooms for textiles and equipment, which are only used by the unit. A separate competent personnel should be attached to the unit and not participate in care/treatment elsewhere. Do *not mix* VRE-positive patients with MRSA-positive patients!
- Ready-treated patients (for basic disease) can be transferred to the home if patient/relatives, home care and primary healthcare services are well-informed about infection prevention and enhanced environmental hygiene.

50.4.4 VRE-Exposed Patients

- Patients exposed to infection are tested and isolated separately (as for MRSA).
- Isolated in single room with own toilet/shower until infection has been clarified.
- Declared as not infected if four consecutive rectal samples/faeces (+ clinical samples) taken on separate days are negative in a patient who has not been on

antibiotics for the past 14 days and has previously not been VRE-positive. If these samples are negative, there is little risk of infection.

- In uncertain and persistent exposure to infection in the ward, implement control specimens for exposed patients every 14 days to once per month for 6 months.

50.4.5 Other Patients at the Ward with Outbreak of VRE

- Other patients at the department may be exposed to infection if they are taken care of by the same VRE-exposed personnel, common service room, living room, kitchen, serving, etc. When submitting clinical samples to the laboratory, mark them with “VRE”. Evaluate testing of all in-patient patients and contact infection control personnel.
- Non-infected patients in the department must be protected from infection by VRE-exposed employees by being treated with “protective isolation”; use surgical mask/cap, gloves and gown during the period of the outbreak (see MRSA).

50.4.6 Large Outbreaks

- Close the ward for new admissions until tracing is finished and the measures are organized.
- Divide the ward into three units:
 - Isolation unit for all VRE-positive patients.
 - Isolation unit for all VRE-exposed patients.
 - Unit for patients who are not/have not been exposed to VRE infection.

Staff are informed about infection, but not tested:

- Employees are informed of infection protection, PPE and good hand hygiene and must comply strictly with the prescribed isolation measures.
- Personnel working on a VRE-infected unit with direct patient care do not participate in serving of food, cleaning or other common service work.
- Personnel shall not work in other units while working in a VRE device. If necessary, inform the department manager/infection control personnel.
- Employees are not tested for VRE infection and may therefore be spreaders in the environment.
- In case of repeated outbreaks associated with some of the staff, testing may be applicable. This must be discussed with the infection control doctor/the hospital's medical officer since there are no good routines for sanitation/disinfection of VRE, as the bacterium is part of normal intestinal flora [1, 13, 18–20].

50.4.7 Environmental Sanitation and Eradication Is Important!

- VRE is resistant to several disinfectants and to heat. Dishwashers and decontaminators must have a temperature above 85 °C!
- *Extra daily disinfection and cleaning* of floors and surfaces in the patient's room is carried out. In addition, all contact points are treated with alcoholic wipes three times/day. As a disinfectant use 5% chloramine or peracetic acid or other chemical that has proven effect on VRE. Virkon may have an uncertain effect. All cleaning equipment must be treated as contaminated and treated in a decontaminator. VRE can survive in the environment for 3–4 years if not removed well enough [1, 2, 25].
- *Final disinfection* after termination of stay is carried out with thorough decontamination of the rooms the patient has used. Optionally, hydrogen peroxide gas can be used in rooms with a lot of equipment, followed by good disinfection of all surfaces.
- Disinfect all rooms where the patient has stayed before infection was detected!
- Cleaners must follow routines for using PPE equipment: surgical mask/cap, gloves, gown, room-bound shoes/shoe covers—learn taking on and off PPE! See routines for MRSA!
- Final disinfection is also assessed at other parts of the department since employees are not tested.

50.4.8 Control

- Antibiotics and type of antibiotics should be checked on units where VRE occurs. Reduce the use of third-generation cephalosporins, carbapenems and other broad spectrums, as well as metronidazole. Do not use vancomycin and similar preparations, if unnecessary. Contact infection medicine physician/infection control doctor for advice.
- Workload and patient care ratio are known risk factors and must be checked where VRE occurs [1].
- Update personnel with regard to hand hygiene and infection protection, isolation measures and treatment of infectious waste/equipment/clothing, etc.

50.4.9 Transport and Transfers

- For examinations, treatment etc. elsewhere, message about VRE is sent in advance to the recipient. The patient arrives in a clean bed with clean clothes and a surgical mask is used if there is cough. The recipient treats the patient as contact precaution (see above) and with decontamination of the room afterwards.

- When transferring between healthcare levels, healthcare personnel must be informed in advance of infection status. This includes ambulance transport.
- The patient and possibly relatives are informed of the duty to provide information in the health service.
- Visitors/relatives follow the infection protection regime of the institution and do not use the hospital's common rooms.

50.4.10 Follow-Up of VRE-Infected Patient

Prolonged condition and carrier state are usually not disinfected! Negative faeces in between positive findings is natural, also after attempting disinfection [26–28]. A carrier period of at least 45–50 days is common (median 42 days), and it may last for almost 2 years with relapses [1, 26–28]. Reinfection in a contaminated home environment or patient room, etc. cannot be excluded since the bacterium survives for many years in the environment [25]. Therefore, environmental sanitation and eradication is very important. In the case of new antibiotic cures, such strains are most often selected in the faeces. Chronic carrier state may be relevant.

- In the case of proven VRE, four consecutive test sets taken at 1-week intervals shall be negative before the person is defined as *low VRE risk*. Prerequisite is that the sampling starts at least 14 days after the end of the use of antibacterial agents (and at least 10 days after completion of disinfection if this is completed).
- *After four consecutive negative VRE samples*, follow-up of the patient is started for 1 year to ensure that the infection disappears. Initially, samples are often taken to prevent spread of infection to patients, personnel and the environment. If at least 20 consecutive tests are negative during 1 year and no positive tests in between, the patient is considered to be a noncarrier of VRE.

50.4.11 Important Information

If there has been a significant spread of infection in the environment of a department, repeated patient checks may occur, in addition to common routines.

In long-term institutions such as nursing homes, VRE can spread a large extent if no special measures are taken over time. See special measures for infection monitoring of VRE-positive patients at long-term institutions [8].

50.5 Background Information

Antibiotics, combined with lack of hygiene and infectious barriers and infected patients, promote selection of multidrug-resistant enterococci [1, 2]. The most common and serious type today is vancomycin-resistant enterococci (VRE), especially *Enterococcus faecium* [1, 2]. From a few imported cases each year, VRE has become a problem at health institutions all over the world, including Scandinavia [1–9].

- In accordance with international and national laws and guidelines, neither patients nor personnel shall be subjected to unnecessary risk of infection with resistant and potentially dangerous bacteria such as VRE [1, 6, 7, 10–24].
- *The infection is transmitted via direct and indirect contact, faecal-oral infection, via equipment, environment and textiles and occasionally via air [1, 7].*
- Enterococci are normal skin and intestinal bacteria in humans and rarely cause infections in healthy subjects [1]. They are very robust, long-term survivors, up to 4 years in the environment—on bedside tables, bedside borders and other contact points—and they are naturally resistant to a variety of common antibiotics, chemicals and heat treatment [1, 2, 25].
- Enterococci in the intestine have been able to absorb and give rise to different resistance genes/signals to other bacteria. High consumption of antimicrobial agents leads to the selection and development of special antibiotic-resistant enterococci like VRE [1]. VRE can at the same time be resistant to ampicillin and gentamicin, which reduces treatment options [29].
- Clinical VRE infection is particularly related to urinary tract infections, sepsis, endocarditis and postoperative wound infection—especially in the abdominal region—in elderly long-term patients with kidney disease, haematological disease or cancerous diseases [1, 2, 30, 31].
- As in most other countries in Europe, VRE is an increasing problem in Norwegian health institutions and in home nursing care [1, 8]. Therefore, the measures to prevent spread of infection are extra strict here [8]. There is no search for VRE outside the healthcare service. VRE poses no risk to healthy persons and usually low risk to patients with normal infection defences.

50.5.1 Occurrence, Costs and Mortality

VRE was first detected in Europe in the 1980s in connection with the use of a vancomycin-like growth enhancer, avoparcin, in chicken feed, which was then banned around 1995 in Norway and in 1997 in Europe [1, 30–34]. Some years later, VRE-positive patients were detected in hospitals in the United States, linked to a high consumption of vancomycin in patients with *Clostridium difficile* infections and to lack of isolation measures around such patients [1, 30, 31].

For the last 10–15 years, VRE has caused increasing problems for a large number of patients in the United States, Europe and the rest of the world, especially related to hospital outbreaks and outbreaks in long-term institutions [1, 4, 7, 24, 29–31, 34–41].

In Sweden and Denmark, VRE has had a dramatic increase in patients, with a high environmental pollution of VRE in animal production (chicken, pigs) and in sewage, in the last 5–10 years [24, 29, 35–39]. The same increase is observed in Germany, England, Ireland and a number of other countries (see Fig. 50.1, source: ECDC) [35, 42]. In Sweden, the outbreak started in 2007, and in Denmark there was an increase among hospital patients registered in 2010 [29].

In Norway, VRE was until 2010 largely an imported infection with 0–8 cases annually [3]. In 2010, a VRE (vanB) hospital outbreak started at Haukeland

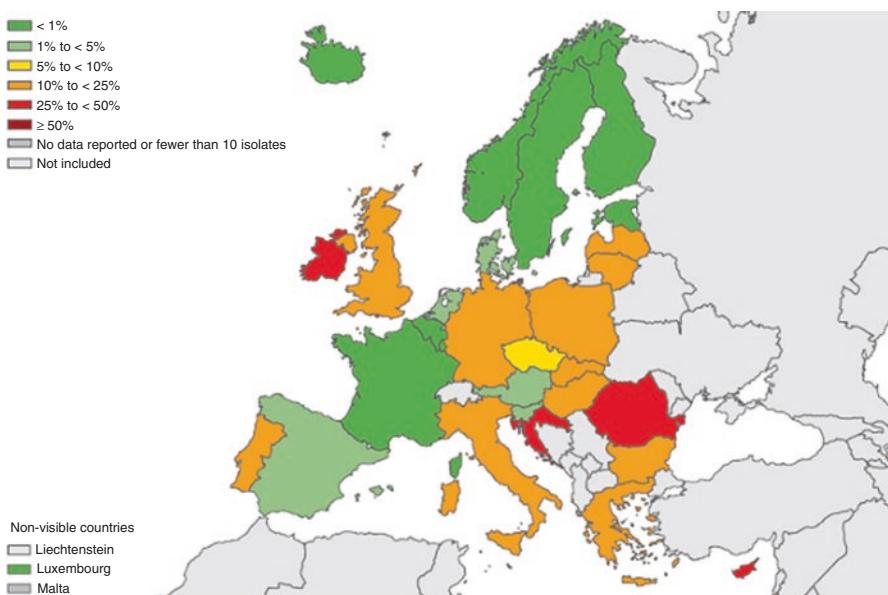


Fig. 50.1 Percentage (%) of invasive *Enterococcus faecium* isolates resistant to vancomycin, by country, EU/EEA countries, 2015. Source: ECDC, January 2017 [35]

University Hospital, Bergen, with more than 150 cases [4, 5]. The same type had been registered a few years earlier. From 2011 on, there have been several minor outbreaks of VRE (vanA) at hospitals and nursing homes in Eastern Norway and in Central Norway [7, 9, 34].

Food industry has the control. A significant problem today is that food manufacturers and government authorities do not stop the development of severe antibacterial resistance in food and animal production. From 1994 on, the regular control of all food and drink done by Norwegian Food Safety Authority was shut down. Instead the food industry itself took over the control, which led to a reckless profit in the food industry, strongly linked to the unjustifiable consumption of growth-stimulated substances with antimicrobial effects [43, 44].

Mortality. The combination of VRE- and ESBL-producing *Enterobacteriaceae* in the intestine in patients with haematological and other cancer diseases is associated with sepsis and increased mortality with these agents, and therefore faeces screening is recommended for such patients [45]. Multidrug-resistant enterococci is also a serious risk of surgery [46]. A study of end-stage renal failure did not show increased mortality associated with VRE, but extended admission time [47]. Compared to vancomycin-sensitive enterococci, VRE has about twice as high mortality [1, 30].

Costs generated by VRE infection (prolonged stay in hospital, isolation, medication, etc.) are high, and most measures that reduce spread of infection are cost-effective [1, 30, 31, 48, 49].

50.5.2 Infection Risk

Transmission of VRE occurs mainly through direct and indirect contact, faecal-oral infections (foods, hands, etc.), via equipment, textiles, uniform and occasionally via air; by re-aerosols from treatment, examination and care and by cleaning. The environment contamination is widespread and lasting and is a risk to fellow patients if not removed [1, 25, 27, 28, 50–54].

VRE is a threat to nursing homes and long-term institutions due to lack of isolation and lack of competent healthcare personnel, combined with unusually robust and resistant bacteria with long survival in the environment. Long-term problems in some countries are an increase in patients that are at the same time infected with a mixture of multidrug-resistant bacteria, such as VRE, MRSA, *C. difficile*, ESBL and/or multidrug-resistant gram-negative rod bacteria and which eventually develop combined “worst-case microbes” like vancomycin-resistant MRSA during major antibiotic pressure [26, 35, 45, 55–58].

Patient groups who often have infections and use a lot of antibiotics that affect the intestinal flora for long periods are prone to infections/carrier state with more resistant bacteria, such as VRE [1]. Single room with own toilet and bath and good environmental hygiene around patients who use a lot of antibiotics will generally reduce the spread of resistant microbes.

Patients from abroad are more likely to be infected/colonized with VRE and other resistant bacteria.

Clostridium difficile infections treated with vancomycin are associated with the risk of developing VRE [1, 21, 22, 26, 30, 31].

In endemic areas for VRE, risk is particularly related to haemodialysis patients, elderly patients and MRSA-infected patients during the last year, admitted to long-term institutions and admittance to the hospital during the past year [30].

50.5.3 Control Over VRE: Isolation and Testing

VRE is a preventable infectious disease if recommendations are followed [1, 6, 8, 15, 21–24]. CDC recommended in its isolation guide of VRE (1994) contact isolation, training in infection protection, enhanced hand hygiene, screening for VRE and careful use of certain types of antibiotics [21–23]. Now it also generally recommended isolation and screening on *suspicion* of VRE (pre-emptive contact isolation), i.e. high-risk cases such as patients from the health service abroad last 12 months, previous VRE-positive patients or patients exposed to VRE infection [1, 6, 8, 21–23, 30, 31, 41, 48]. Nevertheless, there has been a global spread of VRE over many years, and the guidelines are often not followed [59].

50.5.3.1 Contact Isolation (Contact Precaution, CP): Not Effective Enough

In highly endemic areas where 3–10% of hospitalized patients are infected/carriers with VRE, the use of CP (gloves, gown and isolate/single room) is discussed—if it

has any protective effect against the spread of VRE in hospitals [30, 31, 60–63]. Many studies are inadequate with regard to documentation and isolation conditions or have low compliance with the use of hand hygiene and personal protection equipment, etc. [31, 60]. Examples of some studies are shown below.

- About 26,200 patients at 20 ICUs in the United States were tested for MRSA and VRE during arrival and discharge during a period of 10 months [61]. The control group of patients was contact- isolated using CP (gloves and gown) if detected infection (MRSA or VRE), according to recommendations from CDC [23]. All patients in the intervention group were universally contact-isolated with CP, regardless of infection status. Both in the control and intervention group, a non-significant reduction of MRSA or VRE infections while the patients were in the department were recorded [61]. For MRSA alone, there was a significant but low effect, while for VRE infection separately, there was no difference in effect between the two groups. However, the general CP routine (intervention) for all patients led to fewer visits to the patient’s room, increased compliance with hand hygiene when leaving the room and no significant adverse effects on the patients [61].
- Another American study demonstrated high transmission of VRE infection among patients admitted to a medical intensive care unit, and no effect of CP isolation [62]. Patient samples were taken upon admission, while in-patient and at the discharge. During a 3-month phase, VRE-positive patients became CP-isolated (CDC) [23, 62]. During the next 3-month phase, all patients were treated with only general glove use and no isolation. During the stay in ICU, 18% (35/192) were VRE infected in phase one using CP, against 0.5% (1/192) when admitted. In phase two, with glove use on all patients, 14% (35/257) were infected, against 0/257 when admitted! [62]. It was concluded that the use of only gloves for all patients in the ICU gave the same result as CP isolation of patients with proven infection [62]. Isolation procedures were not effective enough.
- Two ICU groups of a total of approximately 9000 patients were compared [63]. The intervention group were using CP isolation in all patients with proven VRE/ MRSA and universal glove use for contact with all other patients, as well as rapid information on test results upon admission [63]. The control group used CP isolation for known infections of MRSA and VRE; they were also tested at admittance, but no response was given on the result to the ward. There was no difference between the two groups—both with CP in their “arm”. However, there was a low compliance with the use of CP. The proportion infected was approximately the same upon entry as at discharge, in contrary to the former study [62, 63].

50.5.3.2 Rapid Control in Case of Minor Outbreaks and Intensive Measures

- Lucet et al. describe a VRE outbreak in Paris in 2007, with a total of 39 VRE cases before the outbreak stopped after 4 weeks [64]. The index patient had urinary tract infections with VRE and infected fellow patient in the same room. Screening was carried out, and two new cases were found, and after a new screening round of the department, three new cases were discovered. The index patient had moved to another ward before VRE findings were known, and there he infected three new

patients. All patients were isolated, the staff were informed and trained in infection control and tracing and a screening program was followed up over time for high-risk units, defined as intensive medicine, renal medicine, haemodialysis, rehabilitation and infection units [64]. A separate cohort unit for patients with VRE was established, with own personnel and equipment and with environmental disinfection twice a day. VRE patients were followed up when readmitted. It was recommended to avoid the use of third-generation cephalosporins, glycopeptides and amoxicillin—clavulanic acid, imipenem, piperacillin-tazobactam and metronidazole [64]. Readmitted VRE carriers (flagged out) were CP-isolated until three rectal samples at 1 week interval were negative [64].

- An outbreak at Ullevål University Hospital, spring 2011, included 13 VRE cases in an open haemodialysis department that had 70 patients for dialysis treatment on 22 treatment sites [9]. The index patient had been admitted to all four hospitals in Oslo (OUS), had received a lot of antibiotics over time and was known as VRE-positive. Because of some misunderstanding, the person was not isolated during dialysis treatments and divided dialysis site with a number of other patients who eventually became infected. The ward was run down and heavily overcrowded [9]. The outbreak stopped within 1 month after the infection was detected, using strict isolation of infected carriers (PPE: gloves, gown, surgical mask/cap), as well as general use of gown, gloves and surgical mask/cap on contact with all other patients. There was no intake of new patients, but all 70 previous patients were still treated by the unit under strict hygiene measures. No more cases were registered than the 13, and 1 year later, all were negative [9].

50.5.3.3 Contact- and Airborne Isolation as by MRSA Is Recommended

Contact isolation for VRE has not led to effective infection control in endemic VRE infection, although most studies are inadequate [33, 31, 60–63]. Therefore, these patients should be isolated as MRSA by contact- and airborne isolation and with strict enhanced environmental hygiene [1, 2, 8, 9, 64, 65].

50.5.3.4 Testing for VRE

Routine testing for VRE has been discussed and is recommended today for risk patients while personnel should usually not be tested [7–9, 48, 64, 66, 67].

50.5.4 Spread of VRE Via Personnel/Visitors/Attendees, Equipment, Textiles and Environment

VRE is more than conventional resistant against antibiotics, disinfectants (chloramine 5% and peracetic acid have good effects) and against heat (usually killed after a certain treatment time above 85 °C but can withstand higher temperatures encapsulated in biological material) [1]. Some VRE types may be harder to control than others. Vancomycin-resistant *Enterococcus faecium* can cause more problems than *E. faecalis*, associated with a very long environmental survival of *E. faecium* for 4 years [25, 40].

VRE is like other bacteria in the intestine, does usually not give disease in a healthy person but survives in the intestine for a long time and easily reaches the skin and hands. Infection is transmitted primarily by contact. This means that the infection is transmitted through unclean hands or that an infected patient has “left” the bacterium on items like washing, toilet, door handles or the like. Equipment such as BT apparatus, stethoscope and the like are prone to infection unless routine infection is performed between patients.

Carriers of the bacterium usually have no symptoms and should not be treated with antibiotics. Some sanitation attempts have been done, including the use of Bacitracin 30,000 IU three times for 15 days or whole body wash with chlorhexidine [68, 69]. Studies of 82 VRE carriers showed a carrier period of median 42 days, maximum measured was 708 days [28]. Antibiotics are only given to patients with clinical VRE infection, which occurs relatively rarely. There are a number of good antimicrobial medicaments that can be used if there should be a clinical infection.

Hygiene and environmental control provide good protection against infection [70]. Good cleaning and disinfection of rooms, surfaces and equipment can stop the spread of infections [70]. There is, however, a high risk of transmission to fellow patients, even after apparently good disinfection and cleaning before the next patient [30]. The more colonized by VRE, the more environmental contamination and infection pressure; especially in faecal incontinence and when using certain types of antibiotics [30, 70–72]. Good environmental sanitation and routine disinfection of equipment such as stethoscopes, blood pressure devices, etc., lead to a significant decrease in VRE in endemic areas [30, 53, 54, 70]. Therefore, environmental sanitation is a core area for measures against VRE infection [30, 53, 54, 70, 73–75].

Transport, patient relocation, overcrowding, many patients on same room, etc. are known factors that increase the risk of cross contamination and spread of infections [9]. Information is important when moving patient with VRE.

Workload and too high patient-nurse ratio are very well-known risk factors. Excessive activity often leads to a breach of hygiene barriers; patients get infections, then they receive antibiotics for infections, then they spread to others because of infectious barriers are breached, then workload increases on employees, then more patients are infected and must be isolated, etc., and the activity is stopped up.

Healthcare personnel are prone to be contaminated via hands and uniforms, other textiles and equipment [30]. VRE is found on both gloves and gown in larger or smaller numbers after treatment of VRE-infected patients [76–84]. Although hand hygiene is not always 100% effective [83, 84], employee should constantly be encouraged to and given time to this important procedure in all work with patients.

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Multidrug-Resistant Gram-Negative Rods

51

Abstract

Overuse of antibiotics, lack of infection control and increased mobility in the population result in the spread of multidrug-resistant (MDR or MDRO resistant to many types of antibiotics) gram-negative bacteria. *Escherichia coli* are present in intestines and faeces and present in the environment (toilet, bathrooms, etc.). Others, like *Klebsiella* sp., *Enterobacter* sp., *Serratia*, *Proteus*, *Citrobacter*, *Pseudomonas* sp., *Acinetobacter* sp., *Burkholderia cepacia*, *Stenotrophomonas maltophilia*, etc. may be contaminants in the environment and sometimes colonize or infect the patient. MDR bacteria may be resistant to all penicillins and cephalosporins (ESBL), all carbapenems (CRE) or quinolones or aminoglycosides. They are robust survivors who migrate between humans, animals and the environment and may tolerate dry conditions, antibiotics and disinfectants. The most vulnerable to infections are persons with reduced infection defence, elderly and new-borns, and the main arena is usually in the healthcare system. Good infection control with removal of microbes from the environment and equipment is among the best preventive measures against the spread of these bacteria. The following chapter is focused on practical measures to detect and prevent transmission of multidrug-resistant gram-negative rods in healthcare institutions.

Keywords

Gram-negative bacteria · Multidrug resistance · MDR · Multidrug-resistant organisms · MDRO · Gram-negative rod · *Enterobacteriaceae* · *Escherichia coli* · *Klebsiella* sp. · *Serratia* · *Enterobacter* sp. · *Pseudomonas* · *Acinetobacter* · *Burkholderia cepacia* · ESBL · Extended beta-lactamases · CRE · Carbapenemase production · Super resistance · NDM-1 · Aminoglycosides · Fluoroquinolone · Cephalosporins · Imported from abroad · Admission control · Pre-examination Information · Screening · Isolation · PPE · Decontamination of environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

51.1 Purpose

Prevent transmission of resistant gram-negative rod bacteria to patients, staff and the environment. Prevent imported infection of super resistant bacteria through patients, personnel and/or visitors.

51.2 Comprise

- All close contacts (patients in the same room, nursing staff, relatives, others).
 - Patient room and equipment, toilet, ward office, living room, disinfection room, storage rooms, kitchen, etc.
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51.3 Responsibility

The hospital's management is responsible, according to law and regulations [1–9], to ensure proper isolation and control of patients with suspected/proven infection with resistant microbes and that written procedures are available.

The department management has the overall responsibility for the follow-up of routines and to report to the director if preventive infection control routines are not followed up for suspected/detected cases with multidrug-resistant bacteria, such as lack of isolation, disinfection routines, lack of expertise and use of PPE and the like [10] (see isolation routines).

Employees are responsible for following the department's routines.

Information is a duty. Medical doctor or other healthcare provider/home care/hospital department/healthcare institution is obliged to report known or suspected/exposed multidrug-resistant bacteria (current or previously proven) to the recipient and to others who are going to treat/examine the patient.

51.4 Practical Measures

Overuse of antibiotics, lack of infection control and increased mobility in the population results in the spread of multidrug-resistant (MDR) microbes (resistant to many antibacterial agents) as gram-negative rods [10–12]. Gram-negative rods are robust survivors in the environment, migrating between humans, animals and the environment and tolerating drying, antibiotics and disinfectants [10–46].

- Infection control measures are same for all MDR gram-negative bacteria.
- Patients should be examined and treated properly and isolation should be facilitated in the best possible way.
- The general hygiene standard should be high with a prudent use of antibiotics.

51.4.1 Check upon Admission

Patient receipt form should contain current questions regarding infection. See admittance to hospital.

51.4.2 Notification

Notification of proven multidrug-resistant gram-negative bacteria should be sent immediately to relevant health contacts at all levels that have received, examined or treated patients exposed to infection. The ambulance unit that serves the relevant institution in which it is infected must also be notified.

Outbreaks are reported to the infection control personnel, the hospital director, the county doctor and the National Public Health Institute.

51.4.3 Screening at Admittance/Readmittance

- Patients contact with healthcare abroad during the last 12 months.
- Patients have been in a health institution with ongoing outbreak of resistant, gram-negative bacteria or previously infected.
- Screened as for MRSA, + any clinical samples.
- Personnel only screened if they are patients (or in special situations).
- *Remember:* Request the laboratory for examination of resistant bacteria—written on the referral!

51.4.4 Admittance/Treatment/Examination

The patient is immediately isolated. Exposed rooms are disinfected and cleaned (only where the patient has been). Microbial sampling is done.

51.4.4.1 Good General Hand Hygiene

The patient's and staff's hand hygiene prevents spread of infection. Also include visitors.

51.4.4.2 Good Information About Infection Prevention

To all employees, including extra workers and informed, and to the patient and visit to the patient.

51.4.4.3 Isolation and Use of Personal Protective Equipment (PPE)

- *Infected patient or carrier* with multidrug-resistant bacteria is isolated in a single room with its own toilet/shower. The infection or carrier state is often prolonged and alternates between positive and negative test findings. A well-equipped

negative air pressure isolate with good space and direct entrance is a good long-term solution.

- *Exposed patients* are also isolated in single room with own toilet/shower until the infection state has been clarified. Declared non-infected if *three* consecutive rectum pencils/faecal samples and clinical samples from drain, urine catheter, wound, etc. taken on separate days are negative, in a patient who has not been on antibiotic past 14 days and not previously infected with multidrug-resistant bacteria.
- *Cohort isolation.* Patients who are infected with the same multiresistant bacterium can be isolated in the same room, if they not have any other infection at the same time (MRSA, VRE, etc.).
- *Infection control equipment.* Personnel who treat/clean/visit infected or exposed patients use surgical mask, cap, gown with long sleeves and cuff and gloves. Room-bound shoes and shoe covers may be used. A chlorine mat outside the door can be used.
- Take off used PPE in anteroom or sluice or, if not, at the door in the patient's room. Learn taking off PPE! Never take off used PPE outside—on a common corridor—and never deposit used, contaminated equipment on the corridor!
- *Protect the uniform and hair/head* to avoid contamination. Use disposable equipment.
- *Visitors* follow the department's routines. See Chaps. 14–16 on isolation routines.

51.4.4.4 Personnel in Work with Multidrug-Resistant Cases

- *Staff* who care and treat these patients do not participate in work with serving foodstuffs, cleaning or other common service work.
- *Staff* should not work at other wards at the same time.
- *Testing of personnel* is not recommended. Exceptions may be suspected of repeated spread. Should be discussed with infection control personnel.
- *In case of personnel infected.* If the person is healthy and has a proper personal hygiene, there should be no work restriction, except for repeated outbreaks associated with the same person.
- *Transmission of infection to healthcare professionals and family/visitors* is likely to occur unless the use of PPE and other measures is carried out in a proper manner.

51.4.4.5 Disinfection and Cleaning

- *Multidrug-resistant bacteria have varyingly resistance* to disinfectants (can even grow in disinfectants) and to heat. Dishwashers and decontaminators must have temperatures above 85 °C! Textiles should be washed at temperatures above 85 °C (10 min × 2).
- *Extra daily cleaning* of floors and surfaces in the patient's room is carried out. In addition, all contact points are wiped over with alcohol three times a day. As a disinfectant use 5% chloramine, chlorine, household bleach, or per-acetic acid. "Virkon" may have an uncertain effect. All cleaning equipment must be treated

as infectious. Multiresistant bacteria can survive in the environment for several months to years if not removed well enough.

- *Final disinfection* after completion of stay is carried out with thorough decontamination, possibly by hydrogen peroxide gas with spore control, followed by main cleaning in the rooms the patient has used [47–50]. See *Isolation regimes*.

51.4.4.6 Transport and Transfer

- For examinations, treatment, etc. elsewhere, message about multidrug-resistant bacteria is sent in advance to the recipient. The patient arrives in a clean bed with clean clothes and a surgical mask is used if coughing. The recipient treats the patient as contact precaution (see above) and with decontamination of the room afterwards.
- When transferring between healthcare levels, healthcare personnel must be informed in advance of infection status. This includes ambulance transport.
- The patient and possibly relatives are informed of the duty to provide information in the health service.
- Visitors/relatives follow the infection protection regime of the institution and do not use the hospital's common rooms.

51.4.4.7 Check and Control

- Antibiotics consumption and type of antibiotics should be checked. Reduce the use of broad-spectrum agents (cephalosporins, carbapenems, ciprofloxacin). Contact infection medicine physician/infection control doctor for advice.
- Carrier status should not usually be treated with antibiotics.
- Workload and patient/care ratio are known risk factors and must be checked.
- Update personnel with regard to hand hygiene and infection protection, isolation measures and treatment of infectious waste/equipment/clothing, etc.
- Overcrowding and corridor-beds pose a risk of spreading! [26]
- Training/review of infection protection, isolation measures and treatment of infectious waste/equipment/clothes, etc. are important.

51.4.5 Unexpected Finding of Multidrug-Resistant Bacteria in the Ward

- Consider intake stop while infection tracing is in progress.
- The patient and exposed patients are isolated separately.
- At least three rectal samples (+ any clinical material from the wound, drain, urine, catheters) on separate days from each exposed patient.
- Eventually, samples from all patients in the same department. Clinical samples are examined for these bacteria, inform about the problem in the referral to the laboratory.
- Notify the units that have treated/examined the patient for the last 12 months. Contact infection control personnel for advice.

- If several cases are infected, extend the infection tracing to the units that have treated/examined the patient for the last 12 months.
- It is not recommended to take samples from the staff.
- While infection tracing is in progress, the ward is treated as with MRSA outbreaks with use of PPE in the care of all patients. The patients are staying in their own rooms and have no common activities with other patients on the ward.
- Buffet service ceases, including coffee and other vending machines in the actual ward.

51.4.6 Major Outbreaks of Multidrug-Resistant Bacteria

- Admission stop until infection tracing is complete and the department/hospital is organized.
- Divide the patients eventually into three units:
 - Cohort isolation unit for all patients with proven infection
 - Cohort isolation unit for all patients exposed to infection—until status is clarified
 - Unit for nonexposed/exposed patients

51.4.7 Microbial Sampling

Rectal pencil, faeces sample and any clinical trial material (urine, drain, wound) are sent for growth on selective media for 24–48 h. The laboratory calls out findings of multiresistant bacteria. Rapid sampling and test response are required to stop major outbreaks.

Exposed patients: minimum three rectal samples (+ clinical trials) in 3 separate days. If the samples are negative, there is little likelihood of infection.

51.4.8 Follow-Up of Patients Still Exposed to Multiresistant Bacteria

In case of uncertainty and persistent exposure to infection in the ward, control tests are carried out over a period of approximately 6 months, depending on the infection and in collaboration with the infection control doctor. Clinical samples from the department are labelled. Note multiresistant bacteria.

51.4.9 Follow-Up of Patients with Multidrug-Resistant, Gram-Negative Bacteria

- *Prolonged condition: the patient is usually not decontaminated.* Negative faeces samples in between positive are natural. In any case, it may be considered as a

long-term infectious disease for some months—depending on the type of gram-negative bacteria and use of antibiotics.

- Reinfection in the home environment/patient room, etc. cannot be excluded. In the case of antibiotic treatment, such strains are selected in the environment.
- *Patients are isolated like MRSA routines* and checked for multiresistant bacteria upon admission to another health institution.
- *Cohort in a separate infection control unit* can be used in case of outbreak where several persons are infected/carrier with the same bacterial type. The unit must have its own service rooms, stockpiles, sterile storage rooms, waste rooms, kitchens, etc., which are only used by the unit. Own competent personnel should be affiliated with the unit and shall not participate in care/treatment elsewhere. Do not mix patients with multidrug-resistant gram-negative bacteria with MRSA- or VRE-positive patients!
- *Patient journal is flagged out*—critical information.
- *Negative control* tests are followed up for 1 year with samples taken after 3, 6, 9, and 12 months. If at least 15 consecutive tests are negative during 1 year, the patient is considered to be free of the actual microbe.

51.4.10 When to Terminate Isolation?

Infected patients with risk factors, repeated carrier state or infection, wounds, drainage, eczema, etc., should be isolated until several controls have been completed. There is a release of, from the skin and hair, bedclothes, own clothes and equipment, relatively large amounts of bacteria, some of which may be multiresistant. A very good daily cleaning with daily disinfection of floors, surfaces and central points and good patient hygiene are important. In hospitals, the patient should be isolated during the admission period.

Infected patients with reduced risk. First-time infected with multidrug-resistant bacteria and *without* wounds/drainage/skin disorders. After *three consecutive negative* test sets are taken properly (sampling starts at least 14 days after discontinuation of antibacterial agents), the likelihood of infection risk is reduced. A carrier state of several months is common as is relapse after shorter or longer time. A careful transition from isolation to fewer infection prevention measures is necessary in order not to infect other patients and personnel.

Special measures for follow-up are conducted at home care, nursing homes and long-term institutions [11].

51.5 Background Information

Multidrug-resistant (MDR) gram-negative bacteria are challenges in European hospitals with absence of guidelines, isolation capacity and lack of competent healthcare professionals (Figs. 51.1 and 51.2). In many countries, there is, in addition, an increase in patients that are infected at the same time with a mixture of

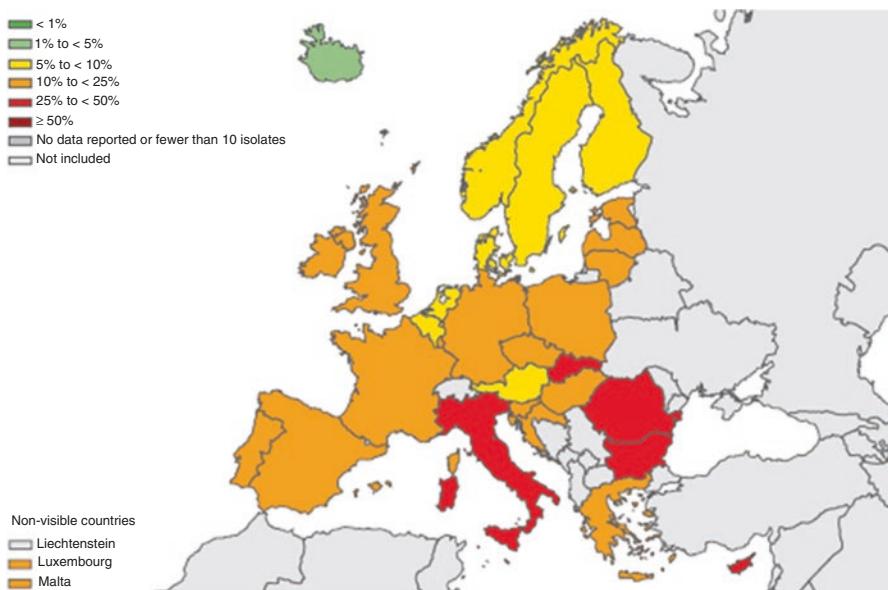


Fig. 51.1 ESBL resistance in invasive *E. coli* isolates in EU/EEA countries, 2015. Source: ECDC, 2017 [43]

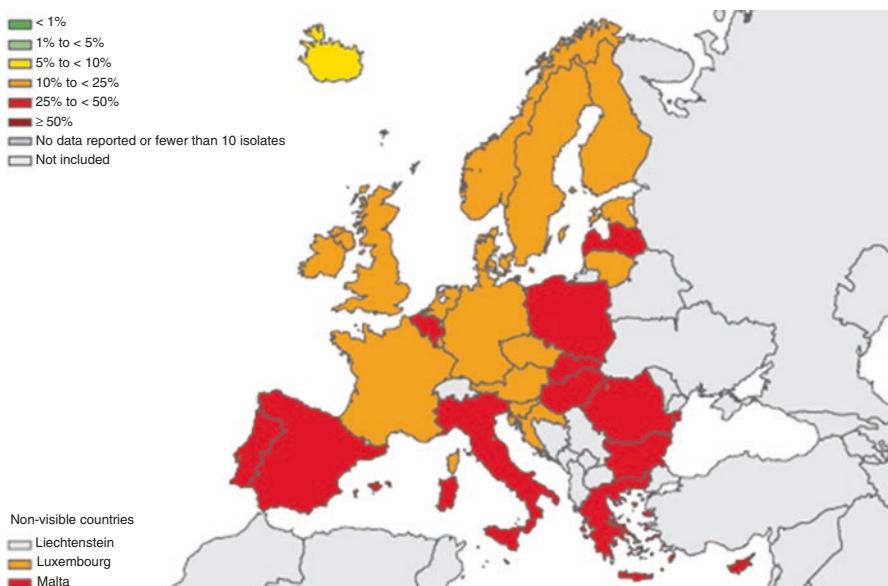


Fig. 51.2 Invasive *E. coli* isolates with resistance against fluoroquinolones in EU/EEA countries, 2015. Source: ECDC, 2017 [43]

multidrug-resistant organisms (MDRO) such as VRE, MRSA, *C. difficile* and/or multidrug-resistant gram-negative rod bacteria. Such problems are present also in countries with more prudent use of antibiotics [10, 20, 21].

The most vulnerable to this type of infection are persons with reduced defence against infections, elderly and new-borns, and the main arena is usually in the healthcare system. Good infection control with removal of microbes from environment and equipment is among the best preventive measures against the spread of these bacteria [10–12].

51.5.1 ESBL (Extended-Spectrum Beta-Lactamase) Bacteria

E. coli, *Klebsiella*, *Enterobacter*, *Citrobacter*, *Serratia* and other *Enterobacteriaceae* may develop resistance to all beta-lactam antibiotics: all penicillins, cephalosporins and carbapenems (when used) [10]. The ESBL enzyme breaks down and destroys all beta-lactam antibiotics [10–13]. Treatment failures for a variety of infections may occur [14–21]. Transmission (contact and air borne) of resistant strains may follow infected or colonized patients between levels of healthcare, causing urinary tract infections, sepsis and lower respiratory tract infections [10–12, 14–19, 21–30]. ESBL-producing bacteria can be detected in drinking water sold locally in a variety of countries [10, 29].

Relatives, in the same household as patients with ESBL, are easily infected and become carriers of ESBL: 24–50%. Most carriers are asymptomatic, but in some cases severe infectious disease is reported in relatives and other contacts [10].

Healthcare workers. ESBL transmission is described from a sick healthcare worker (gall bladder infection) to relatives who developed pyuria and renal failure with the same MDR-resistant *E. coli* strain [10].

In Norway, ESBL is an increasing problem with significant increase in prevalence of ESBL in *E. coli* blood culture isolates, “from 3.5% in 2011 to 5.8% in 2014–2015 and 5.1% in 2016”, and in *Klebsiella pneumoniae* isolates, “from 2.0% in 2011 to 6.3% in 2014 and 4.4% in 2016” (NORM) [21]. The increasing ESBL problem at Norwegian hospitals is transmitted to patients in primary care.

51.5.2 Carbapenemases and Super Resistance that Break Down All Antibiotics

Carbapenemases are enzymes breaking down all types of beta-lactam antibiotics, including imipenem, meropenem and other carbapenems (CRE bacteria). *Klebsiella pneumoniae* and other carbapenemase (KPC)-producing bacteria within the family *Enterobacteriaceae* are spread widely in most countries in Europe and America, today, and is also a problem in Norway [10, 11, 21, 32–37, 43]. Several resistance mechanisms are forming these bacteria. Different resistance genes are spread

between bacteria types like a very contagious epidemic. This happens in the intestines, but also in an environment burdened by a bad hygienic standard. Little by little, this will occur as local nosocomial outbreaks in primary healthcare and spread between different healthcare levels with frequent patients exchanges.

Super-resistant, gram-negative bacteria are often completely resistant to common antimicrobial agents due to special resistance genes that are easily transmitted between bacteria [10–12]. New Delhi metallo-beta-lactamase 1 (NDM-1) gene has led to almost complete antibiotic-resistant environmental bacteria, first discovered in Asia (New Delhi) in 2007, and is now spread all over the world [31–42]. Up to 40% of cases dies [10, 35, 38–42]. Medical tourism is spreading microbes worldwide and nosocomial between health institutions in Europe [43]. Patients from areas with NDM-1 bacteria are recommended to be isolated, screened and handled as with MRSA [10, 11, 20, 35, 44–46].

E. coli may be infected by the NDM gene that is easily spread between bacteria types. Since *E. coli* is one of the common causes of serious infections inside and outside hospitals, like urinary tract infection, sepsis, lower respiratory tract infections, postoperative wound infections, osteomyelitis, etc., its development is very serious for the global health. The NDM gene is detected in drinking water in New Delhi. Especially exposed to infection are people living in India, Pakistan and Bangladesh. It is assumed that up to 20% of the population in some areas of Pakistan are carriers of NMD-1-producing bacteria [10]. Cholera bacteria (*Vibrio cholerae*) with NDM-1 gene have been detected in India. This can cause major problems since cholera is an additional serious infection disease spread through contaminated drinking water in large areas [10]. Polymyxin (colistin) resistance is developing and is causing even greater therapeutic problems. One case of NMD-1 was detected in Norway in 2010.

51.5.3 Other Important Resistance Types Among Gram-Negative Rods

Aminoglycosides. Resistance to aminoglycosides is a major problem in countries around the Mediterranean, especially Greece [10, 12, 43]. It is the result of overuse of aminoglycosides and lack of infection control, i.e. to “treat bad hygiene with antibiotics”, mostly imported problems from the defined areas.

Always resistant bacteria at risk. Some gram-negative rods—mainly environmental bacteria—are always resistant (or are becoming) against many commonly used antimicrobials. Most problems are done by *Pseudomonas aeruginosa*, *Acinetobacter*, *Stenotrophomonas*, *Burkholderia*, *Serratia* sp., *Citrobacter*, *Enterobacter* sp., etc.,—all present in the environment of most health institutions all over the world [10–12, 14–19, 21, 32].

51.5.4 Disease of Multidrug-Resistant Gram-Negative Rod Bacteria [10]

Resistant bacteria spread between healthcare levels cause many types of infections [10–12, 14–19, 21–30]:

- Urinary tract infection—especially associated with catheter use
- Postoperative wound infection or pressure ulcer infection
- Pneumonia or other infections in the middle or lower respiratory tract like COPD/ cystic fibrosis—chronic lung disease
- Bacteraemia and septicaemia—especially in the case of reduced infection defence
- Osteomyelitis or joint infection
- Diarrhoea or other intestine disorders
- Infections in patients with severe immune deficiency

51.5.5 Ways of Transmission

- *Contact* via hands and equipment.
- *Contact* transmission can often become *air* transmission (bed linen and other activities)!
- From own bowel and skin flora.
- Pus that infects equipment, hands and wounds. Lack of cleaning of technical equipment.
- Infected bandages, drainage and intravascular equipment.
- Urinary catheterization, catheter and open drainage.
- Contaminated diapers.
- Patients with gram-negative pneumonia and cough/expectorate may especially cause airborne transmission.
- Highly contaminated environment—floors, surfaces and focal points.

51.5.6 Isolation [10, 11]

Contact- and airborne isolation in particularly resistant bacteria:

- Always isolation when resistant bacteria: *Pseudomonas*, *Serratia*, *Stenotrophomonas*, *Acinetobacter* or other gram-negative bacteria that are proven to be resistant to one of the groups below:
- Three-generation cephalosporins

- Aminoglycosides
 - Carbapenem (meropenem, imipenem)
 - *Airborne isolation* when super-resistant gram-negative bacteria such as NDM-1 bacteria and highly resistant *Acinetobacter* sp. and *Burkholderia cepacia*—at uncontrolled amounts of pus and pneumonia [10, 11, 30]. Internationally, patients with NDM-1 bacteria are recommended to be isolated as with MRSA.
 - *Airborne, infectious* multiresistant bacteria (MDRO) has been detected in 67% of patients' rooms of patients colonized with MDRO [30].
-

51.6 Remember!

- Gram-negative rod bacteria can have a very long life in the environment for up to several years. Therefore, decontamination and other disinfection are particularly important! [47–51].
- Note that some resistant bacteria may be more resistant also to chemical disinfectants [10].
- Textiles, gloves, coat and equipment around the patient are usually contaminated [52–55].
- Studies show that after wearing gloves and before hand hygiene, hands can be contaminated with resistant bacteria [56].
- Medical equipment is an increasing problem due to defects/deficiencies in decontamination [48, 51].
- Transport, patient relocation, overcrowding, patients on corridors, etc. are known factors that increase the risk of cross contamination and spread of infections. Information is important when moving patient with infections.
- Resistant bacteria usually occur in hospitals but are at the highest risk of spread in nursing homes and home nursing that receive these patients for further treatment.
- Persistent carrier status is not uncommon and three negative test sets can later be followed by positive in 10–25% of patients [57].
- Workload and patient/nurse ratio are very well-known risk factors. Excessive activity often leads to breach of hygiene barriers; patients get infections and receive resistance-driving antibiotics for their infections that are further spread to others because of broken infection barriers [10].

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Gastrointestinal Infections

52

Abstract

Gastroenteritis with vomiting and/or diarrhoea frequently occurs in healthcare institutions, caused by bacteria, viruses or parasites, either brought into hospitals or spread within hospitals. Symptoms may include vomiting, abdominal pain, diarrhoea, or frequent bowel movements, and often fever. Late autumn, winter and early spring may be periods of epidemics of norovirus, and other viruses occur both inside and outside health institutions, while *Clostridium difficile* (CD) diarrhoea is associated with antibiotic treatment. *Listeria* may be a serious risk in special vulnerable patient groups, associated to unpasteurized food or beverages. Travelling to other countries with lower state of hygiene or consuming contaminated food and drinks may cause outbreaks of entero-pathogenic bacteria like *Salmonella*, *Shigella*, *Yersinia*, entero-pathogenic *Escherichia coli*, *Campylobacter* and others. Outbreaks of cholera have been associated with catastrophes like earthquake, tsunami, war, starvation and breakdown of sanitary functions. However, in hospitals in developed countries, gastrointestinal outbreaks are most often caused by CD or norovirus. The following chapter is focused on practical measures to detect and prevent transmission of infections associated with gastroenteritis, vomiting and diarrhoea in healthcare institutions.

Keywords

Gastroenteritis · Vomiting · Diarrhoea · Abdominal pain · Frequent bowel movements · Entero-pathogenic bacteria · *Salmonella* · *Shigella* · *Yersinia* · Entero-pathogenic *Escherichia coli* · EHEC · *Campylobacter* · *Cholera* · *Clostridium perfringens* · *Bacillus cereus* · *Staphylococcus aureus* · *Listeria* · Bacterial toxins · Entero-pathogenic viruses · Entero-pathogenic protozoa · Food and beverage control · Imported · Admission control · Pre-examination Information · Screening · Isolation · PPE · Decontamination · Environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

52.1 Purpose

Prevent transmission of gastroenteritis-inducing microorganisms to other patients, personnel and the environment [1–9].

52.2 Comprise

All close contacts of patients (patients in the same room, personnel, visitors, etc.) and equipment, textiles, fixtures, rooms, etc. that the patient has been in direct or indirect contact with. Also includes the hospital's kitchen, ward office and the serving of food and drink, in case of suspected food-borne infection.

52.3 Responsibility

Hospital management ensures procedures for isolation and control of patients with suspected gastrointestinal infections.

The department management implements routines and reports to the director in the absence of resources (isolate, expertise, personnel) that may expose patients, personnel or visitors to unnecessary infection.

Employees follow routines and guidelines.

52.4 Practical Measures [2, 3]

Gastroenteritis with vomiting and/or diarrhoea frequently occurs in healthcare institutions, caused by bacteria, viruses or parasites, either brought into hospitals or spread within hospitals [1–7]. Symptoms may include vomiting, abdominal pain, diarrhoea, or frequent bowel movements, and often fever.

- See also Clostridium difficile, Chap. 53 and norovirus, Chap. 54.
- 1. Check before and upon admission:
 - Patient receipt form should contain current questions regarding infection. See admittance to hospital.
 - *If detected infection/exposed to infection*, there are at least two possibilities:
 - (a) wait for admission/treatment until the infection status is cleared; (b) isolate and treat the patient as infectious until infection status has been clarified.
- 2. Clinical tips on type of infection and cause:

Initially, it is often unclear what type of infection the patient has. Fast and drastic measures from the start prevent larger spread. Once the infectious agent is known, special measures may be implemented.

- Acute vomiting and/or diarrhoea, short incubation time, one after another becomes acutely ill, and there is an epidemic going on in the society as a whole—think of norovirus or other intestinal pathogenic viruses (see separate chapter).
 - Single cases of diarrhoea in connection with antibiotics (cephalosporins, clindamycin, ciprofloxacin), long-term healthcare, elderly patients—think of *Clostridium difficile* (see separate chapter).
 - After staying abroad, think about intestinal bacteria: *Salmonella*, *Shigella*, enteropathogenic *E. coli*, *Campylobacter*.
 - *Campylobacter* is often a summer disease in most countries, associated with grilling, unprocessed meat and contaminated water. Often convulsive pain attacks and bloody diarrhoea in the lower part of abdomen.
 - Acute gastric problems with vomiting and diarrhoea and stomach ache, many ill at the same time; think about common food or drinking sources and food poisoning with bacterial toxins (toxins from *Staphylococcus aureus*, *Salmonella*, *Clostridium perfringens*, *Bacillus cereus*, etc.).
 - Diarrhoea and sepsis-like symptoms, meningitis and endocarditis in immunosuppressed, pregnant, new-borns and people with intestinal diseases; unpasteurized food and drink—check *Listeria*.
 - Waterborne, large outbreaks—think of enteropathogenic protozoa, *Campylobacter*, *Shigella*, *Vibrio cholerae* (*cholera*) (in special areas) and enteropathogenic virus (norovirus/sapovirus).
3. The patient is isolated:
- Directly in contact isolation or single room with priority and separate toilet/bathroom attached to the room. The door of the room must be marked. See separate Chap.[16](#) on isolation.
 - Infection gown (gown to protect), gloves and eventual surgical mask/cap/face shield by vomiting or splashing and preferably room-bound shoes or shoe covers. Learn to take on and off PPE.
 - The hands are washed with soap and water—also after removing of gloves, mask/cap/gown and shoes.
 - More patients with the same symptoms should preferably not share rooms due to reinfection! In difficult circumstances may patients be isolated in cohort [[2](#), [5](#), [6](#)]
 - Inform all (patient, personnel, visitors) that hand washing with soap and water is important after toilet visits, before and after meals, etc.
 - Visitors of the infectious patient should be informed, follow routines for PPE, and not stay in rooms with other patients.
4. Sampling—investigation phase:
- Sampling usually *only from patients with symptoms*. In case of large sample numbers, contact the microbiological laboratory in advance.
 - Common faeces test for bacteriological examination and faeces test (or vomitus) in dry vials for viral examination.
 - Take the sample as early as possible during the course of disease and rapid transport to the microbiological laboratory (same day).

- Greater infection tracing is carried out in cooperation with infection control personnel. Microbiological laboratory is informed due to the number of samples and organization.
 - Sampling from food, drinks and environment may be actual in some cases.
5. General infection control measures:
- Avoid shared dining; no serving of food and drinks on corridors.
 - Note: ice machines, water tanks, coffee machines, fruit and the like for shared use may be risks!
 - Limit the visitor number.
 - Check drinking water—if necessary, contact the water system administration for information of quality, and apply bottled water, in case of suspected waterborne infection.
 - Check foods; unpasteurized cheeses/butter/other dairy products should not be served in hospitals; food buffets are not compatible with good food hygiene; cut meat must be replaced in good time before the date of expiry.
6. Patients exposed to infection:
- Isolated in the same way as patients with known infection until incubation time for infection is over (e.g. 2 days for norovirus) or samples show that the patient is not infected.
7. Other patients without exposure to infection:
- Treat with a patient-bound gown (changed daily) for each patient and increased focus on the patient's personal hygiene.
 - Patients are informed about hand washing after toilet visits, before and after meals, before and after medication, etc.
8. Personnel with symptoms:
- Sick leave and follow-up until free of infection, according to the infection type.
 - In the case of viral gastroenteritis: norovirus—recommended to stay at home 2 days after free of symptoms.
 - If personnel is infected or have carrier state of *Salmonella*, *Shigella*, *Yersinia*, epidemic *E. coli* or *Campylobacter*, tracing among others in the ward may be done. Faeces samples should be negative before returning to work.
9. Information [2, 3]:
- The staff, patients and relatives must get accurate information about the risk of infection and specific measures.
 - Other departments, hospitals and institutions that have been in contact with the patient are informed according to the current agent.
 - Personnel should not work elsewhere as long as infection tracing/other measures take place. Extra workers and other personnel (supervision, etc.) must be informed of outbreak at the ward. Contact hygiene nurse for advice.
 - The ward should be closed for walking through or for new admissions while the outbreak is going on.
 - Cleaning staff are informed about infection protection and to avoid work elsewhere during outbreaks of norovirus.

10. Cleaning/disinfection [2, 3]:

The responsible leader provides a rapid implementation of disinfection and cleaning of relevant rooms and objects according to guidelines for contact infection and in cooperation with the hygiene nurse. Sharpen the general and personal hygiene of the ward. Disinfection is directed against the specific agent detected/suspected. See chapters on isolation regimens and on decontamination of rooms Chaps. 14–16 and 66.

- Environment that is easily contaminated like beds, bedside tables, water faucets, on and off buttons and door handles must be disinfected daily.
- Toilets, washbasins and door handles to the toilets are disinfected one to four times a day. Cloths or wipes soaked with alcohol (75–85%) can be used.

11. Textiles, waste, reusable equipment, service, and cutlery (see isolation routines Chaps. 14–16)**12. Notification procedures:**

- Report to infection control unit in case of suspected outbreak of gastrointestinal infection.
- Report suspected infections via *food or water*—to the local authority the same day. The food safety department (national) is also notified.
- Several cases of illness from the same source of infection should be notified to the National Institute of Public Health.
- Nominal reporting may be obligated for diseases in different risk groups (A and B), according to legislation.

13. Consider admission stop at the ward:

- If two or more patients or one employee and one patient are suspected to be infected with the same microbial agent or have the same symptoms.

14. Follow-up on infection:*Carrier or source of infection*

Hospital staff with positive findings of *Salmonella/Shigella/Yersinia/Campylobacter/intestinal pathogens* of *E. coli* are reported and followed up by the occupational health services/general practitioner in cooperation with the infection control unit.

Patients are isolated during repeated admissions at the hospital.

Isolation is lifted

- After cessation of symptoms and after negative samples from faeces.
- In case of major outbreaks, the need of further isolation is considered according to infection type and control.

Exception for isolation in hospital—special cases

In special cases, the patient may leave the single room if he/she:

- Understand and follow precautions not to spread infectious agents
- Does not have diarrhoea, vomiting and uncontrolled incontinence
- Does not have norovirus infection—up to 2 days after freedom of symptoms
- Does not stay in a common room with other patients or use a common toilet/bath
- Does not use “corridor service” or other shared serving (coffee machines, etc.)

- Performs good hand hygiene, and this is done in agreement with the hospital's infection control unit.
15. Control samples after entero-pathogenic bacteria:
- A minimum of three negative faeces samples should be taken with 2–3 days intervals, starting 14 days after any discontinuation of antibacterial treatment. Five negative faeces samples are recommended for *Salmonella typhi* and *Salmonella paratyphi* A and B, as well as one duodenal aspirate.
- Control of faeces: *Salmonella*, *Shigella*, *Yersinia*, entero-pathogenic *E. coli*, *Campylobacter*, etc. First check is taken 2–3 days after symptom freedom.
 - If treated with antibiotics, control samples should be taken at least 14 days after discontinuation.
 - In case of negative findings, further check tests may be taken at least 2 days apart.
 - After three negative tests, the patient can be declared non-contagious.
 - In case of positive findings, the next check should be taken after 1 week.
 - Employees who work with food or patients should be on sick leave as long as they are culture positive. At least three negative samples are required before they can return to work after infection with intestinal bacteria: *Salmonella*, *Shigella*, *Yersinia*, entero-pathogenic *E. coli* or *Campylobacter*.

Registration and information

Patient/staff with proven *Salmonella/Shigella/Campylobacter/Yersinia* entero-pathogenic *E. coli* or other entero-pathogenic bacteria can be carriers and contagious for 1–3 months after undergoing infection (rarely for a longer time). The patient is informed about this, about the importance of good personal hygiene and about special conditions for kitchen hygiene, healthcare and care/contact with children and people with impaired general condition.

- Healthy carriers (no symptoms) of entero-pathogenic bacteria are seen frequently after *Salmonella*, *Shigella* or *Campylobacter* infections. Some may have the bacteria in the faeces for several years after the infection, which represent a risk to their environment.
- Those who still secret *Shigella*, *Campylobacter* or *Salmonella* after 3–6 months should as a rule be investigated and, if appropriate, treated with antibacterial agents and referred to specialist in infectious diseases.

52.5 Background Information

The most common entero-pathogenic bacterial groups are *Salmonella*, *Shigella*, *Campylobacter*, *Yersinia* and various types of entero-pathogenic *Escherichia coli* (including entero-haemorrhagic *E. coli* (EHEC)) and *Listeria* [1–5, 8, 9]. The highest mortality is recorded after food poisoning with *Salmonella* and *Clostridium perfringens*. Norovirus is usually causing the largest outbreaks [6].

- *Gastroenteritis* is most commonly caused by viruses (norovirus, sapovirus, rotavirus, bocavirus etc.), entero-pathogenic bacteria or toxins [1, 6].

- *Food-borne gastroenteritis* from the hospital's kitchen may occur (*Bacillus cereus*, *Salmonella*, *Clostridium perfringens*, *S aureus*, etc.). In 2004, 75 people were infected with *Salmonella infantum* from the hospital's kitchen at a hospital in the South of Norway [4]. Food-borne infections are often linked to poor food control, low hygiene and people that have been abroad [4].
- *Food poisoning* causes gastroenteritis with varying incubation time (2–18 h), caused by the ingestion of bacteria and bacterial toxins (the same as above) from infected foods or beverages [1–4].
- *Enteropathogenic bacteria* are not normal flora in the intestines of people living in northern parts of Europe. Spread in hospitals occurs rarely because of contact isolation [4]. Increased food contamination and travel activity may increase the risk in hospitals [1, 4]. The situation in Norway, for example, is the following for ca 5.5 million inhabitants in 2014:
 - *Salmonella*: 1100 cases, mainly *S. typhimurium* and *S. enteritidis*; 70% were imported; 10% were multidrug resistant (MDR to five antibiotic groups), and there were a few dangerous types such as *S. typhi* (7 isolates) and *S. paratyphi* (8 isolates) [9]. A total of 65 isolates were detected in blood cultures (0.5%) [9].
 - *Shigella*: 96 cases, mainly *S. sonnei* and *S. flexneri*; 85% were imported; 50–90% were MDR [9].
 - *Yersinia enterocolitica*: 65 cases; 50% were mainly serogroup 3 from Norway, with exception of ampicillin—mostly antibiotic sensitive [9].
 - *Campylobacter*: 3386 cases; 46% were imported; MDR varied, highest among imported cases [9].
 - *E. coli* enteritis and EHEC: 334 cases of *E. coli* enteritis and 148 of EHEC [10]. The increase is worrying (see Fig. 52.1).

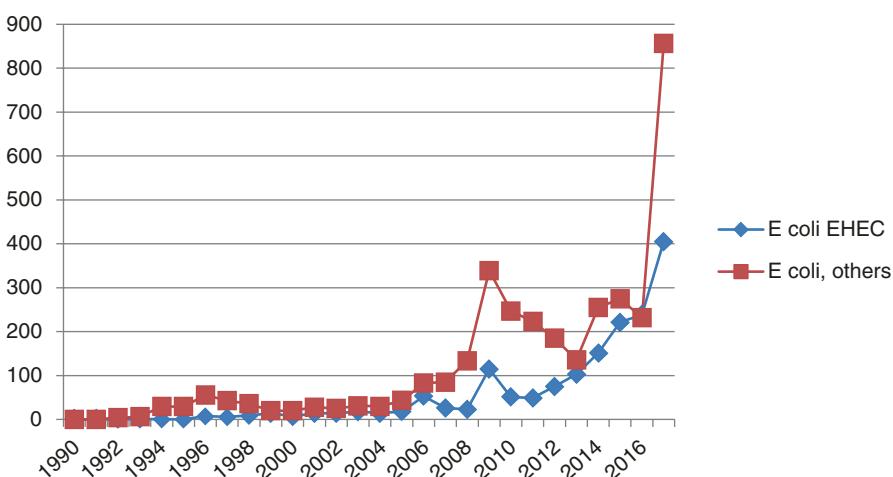


Fig. 52.1 Enteropathogenic *E. coli*—development in Norway, 1990–2017 (Source: MSIS, National Public Health Institute)

- *Helicobacter pylori* is associated with dyspepsia, gastric ulcer and rarely development of cancer [5]. Infections in hospitals are unknown, transmission may occur by poor hygiene [5].
- *Listeria monocytogenes* is a normal intestinal flora in animals and can be found on all types of uncooked foods, vegetables, cold cuts and fruit (in melons) and in water (internally in waterborne amoebas) and grow well in the refrigerator temperature [8, 11]. Gastroenteritis and sepsis may be a risk for patients with immune deficiency, pregnant women, new-borns and cancer patients, especially colon cancer [8]. In 2007, 17 patients were infected with *Listeria*, of which 3 died, at a hospital for cancer patients in Oslo (Radiumhospitalet). The source of infection was camembert cheese made from pasteurized milk, but probably re-infected in the late production phase [8].
- Norovirus and other enteropathogenic viruses show a high tendency to spread like a conflagration in and outside hospitals [2, 3, 6].
- *Giardia lamblia* and *Cryptosporidium* are the most common intestinal protozoa (*Entamoeba histolytica* in tropical areas) spread through infected water, food, bad hygiene and in person-to-person contact, especially in institutions with close contact [2, 7].

52.5.1 Risk Factors in Hospitals

- Poor hygiene and lack of isolation.
- Lack of hygienic control with food and beverages
- Uncritical use of broad spectrum antimicrobial agents
- Impaired general condition, chronic bowel disease, diabetes, kidney failure, immune deficiency and in ventricular operated patients
- Travel to endemic areas without preventive hygiene measures

52.5.2 Message

In case of outbreaks and in connection with primary findings, contact department management and infection control personnel. In case of negative microbiological findings, but more patients/staff (three to four) with similar symptomatology in a short period of time (approximately 1 week), contact the same instances.

In case of *major outbreaks*, the number of new patients is registered each day and sent via the department management to infection control personnel (telephone or mail). The department also contacts microbiological laboratory if there are unusually large sample numbers. Remember nominative notification regarding *Salmonella*, *Shigella*, *Yersinia*, *Campylobacter*, entero-pathogenic *E. coli* and cholera.

Food-borne infections—National aggregated registration and surveillance are essential [9, 11].

52.5.3 Sampling: Extended

Sampling of faeces is recommended on suspicion of:

- Infectious spread in the hospital (nosocomial spread—norovirus in particular).
- Food poisoning.
- *Clostridium difficile*.
- Serious infections and import infection.
- Control of previous findings, chronic carrier status and environmental studies.
- In case of outbreak, samples of up to three first patients are taken (usually).

Samples are taken as early as possible and examined for viruses and bacteria:

- Faeces containing mucus or blood when this occurs—or by vomiting.
- Sent the same day or stored in a refrigerator until the next day.
- In suspected virus- or parasite-related gastroenteritis, the stool sample is sent on sterile container without addition.
- In suspected bactericidal gastroenteritis, the faeces sample is sent in Cary-Blair transport medium or delivered in sterile container directly to the microbiological department immediately after sampling.
- In suspected infection with *Clostridium difficile*, the faeces sample is sent in sterile container without addition directly to the laboratory.

Avoid the use of antibiotics that may prolong and worsen the condition.

- Antibacterial agents; contact specialist in infection medicine.

Note! special conditions like intestinal infections in patients with immunodeficiency, prostheses or grafts or with known aneurysm. Contact specialist in infection medicine for advice on treatment.

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Abstract

Clostridium difficile infections (CDIs) are among the most serious and widespread hospital infections in Europe and the United States and are related to the use of antibiotics combined with lack of hygiene and infection protection. CD is gram-positive, anaerobic, spore-forming rod bacteria, adhesive to mucosa, and may have enzymes and toxins. Only *toxin-producing* CD can cause antibiotic-associated diarrhoea and pseudomembranous colitis. The bacteria die in air. The CD spores survive outside the body for years. Spores are inactivated by autoclaving or treated with certain disinfectants. Virulent CD types may be associated with serious disease, even in young people without contact with the healthcare system. CD is normally found in the intestines and perineum, is transient flora of the hands and skin and is asymptomatic present in many new-borns and in 3–4% of healthy persons. In case of antibiotic treatment, 40–50% may have CD in the intestine due to selection. Environmental contamination is large both with and without symptoms. CDI is associated with prolonged, antibacterial treatment. “Drivers” are third-generation cephalosporins, clindamycin and quinolones. The following chapter is focused on practical measures to detect and prevent transmission of CDI in healthcare institutions.

Keywords

Clostridium difficile · CD · CDI · CD infection · Toxin-producing · Colitis · Diarrhoea · Abdominal pain · Frequent bowel movements · Bacterial toxins · Antibiotics · Admission control · Pre-examination · Information · Screening · Isolation · PPE · Decontamination · Environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

53.1 Purpose

Prevent transmission of toxin-producing *Clostridium difficile* to other patients, personnel and the environment [1–10].

53.2 Comprise

All close contacts of patients (patients in the same room, personnel, visitors, etc.). All equipment, textiles, fixtures, rooms and surfaces the patient has been in direct or indirect contact with, as well as food and beverages contaminated with toxin producing CD bacterial spores.

53.3 Responsibility

The hospital's management provides written procedures for detecting and isolating patients with CD and for monitoring of antibiotic use at the hospital.

The department management ensures that personnel, patients and visitors are informed of infection prevention measures by CD infection and report to the director if resource shortages (capacity, isolation, etc.) cause patient, personnel and visitors to be exposed to CD infection.

Employees follow routines and guidelines for infection protection.

53.4 Practical Measures

53.4.1 Routines for All Admission/Outpatient Clinics/ Day Surgery [5–8]

Preliminary examination: ask patient, relatives and physician *before* admission; check if the patient or people in the local area have symptoms of enteritis.

If suspected or confirmed CD, there are at least two possibilities: (a) wait for admission until the patient's recovery/infection status has been resolved; (b) isolate the patient until infection status has been clarified.

53.4.2 Isolation and Other Preventive Measures [5–8]

- The index patient is contact isolated immediately with private toilet and decontaminator. Do not share toilet/bath or patient room with others.
- Patients in the same room as the index patient are isolated in separate rooms and treated as possible infected.
- Personal protective equipment (PPE) is taken on and off properly to prevent spread of infection to others and environment.

- Donning (dressing) of PPE takes place in a defined clean area in the sluice or anteroom of the isolation unit or on the corridor outside the patient room. *Only clean, unused equipment must be on the corridor outside the isolation unit!*
 - Wash or disinfect your hands before donning.
 - Gown—disposable—with long sleeves and cuffs. Single use.
 - Gloves pulled over the coat's cuff.
 - Room-bound shoes (or disposable cover). Room-bound shoes should be machine washed at 85 °C or autoclaved (due to CD spores).
 - Cap and surgical mask, especially important when bedding and cleaning the room, when the patient is assisted in the toilet and at other major activities that can swirl CD spores up in the air.
- Doffing (undressing) of PPE after use is carried out in a defined area of the isolation unit's sluice or in the patient's room at the exit door (should be avoided). *Never undress PPE on the corridor!*
 - Shoes, room-bound, or disposable shoe covers must be removed first. Gloves are used when gently removing the shoe covers and placed in contaminated waste.
 - Remove the gloves. Learn to undress gloves!
 - Hand hygiene.
 - The gown is taken off by opening behind the back—avoid touching the front and arms—learn to undress gown!
 - Hand hygiene.
 - Remove surgical mask by loosening back in the neck—learn undressing mask.
 - Remove the cap by taking off from back, not in front—learn undressing cap.
 - Hands are finally washed with soap and water.
 - Use eventually a “cloth” with chloramine 5% in anteroom/sludge for wiping off shoes. Replaced each shift.
- *The CD spores* firmly adhere to the skin. There is no complete effect of either hand wash or hand disinfection on CD spores. Hand wash with soap and water can have a slightly better effect than hand disinfection and is therefore used for CD. The use of gloves and a good hand hygiene before and after wearing gloves are therefore central.
- *Visitors* follow the same routine as personnel and leave the department directly—not in the living room/corridor and the like.
- *Self-service drinks, food, etc. on the corridor are removed.* Ice and coffee machines, etc. on the corridor are emptied, decontaminated and washed. Should not be used during outbreaks.

53.4.3 Disinfection of Rooms and Surfaces

There is a heavy contamination of CD spores in the environment and equipment around the CD patient, which often can be detected even after disinfection [11, 12]. The spores are killed by autoclaving (equipment, etc.) or by disinfection with 5%

chloramine for a minimum of 5 min [4, 8]. Also household bleach 10% or peracetic acid kills spores. Afterwards, clean with soap and water.

- *Disinfection daily* with 5% chloramine disinfection or peracetic acid; wipe over fixtures, door handles, on and off knots etc., wipe over the floor, and cleaning with soap and water immediately afterwards. Disinfection of the entire room, including the floor when termination the isolation, see isolation regimens Chaps. 14–16.
- *Hydrogen peroxide gas/aerosol* can effectively kill CD spores if used properly; use spore control for terminal disinfection [8, 13–15].

53.4.4 Isolation Time, Readmissions and Transfers

- *The patient is isolated throughout the hospital stay* even after the diarrhoea is stopped [5–8, 16].
- *In case of readmission* during the first 3–4 following months, the patient is isolated as a CD patient. This is especially important if the patient is going to be treated with antibiotics and/or cancer medicines.
- *When transferring to another health institution*, inform about CD infection, including for CD-exposed patients. After CD infection, use of antibiotics (clindamycin, cephalosporins, ciprofloxacin) or cytostatics can easily trigger a new outbreak of diarrhoea—at least the first half of the year after CD.

53.4.5 Infection Transmission

- *Contact transmission*: via hands, faecal-oral, equipment, environment, dust, etc.
- *Airborne transmission*: an air transmission in the toilet room has been detected when it is pulled down and the toilet lid is open. [9] CD spores are detected in the air 25 cm above the toilet opening and around the toilet room. [9] Close the toilet bowl before it is pulled down! Helpers use cap and surgery mask in addition to gloves, gown and room-bound shoes.
- Patients should generally be advised not to walk barefoot on the floor of the nursing room in order not to pull bacteria and spores into the bed.

53.4.6 Risk of Infection

- Overcrowding and understaffing [8].
- Airborne spread of spores [8–10].
- Lack of isolation.
- Overuse of selective antibacterial agents (clindamycin, cephalosporins, fluoroquinolones).

- Cytostatics.
- Reservoir development in nursing homes, other health institutions and home nursing, with spread to hospitals [8].
- Large workload and lack of glove use when caring for CD patients may cause one in four healthcare professionals to get CD spores on their hands [17].

53.4.7 Disease Manifestation: Varying

Incubation period is 2–3 days or longer. Varying from asymptomatic CD to diarrhoea that is partly bloody, mucous and painful; pseudomembranous colitis; toxic mega-colon; and perforation of the intestine [4, 8].

53.4.8 Diagnosis

- Diarrhoea:
 - Six aqueous in 36 h
 - Three unformed/24 h for 2 days
 - Eight unformed for 2 days
- Pseudomembranous (continuous mucous membranes)
- Toxin detection (only at diarrhoea)
- Growth of *C. difficile* (anaerobic cultivation—CFA—medium) just by diarrhoea
- No other cause of diarrhoea

53.4.9 Sampling

Preferably, take only aqueous, loose faeces, if not epidemiological examination. Pencil samples are not good enough because of a too small volume for toxicity studies (can be used in epidemiological studies). Lumen content v/operative treatment is applicable. Always ask for the cultivation and identification of CD due to increasing incidence of more virulent CD types.

53.4.10 Personnel Are Not Tested

Personnel caring for patients with CD are usually not becoming ill (except for colonization, use of antibiotics, colon disease, etc.), but may be important spreader if infection prevention measures are not implemented. Hypervirulent strains can attack healthy people, including healthcare professionals [8].

53.5 Background Information

Clostridium difficile (CD) is gram-positive, anaerobic, spore-forming rod bacteria, adhesive to mucosa, and may have enzymes and toxins [4, 5, 8]. Only toxin-producing CD can cause antibiotic-associated diarrhoea and pseudomembranous colitis. The CD bacteria dies when coming out in air (oxygen). The CD spores survive outside the body for a long time—for years—but are inactivated by autoclaving or treatment with 5% chloramine for a minimum of 5 min, household bleach 10% or peracetic acid. CD bacteria are usually sensitive (may be killed) to medicaments like vancomycin and metronidazole. Virulent CD types are associated with serious disease, even in young people, without contact with the healthcare system (ribotype variants NAP1/O27/III, 106, 001, etc.) [4, 8].

Exotoxin produced by CD bacteria is a protein with a toxic A part and a cytotoxic B part, produced in the growth phase of the bacteria. Toxin A is an enterotoxin that increases fluid secretion in the intestine; toxin B, cytotoxin, has a strong cellular affection on the mucous membrane in the colon. Another factor reduces intestinal motility. Toxin-producing CD was associated with the use of antibiotics, especially clindamycin in 1980, and was first called “clindamycin diarrhoea” [4, 5, 8]. The CD infection (CDI) in the colon occurs in 90% of the cases in the sigmaeum and destroys intestinal epithelium and lamina propria with infiltration of leukocytes, erythema and oedema and formation of white to green plaques.

Normal intestine flora contaminates the environment. CD is normal flora in the intestines and perineum and transient flora of the hands and skin. It is asymptomatic present in many new-borns, in 3–4% of healthy persons over 2 years and at 15–25% of hospital patients. In case of antibiotic treatment, 40–50% may have CD in the intestine due to selection. Environmental contamination is large when CD, both with and without symptoms [8–12].

CD infection (CDI) is most often antibiotic-induced diarrhoea. CDI is associated with prolonged, antibacterial treatment. Clindamycin selects for CD, and that does also cephalosporins (third-generation), ciprofloxacin, ampicillin, etc. Compared with penicillin V, causes penicillinase -stable penicillins more frequent CD diarrhoea ($\times 8$), cephalosporins even more frequent ($\times 40$), and clindamycin most frequently ($\times 70$) [8]. Use of antibiotics may increase the risk of CD infection 7–10 times for up to 1 month after discontinuation of antibiotics. Then there is a threefold increase in risk for the next 2 months [2, 4]. “Drivers” for CDI are third-generation cephalosporins, clindamycin and ciprofloxacin (quinolones) [3, 4, 8, 18, 19].

53.5.1 Risk

Risk score for CDI in endemic hospitals constitutes contamination pressure, elderly patients, previous institutional admittance, previous CD infection, intensive treatment and a variety of clinical parameters [2, 20]. Patients with leukaemia in hospitals have a greater ($2\times$) risk of CD infection than non-leukaemia patients, and the CDI results in increased mortality, longer hospital stays and higher hospital

expenses. [21] At Ullevål University Hospital, Oslo, there was a CD outbreak in 2003 among many children with leukaemia and other forms of cancer. [8] The outbreak came quickly under control; none of the children died. Isolation and “home hospital treatment” were established, the antibiotic therapy was changed and parents and employees understood and followed the hygiene measures [8].

Good terminal disinfection of rooms and equipment reduces CD in hospitals by approximately 20% [2].

53.5.2 Occurrence, Costs and Mortality

Monitoring of CDI is important as it is done in several places in the United States and Europe [22]. In 2013, 20 states in the United States reported to the health authorities [22]. In endemic areas, CD is defined by where the infection has occurred, “hospital onset” or “community onset”, which results in an economic and therapeutic responsibility [23]. Monitoring of CDI started in Norway in 2013, with approximately 1400 cases in 2014 and a doubling to 3000 cases in 2017 (Fig. 53.1. MSIS, National Public Health).

Spread with transport and interaction. CD is a typical institution-bacterium, spread between hospitals, other healthcare institutions and primary healthcare in general, by extensive patient transport between the different treatment levels as shown in the United States [24]. This may expose other patients to infection [25].

Global outbreak of virulent strains. In recent years there have been global outbreaks of ciprofloxacin-resistant CD 027 with high mortality rates, 20–25% within 60 days, and with relapse in approximately 15% or more of the cases within 40 days [4, 8, 26].

Large relapse hazard and prolonged stay in hospital. There is a high chance of relapse within 30 days after discharge, ca. 20–30% [4, 8, 27, 28]. Extended length

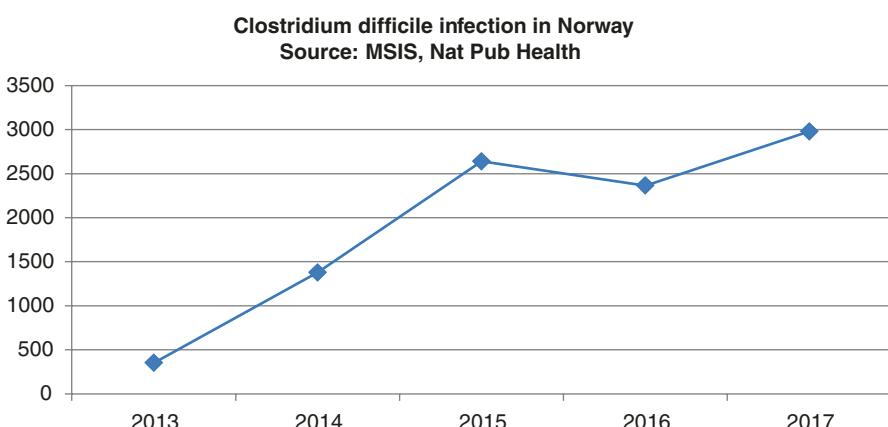


Fig. 53.1 *Clostridium difficile* infections are increasing in Norway (ca. 5.5 million inhabitants).
Source: MSIS, Nat Pub Health

of time in hospital depends on the severity of the disease. A study of 43,500 CD cases in the United States showed an average of 14 additional days in hospital due to the disease, while a multistate model came to less extra days. [29]

Endemic conditions and death. In the United States, CDI is endemic with 1 of 100 (1.3%) hospitalized patients in 2008. In 2011, half a million patients in the United States had CDI, and approximately 29,000 died [30]. In 2012, the incidence, mortality and cost of CDI reached “historical heights” in the United States, with more than 14,000 deaths/year (4.7/100,000 inhabitants) [2, 3].

Hospital-associated CDI costs 5000–7200 USD per patient, with a national expense of 0.9–1.3 billion USD/year [2, 3]. Proper measures over a 5-year period will prevent more than 500,000 CD cases, 82,000 deaths and a national savings of 2.5 billion USD [31]. Such measures are profitable; cost benefit to the society.

In Europe, mortality rate 30 days after start of the CDI varies from 2% in France to 42% in the UK [32].

Restriction of antibiotics The United Kingdom has registered about 60% reduction of CDI from 2008 to 2012, with a simultaneous reduction of use of cephalosporins and quinolones [33]. A multifaceted model was used with the restriction of certain types of antibiotics, patient isolation, hand hygiene and environmental management, as well as control [1].

At an orthopaedic department in Mexico, a 92% restriction of clindamycin—without increase of other antimicrobials—led to approximately 90% reduction of CD infection [19]. Studies show that fidaxomicin treatment can reduce environmental contamination around CD patients, compared with the use of metronidazole and/or vancomycin [34].

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Norovirus and Other Viral Gastroenteritis

54

Abstract

New and old entero-pathogenic viruses are increasing in the society and in the healthcare, like the *Calicivirus* family (*Norovirus*, *Sapovirus*, *Astrovirus*), *Reovirus* family (*Rotavirus*) (especially infant, toddler and elderly) and rarely other viral types such as adenovirus (especially serotype 40, 41), bocavirus, parechovirus, enterovirus and a variety of other types. In all types of gastroenteritis, infection prevention measures are performed as with norovirus, described below. The following chapter is focused on practical measures to detect and prevent transmission of entero-pathogenic viruses in healthcare institutions.

Keywords

Enteropathogenic viruses · Norovirus · Sapovirus · Rotavirus · Viral gastroenteritis, enteritis, vomiting, diarrhoea · Abdominal pain, frequent bowel movements · Admission control · Pre-examination · Information · Screening · Isolation · PPE · Decontamination · Environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

54.1 Purpose

- To prevent transmission of viral gastroenteritis to patients, staff and the environment.
 - The infections are transmitted via contact, faecal-oral and/or air (droplets, aerosol).
 - Actual virus types are norovirus, sapovirus, astrovirus, rotavirus and rarely other viral types such as adenovirus (especially serotype 40, 41), bocavirus, parechovirus, enterovirus and a variety of other types [1–4].
 - For all types of viral gastroenteritis, infection prevention measures are performed as with norovirus, described below [4–7].

54.2 Comprise

All close contacts of patients (patients in the same room, personnel, visitors, etc.)
All equipment, textiles, rooms and surfaces the patient has been in contact with.

54.3 Responsibility

The hospital's management provides written procedures for detecting, isolating and controlling infectious patients with norovirus and other infectious gastrointestinal viruses.

Department management implements guidelines and ensures that personnel, patients and visitors are informed of infection prevention measures in connection with outbreaks of norovirus and other viral gastroenteritis and reports to the Director about resource problems (personnel, expertise, isolates) that may expose other patients, personnel and visitors to infection.

Employees follow routines and guidelines for infection protection.

54.4 Practical Measures

54.4.1 Routine at All Admissions/Outpatient Clinics/Day Surgery

Preliminary examination: ask the patient, relatives, physician *before* admission if the patient has symptoms of gastroenteritis. This is especially important in periods of epidemics of norovirus and rotavirus; especially autumn and winter.

If suspected/confirmed viral gastroenteritis, there are at least two options: (a) postpone admission to the patients infection status is resolved; (b) admit and isolate the patient until infection status is clarified.

54.4.2 Isolation and Other Preventive Measures [4–6]

- *Index patient* is contact isolated with own toilet/shower and preferably own decontaminator. Avoid cohort isolation due to repeated outbreaks. The patient cannot walk into the corridor or common patient rooms but can walk directly out of the hospital.
- *Patients exposed*—have been in the same room as the index patient with symptoms—are isolated separately from the index case during incubation time for a minimum of 2–3 days [1–7]. Treat as possible infected.
- *Personnel wear PPE* (gown, gloves, surgical mask/cap (air transmission, especially when vomiting) and room-bound shoes that can be disinfected or shoe covers). Follow routines for taking off infection control equipment. Carefully remove any shoe covers with gloves on, and wash hands after wearing gloves.

- *The use of PPE* must be properly implemented to prevent spread of infection. Taking on PPE is carried out in a defined clean area in the sluice of the isolate or on the corridor outside the patient room. *Only clean equipment must be on the hallway!*
 - Wash or disinfect hands before donning.
 - Gown (single use), long-sleeved cuff.
 - Gloves pulled over the gown's cuff.
 - Room-bound shoes (or disposable cover). Room-bound shoes should be machine-washed at 85 °C or autoclaved.
 - Surgical mask/cap.
- *Taking off the PPE* is carried out in the defined area of the isolate sluice or in the patient room at the exit door. *Never doff in the corridor outside the isolate!*
 - If using shoe covers, these must be removed first. Gloves are used when gently removing the overcoat shoe deposited in contaminated waste.
 - Remove the gloves; grab the left glove at the wrist (not higher up) and gently turn it inside out, and use the inverted glove as a cloth to grab through to remove (roll off) the remaining glove. Learn to remove gloves without contamination!
 - Hand hygiene.
 - The gown is taken off by opening behind the back (neck)—avoid touching the front and arms—pull the cuffs over the hands, and roll the gown gently along from the sides and from above downwards without touching the outer side. Place gently in the waste bag.
 - Hand hygiene.
 - Remove surgical mask/cap by loosening back on the head—not touching the front.
 - The hands are finally washed with soap and water.
 - Use eventually a “cloth” with chloramine 5% in the sluice for wiping off the shoes. Replace this for each shift.
- *Norovirus and other intestinal pathogenic viruses* attach easily to the skin [4, 8, 9] There may be a failure effect of both handwash and hand disinfection.
- *Handwash with soap and water* may work probably better than hand disinfection and is therefore used for norovirus [4–9]. Always wear gloves when there is suspected gastrointestinal infections, and perform hand hygiene before and after use of gloves!
- *Personnel* with symptoms report sickness and stay at home for at least 2 days after symptom freedom [1, 7].
- *Inform* all personnel and visitors.
- *Visitors* should follow procedures for using PPE and hand hygiene and should not stay in common rooms, corridors, etc. together with other patients/visitors. They may be infected with the same microbiological agent and spread the infection in the department. Visitors with symptoms should be at home until 2–3 days after freedom of symptoms (except for relatives of children and critically ill).
- *Limit general access*, and avoid thoroughfare.
- *Limit surveys/treatment* of the actual patients at other departments while the outbreak is going on.

54.4.3 Other Measures [4–6]

- *Exposed healthcare professionals* should not work at other healthcare institutions or other departments before the outbreak is over.
- *Hand hygiene* is reviewed and sharpened. Alcohols have limited effects on norovirus. Therefore, important with glove use.
- *Admission stop* is considered, depending on the isolation conditions. Admission should be stopped for 48–72 h after the last new case with gastroenteritis (diarrhoea and/or vomiting).
- *Discharge of patients* who can manage at home should be considered. Do not discharge to other healthcare institution from the unit before 48–72 h after symptom freedom.
- *Drinks and food service, etc. on the corridor are removed.* The ice maker machine is emptied, decontaminated and washed. Should not be used during outbreaks at the department. Do not use common coffee machines, etc. on the corridor. No self-service.
- *Report to infection control unit daily while the outbreak is going on.*
- *Closure and disinfection of wards.* Occasionally, the entire department must be closed, emptied and disinfected. Particularly important are common service rooms, equipment stores, clean textile rooms, kitchens, etc.

54.4.4 Sampling

Preferably, only aqueous, loose faeces samples if not epidemiological examination. Faeces from patients in the acute phase and preferably within the first 3 days (up to 7 days) after the disease starts. Take samples from all cases during the primary outbreak, including personnel with symptoms. If the outbreak continues, sampling is unnecessary if the virus is already detected. 5–10 g faeces (a spoon) is sampled in a sterile test tube and sent immediately or stored in a refrigerator until sent to the laboratory (no more than 2 days).

54.4.5 Disinfection of Rooms and Surfaces [4–7]

Environment and equipment around the patients may be heavily contaminated by norovirus or other intestinal pathogens [4–7, 10, 11]. Norovirus may survive for more than a year in the environment if not removed and if the transmission dose is very low: 10–100 virus particles [1, 4]. All decontamination should be carried out thoroughly. Proper use of effective disinfectants as 5% chloramine or 10% household bleaches (home) or peracetic acid is important [4, 7].

- *Daily disinfection* of all patient-related equipment and common touch points × 3 with alcoholic wipes (eventually, chloramine 5% or household bleach 10%).

- *Daily disinfection* with 5% chloramine; wipe over fixtures, door handles, off and on knots, the floor and all surfaces. Then use normal soap and water over the same surfaces immediately afterwards. See isolation regimens.
- *Terminal disinfection* of all rooms where the patient has stayed.
- *Hydrogen peroxide gas/aerosol* can be effective at terminal disinfection in an empty room [4, 12, 13].

54.4.6 Isolation Period, Readmission, Transfers [4–7]

- *The patient is isolated throughout the hospital stay* even after the diarrhoea/vomiting is stopped. Especially elderly can shed viruses for days to weeks after symptoms have disappeared, and up to 30% may be healthy virus carriers [1, 6, 14–17].
- *When transferring to another health institution*, inform about norovirus infection and also for patients exposed to infection.

54.5 Background Information

New and old enteropathogenic viruses are increasing in the society and in the healthcare and may cause large, global outbreaks. The *Calicivirus* family (norovirus, sapovirus, astrovirus) and the *Reovirus* family (*rotavirus*) (especially infant, toddler and elderly) are the most common. More rarely may other viral types such as adenovirus (especially serotypes 40 and 41), bocavirus, parechovirus, enterovirus and a variety of other types (including sars) cause outbreaks [1–4]. In all types of gastroenteritis, infection prevention measures are performed as with norovirus [4–7].

54.6 Norovirus

Small, round virus with high infectivity; <10–100 virus particles are enough to start a gastroenteritis [1, 4]. Norovirus (former Norwalk virus) is the cause of “winter vomiting disease” inside and outside institutions, especially winter time (see Fig. 54.1). There is large amount of virus in vomit and faeces (10^{12} viruses/gram faeces) during acute disease, and it is rapidly transmitted via vomiting; drops/aerosols; contaminated equipment, textiles, faeces, food and water; etc. [1, 4, 7]. Epidemics are especially associated with certain genotypes with more virulent viruses that develop and change over years [1, 4].

Norovirus is heat resistant, survives 75 °C, and is also resistant to a variety of disinfectants, including chlorine in lower concentrations, and survives dry for days to months (>10 months) on equipment, textiles, food and water and otherwise in the environment [4, 7–11, 18].

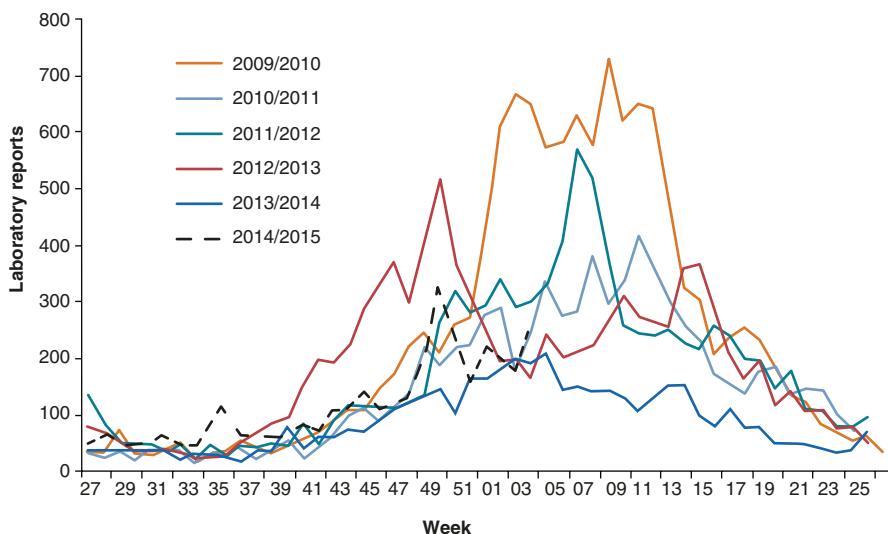


Fig. 54.1 Norovirus outbreaks causing closure of hospital wards in England: variation in seasons. In 2014, there were 690 outbreaks with closed wards in 640 cases. (Source: Public Health England. August 14, 2015) [23]

Mild disease symptoms occur in most patients, with short or no immunity, so repeated sickness may occur in the same patient, and there is no vaccine and no specific treatment. Up to 50% of a ward or department may start with symptoms approximately simultaneously (both patients and personnel) [4, 16].

Incubation time of 1/2–2 days may often start abruptly without any other symptoms other than vomiting.

Clinical symptoms: elderly and patients in a poor condition are more likely to have severe progression and longer diarrhoea and can shed viruses for a very long time [1, 4, 14, 17–19]. Symptoms include nausea, vomiting (2–3 days), diarrhoea (2–5 days), incontinence and fever 38–39 °C, of approximately 2–3 days duration.

Reinfections and subclinical infections are common.

54.6.1 Occurrence, Costs and Mortality

Global spread pattern since 1995 with more than 300 million cases a year and has become a year-round disease, although the winter frequency increases over 200-fold when people are closer together. The virus circulates in the environment and creates hyperendemic periods—especially in 2002, 2003, 2007 and 2010. In 2003, 23 million were sick of norovirus in the United States (12–13% of the population), and CDC (Centers for Disease Control and Protection) estimates that 1 in 14 people becomes ill each year [4]. Nowadays approximately 40% of all foodborne

infections are caused by norovirus. It is observed as a large problem in connection with outbreaks in cruise ship traffic; up to six consecutive cruises with the same boat have led to major outbreaks [4, 20–22]. CDC register cruises with norovirus outbreaks, and Norwegian ships are often involved [21].

The major epidemic waves in the society, schools, kindergartens, colleges, universities, passenger ships, hotels, conferences, trains, military camps, sports (Olympic ski sport in 2018), etc. are steadily further entering hospitals, nursing homes and other health institutions, often with long-lasting outbreaks: 19 days in hospital at average, 16 days in nursing homes and 7 days outside the health service [4, 14–17, 20–22].

Healthcare institutions with norovirus outbreaks lead to closure of departments and even hospitals. England is continuously registering outbreaks in hospitals [23]. In 2014 there were 690 outbreaks that resulted in closure of departments/units in 640 of the cases! In the first 4 weeks of 2015, there were already 62 outbreaks that all resulted in closure of the ward [23].

Norway is experiencing larger and smaller outbreaks, especially related to food and drink, international food trade and cruise boats [20–22, 24–26]. Also hospitals and nursing homes are strongly exposed to the infection [27, 28].

Outbreaks described in Norway from the Norwegian Institute of Public Health:

- 2001: Eikedalen, Hordaland; alpine resort, 400 were sick from drinking water.
- 2003: Bergen; seminar for health professionals, > 50 were ill.
- 2005: Oslo; 2 major outbreaks, 138 soldiers (starting with the kitchen staff) and 33 cases participating in a seminar after eating food from a catering company.
- 2006: Asker and Bærum; 17 were sick from eating oysters from France—part of an international outbreak.
- 2007: Stavanger; 81 were sick in 6 different parties with food from the same catering company.
- 2008: Oslo; 70 were sick in 6 different parties been on the same restaurant. Oysters from Ireland.
- 2008: Hamar; 150 were sick after hotel stay, kitchen staff infected.
- 2008: Ullensaker; more than 200 were sick at an airport hotel. Sick kitchen workers.
- 2009: Passenger ship from Oslo to Copenhagen; 36 were ill from 5 different sport teams (orientation). Some of these were probably sick in advance.
- 2010: National outbreak; Lollo lettuce from Denmark. At least ten outbreaks.
- 2010: Cruise ship from Oslo; springtime, several hundred were sick in three different trips from Oslo with “Vision of the seas”. Several returns during the cruise.
- 2012: Oslo; 41 sick at “Christmas dinner” at a hotel. Infected oysters [24, 25].
- 2015: Cruise ship, on the Norwegian Fjords, May–June; 300 or more were probably sick [22].
- In addition, outbreaks at several healthcare institutions with 40–100 people involved per outbreak, almost as many personnel as patients.

54.7 Rotavirus

The rotavirus is the most common cause of disease in small children and the elderly but can also cause epidemic outbreaks in the community and in healthcare institutions [3, 4]. 40–60% of infant gastroenteritis is caused by rotavirus. 80–90% has had rotavirus infection at 4 years of age.

Clinical symptoms: acute vomiting, followed after a few hours of heavy diarrhoea with rapid dehydration and rapid, cholera-like diarrhoea with development of dehydration and loss of electrolytes, especially in the smallest children. Sunken fontanelle in infants, hollow orbital cavity and standing skin folds are classic signs of severe dehydration in toddlers. Infants/toddlers are admitted to hospitals for observation and rehydration.

If no prompt administration and treatment with intravenous therapy, it may lead to shock and death. It is estimated that 450–750,000 children die of rotavirus infection each year, globally. Vaccine is available.

Incubation period: 1–3 days

See also references [1–4] for more information.

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Abstract

Prion disease (Creutzfeldt-Jakobs disease (CJD), bovine spongiform encephalitis (BSE), “mad cow disease”, etc.) is a slowly evolving degenerative disease caused by different types of “infected proteins” that can be found in all tissues and secretions from infected humans and animals (scrapie in sheep, chronic wasting disease of deer, moose, etc.). It is believed that the “infection” may also be associated with special neurodegenerative forms of dementia and other neurological diseases.

The following chapter is focused on practical measures to detect and prevent transmission of prion disease in healthcare institutions.

Keywords

Prion protein disease · Creutzfeldt-Jakobs disease · CJD · Bovine spongiform encephalitis · BSE · “Mad cow disease” · Scrapie · Prion protein scrapie (PrP^{Sc}) · Chronic wasting disease · Dementia · Neurological disease · Information Screening · Isolation · PPE · Decontamination · Environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

55.1 Purpose

- To prevent transfer of prion disease to patients, staff, visitors and environment in the hospital.
- The transmission is mainly via blood and tissue, but secretions and excretions from humans and animals may be contagious [1–16].

55.2 Comprise

All patients, who are suspected of prion disease or unknown degenerative brain disease, having a rapid developing dementia. All equipment that has been used for such patients and been in contact with their tissues, secretes or mucous membranes. All patients and personnel who may be exposed to prion infection via transplants, transfusions, insecure sterilized/disinfected equipment from suspected prion cases, etc. [1–5, 17–23].

55.3 Responsibility

The hospital's management provides written procedures for diagnosing, isolating and treating patients with suspected prion disease and guidelines for how to treat potentially exposed equipment, patients and personnel.

The department management implements guidelines and reports to the Director concerning resource problems (personnel, expertise, isolation, disinfection methods) that may lead to infection risk for patients or personnel.

Employees follow routines and report if general and special preventive procedures are not followed.

55.4 Practical Measures [1–5, 17–23]

55.4.1 General Prophylaxis Against CJD and Other Prion Disease

- *Human biological material* should always be treated as potentially contagious, and procedures for this should be followed (gloves on direct contact with blood/tissue, surgical mask/screen at risk of blood/tissue spray).
- *Sterilization of instruments and equipment that penetrates skin/mucous membranes:* equipment should be autoclaved after thorough cleaning in the instrument washing machine/ultrasonic bath. Autoclaving often occurs at lower temperatures or shorter times than is necessary to remove prions!
- *Used instruments should be cleaned immediately after use:* do not let tissue/blood dry in on instruments! [3, 5, 24, 25] Instruments that dry in with protein residues are difficult to clean and can pose a risk. Prions stick strongly to steel and other metal (adhesive) [24, 25]. Therefore, instruments should be cleaned immediately (<1 min) after use; do not dry, but put into liquid.

55.4.2 Removal of Prions: General Recommendation

- Autoclaving at 134 °C for a minimum of 18 min in one pre-vacuum autoclave (no higher temperature) [1–4].
- Or at 132–134 °C for 60 min in gravity autoclave [1, 4].

This should be evaluated and used as a standard routine for autoclaving.

Note: the effect is not sure if much biological material is present, especially with variant CJD [26].

Note: formalin, ethylene oxide vapour or hydrogen peroxide has no effect on CJD!

Protein residues that are difficult to remove from instruments and equipment and are not removed or destroyed by autoclaving require new solutions today [1, 3, 5, 19–29]. Equipment like brushes and dental equipment like root canal instruments are difficult to clean between uses. In such cases disposable equipment is recommended [5, 27–29].

55.4.3 Special Prophylaxis on Suspicion or Detected CJD/Prion Disease

- *Blood contamination:* the patient is treated as “blood contamination”—infection transmitted by blood and tissue. See Chap. 17 isolation by blood-borne infection.
- *Human biological material* should always be treated as potentially contagious. Procedures should be followed: gown and double gloves on direct contact with blood/tissue and in addition surgical mask/cap/goggles/visor at risk of blood/tissue spray. All tissues/blood/secretions/mucosa from patients with suspected prion disease are considered to be infectious.
- *In case of accident*, clean the wound by 5% chloramine (or sodium hypochlorite) or 1N NaOH for 5–10 min, and then wash with soap and water. Mucous membranes exposed to possible infection: rinse with sterile saline for 5–10 min.
- *Skin contact with infectious material:* disinfect with 1N NaOH.
- *Spills mm,* start from the periphery and inwards: disinfect with 1N sodium hydroxide for 1 h.

55.4.4 Treatment of Patients with Suspected CJD/Prion Disease and Equipment Used

- Patients with suspected/proven CJD/prion disease should be treated as with blood/tissue infection.
- The patient is isolated on a single room.
- Use disposable equipment or equipment that can be disposed of (autoclaved and burned) following invasive procedures.
- In case of invasive procedures or spills, use disposal gown, double gloves, visor/goggles and cap/surgical mask.
- All equipment used for dressing is double-packed in the patient room/operating room, placed in thick yellow risk bag, labelled and sent to burn by a special transport.
- Used instruments and blood/tissue material are autoclaved/disinfected before burning (see below). Prions may survive high temperatures; therefore follow instructions carefully.

- After autoclaving/disinfection, the equipment is sent as a contaminant for burning.
- In case of uncertainty, questions, etc., contact an infection control personnel.

55.4.5 Sterilization of Instruments/Equipment Used in Examination/Treatment of Possible CJD/Prion Disease

- *Invasive equipment:* select disposable, single-use equipment or reusable equipment that can be disposed of after the actual use. Immediately after use, the equipment is immersed for 1 h in a risk container of 5% chloramine or with 1N NaOH (at room temperature) [3, 17]. Then it is autoclaved at 134 °C for 1 h, packaged as contamination and sent to burning. If prion disease is suspected retrospectively, previously used equipment is called back and subsequently processed and destroyed as above. The identity of the persons to which this equipment is used is noticed. All instruments used on patients with suspected prion disease should be detected, recorded and destroyed [3, 5, 17, 20].
- *Non-invasive* reusable equipment can either be autoclaved (as described above) or immersed in 1N NaOH (1 h) or chloramine 5% (1 h) with or without subsequent autoclaving.
- *See also Chap. 59, “Technical disinfection”.*

55.4.6 Disinfection of Surfaces/Environment

Follow regular routines: 5% chloramine for 1 h or 1N NaOH for 1 h.

55.5 Background Information

Prion disease (Creutzfeldt-Jakobs disease (CJD), bovine spongiform encephalitis (BSE)) is a slowly evolving degenerative disease caused by different types of “infected proteins” that can be found in all tissues and secretions from infected humans and animals (scrapie in sheep, chronic wasting disease of deer, moose, etc.) [1–15]. It is believed that the “infection” may also be associated with special neurodegenerative forms of dementia and other neurological diseases [1, 5].

Prions are infectious, modified cell proteins, atypically folded and tightly aggregated protein material of an original normal protein structure on the surface of all human and animal cells [1–3]. Prion protein scrapie (PrP_{Sc}), which causes sickness in sheep and goats, differs slightly from normal surface structure (PrP_C) on human and animal cells [1–5]. A new nasal tissue test can provide a fast and reliable diagnosis [30].

Diseases in humans: kuru (cannibalism), Creutzfeldt-Jakobs disease (CJD), Gerstmann-Straussler-Scheinker (GSS, 1/40 million), fatal familial insomnia (FFI, 1 < 40 million) [1–5]. Prion disease occurs due to infection (kuru, CJD), protein

mutation (CJD, GSS, FFI) and unknown (CJD). People may still be nosocomially infected; a patient developed CJD after potential surgical exposure in the United States [31]. Recently, two cases were reported in Salento (Puglia, Italy), an area with a high incidence of CJD, 4/million, against normal, 1/million [32].

Diseases in animals: scrapie sickness is well known in sheep, goat, cattle and other animals. Bovine spongiform encephalitis (BSE) is also called “mad cow disease”. Scrapie sickness has been transferred to 1500 sheep through contaminated vaccine [5]. Otherwise, hundreds of thousands of sheep have earlier been destroyed after detection of the sickness in Norway and other countries. From 1988 to 1995 more than 160,000 cattle in the United Kingdom got bovine spongiform encephalitis (BSE) after ingestion of contaminated feed [5]. Monkeys (macaques) fed with high-dose brain material (>5 g) from cattle with BSE got—all 18 animals—prion disease after median incubation period of 4.5 years (up to 10 years) [15]. Incubation period varies for monkeys and probably also for humans. Prions can be detected in saliva from BSE-infected cattle 2 months before symptoms appear [13].

Occurrence of CJD in man: approximately 1/million people a year [1–5]. Nosocomial infections have been transmitted by coronary transplant, EEG electrodes, implantation of dura mater, human growth hormone, etc. [1–5, 18–23, 33–37]. In England there are over a hundred cases in later years of Creutzfeldt-Jakobs disease variant (vCJD): 1996–2012, 177 cases [4, 5]. These cases are infected by eating contaminated beef from cattle with bovine spongiform encephalitis (BSE). It is estimated that 1 in 2000 Britons is exposed to prion disease by vCJD. Several hundred are exposed to uncertainly cleaned instruments [4, 5, 37, 38]. It is assumed that only 1–3 Norwegians may have been infected during the relevant period (1986–1996) of infected meat in the United Kingdom or from imported meat to Norway [39]. Chronic wasting disease is recently detected among some flocks of reindeers in Norway. The infected flocks are taken out. However, there is a certain prevalence of prion disease (Fig. 55.1) [5].

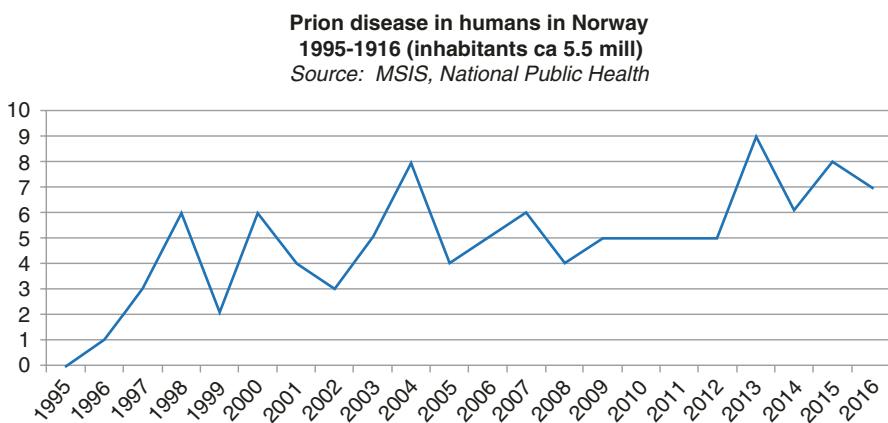


Fig. 55.1 Prion disease in humans in Norway 1995–1916 (inhabitants ca 5.5 million). Source: MSIS, National Public Health

The infection is widespread and consists of small cellular protein molecules that can be found in the blood, lymphoid tissue, tonsils, brain, spinal cord and fluid, appendix, kidney, spleen, lung, etc. [5].

Resistant infectious agents are resistant to high temperatures and chemical substances and have a very long survival in the environment. Therefore, it is important to follow special routines and measures in case of suspected or detected prion disease. Contaminated electrodes stored in ethanol and formalin for several years have been shown to induce CJD in chimpanzees. Four chemicals may reduce prions with >4 logs, of which chlorine (>10,000 ppm for 1 h) show the most consistent prion inactivation. One to 2N NaOH may have failing effect, and aldehydes may increase prion resistance (see also technical disinfection).

Incubation varies in relation to type of prion disease and transmission of infection—from 18 months (intracerebral instrumentation, corneal transplant) up to 40 years (human growth hormone, etc.).

Symptoms: subacute to chronic developing dementia in the ages 40–70 years, cerebellar symptoms, ataxia, insomnia and autonomic dysfunction.

Disease time to death: 4–12 months.

55.6 New Prion Diseases

New types and variations of prion diseases are detected as diagnostics is getting better. The last type is “Shy-Drager syndrome” (multiple system atrophy—MSA) that “raises the question of whether or not also Alzheimer’s and Parkinsonism are contagious” [40]. This syndrome has also misfolding of prion protein (PrP) with accumulation of a substance (alpha-synuclein) in the brain [40]. “All chemicals that kill bacteria and viruses do not harm prions” [40].

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Tuberculosis: Control in Hospitals

56

Abstract

Tuberculosis (TB) has increased globally since 1975 and today is the most common cause of death worldwide, by communicable diseases. One out of 3–4 people in the world has been infected with TB, and about 10% of them get symptoms. Ten million new tuberculosis cases occur each year; 95% of these are in developing countries in Asia and Africa. More than 1000 new cases occur every hour of the year, more than 3.5 million patients are major spreaders of TB and more than three million die every year of tuberculosis. Most patients, 60–80%, have pulmonary tuberculosis. TB is caused by a slow-growing, robust bacterium, called *Mycobacterium tuberculosis*. A wide variety of *Mycobacteria* called the *Mycobacterium tuberculosis* complex are causing the same severe clinical course as TB. Vague symptoms like coughing, night sweats and weight loss may occur 1–2 years after exposed to infection in 10% of the cases. The disease is difficult to detect in previously poor and weakened patients in hospitals. Multidrug-resistant tuberculosis (MDR-TB), resistant to minimum rifampicin and isoniazid, is widely spread and occurs during incomplete therapy. MDR accounts for at least 3–6% of the cases in Europe. In areas with very high incidence of TB like in Mongolia, treatment may fail in one out of three cases, and MDR-TB occurs during relapses. In 2012, totally resistant TB bacteria were detected in India. Problems are all concerning how to detect, isolate and treat such cases. Remember, cardinal symptoms are persistent cough, weight loss and night sweats! Only one single TB bacterium can cause disease and may survive for up to 1 year in the environment! The following chapter is focused on practical measures to detect and prevent transmission of tuberculosis in healthcare institutions.

Keywords

Mycobacterium tuberculosis · *M. tuberculosis* complex · Tuberculosis · TB Pulmonary disease · Multidrug resistance · MDR · Information · Screening Isolation · PPE · Respirator · Airborne infection · Decontamination · Environment Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

56.1 Purpose

- To prevent transfer of TB to patients, staff, visitors and environment in the hospital.
 - The transmission is mainly airborne, but secretions and excretions from humans and animals (bovine and other types of tuberculosis) may be contagious [1–16].
-

56.2 Comprise

Patients, personnel, visitors, equipment, medical equipment, textiles, rooms and surfaces and the complete environment exposed to TB.

56.3 Responsibility [2, 4–8]

The hospital's management is (according to law and regulation) responsible for written practices regarding training, proper preventive measures, isolation, control, contact tracing and information concerning TB infection. The management shall ensure satisfactory isolation and competent personal and adequate personal protective equipment (PPE).

Department management is responsible for implementing hospital routines, for training and information of personnel and patients and for informing hospital management in case of lack of capacity, expertise or infection control equipment.

The Occupational Safety and Health Department/Occupational Health Services should monitor exposed and infected persons and conduct environmental investigations in collaboration with lung medicine specialists, infection control units, specialist in infectious diseases and the tuberculosis coordinator.

Every employee has personal responsibility to report about suspected or detected TB. All personnel are required to inform if exposed to tuberculosis in or outside the hospital or after travelling/working in areas with high incidence of tuberculosis. In such cases there may be state control routines [5].

56.4 Practical Measures

56.4.1 Prevention of Tuberculosis in the Society [2, 4–10]

The level of infection control concerning tuberculosis has been reduced in many developed countries, like in Norway, during the last 15–20 years. It has always been a great variation concerning prevention of TB: vaccination and screening of the population. This is described for Norway as a special approximation to the problem. From the BCG vaccination of all children, tuberculin tests and lung X-ray screen surveys around the country, the Norwegian healthcare system has turned away from the problem. The general social control has disappeared together with the

disappearance of vaccination, TB tests and X-ray control [5]. Only defined risk persons are examined and vaccinated [5]. This is in spite of a steady increase in tuberculosis and imports of more resistant bacteria [2, 3, 5].

Screen examination (lung X-ray) of risk groups is now only undertaken for asylum reception, suspicion of pulmonary tuberculosis and infection detection and screening of particularly vulnerable groups, like drug addicts. Also elderly with previous positive screenshots should be followed up for clinical suspicion of relapses, but this is not performed as a routine today in many countries, including Norway.

BCG vaccination was performed until 2009 in Norway, as a voluntary part of the childhood vaccination program, and was given at approximately 14 years of age. The BCG vaccination for all children was stopped in 2009. The protective effect of the vaccine has been considered to be up to 80% of the first 4 years after vaccination and later on a certain protection against military tuberculosis [1, 2]. Groups recommended for BCG vaccine *after* 2009 are in Norway:

- Tuberculin-negative persons without prior BCG vaccination, coming from risk areas and staying in Norway for more than 3 months.
- Unvaccinated persons in contact with (been in the same room as) detected cases of contagious lung tuberculosis
- Unvaccinated persons who are travelling to TB-risk areas.
- Children in whom one or both parents are from countries with high incidence of tuberculosis.
- Healthcare personnel.

Control of immigrants and others [5]:

- All persons who come from risk areas for tuberculosis and who stayed in Norway for more than 3 months are obliged to undergo tuberculin tests. X-ray thorax (Screenshot) is required for all over 15 years.
- All persons who have been exposed to tuberculosis infection (been in the same room as) must be checked.
- Specific provisions are available regarding tuberculosis and later control of certain occupational groups: healthcare workers, military, teachers, childcare workers and workers on ships and oil platforms.

See Chap.10. also the section on TB control of healthcare professionals.

56.4.2 Tuberculosis Prevention in the Hospital [2, 5, 11, 12]

56.4.2.1 Admission/Examination/Treatment/Outpatient Clinic in Hospital

- If known or suspected tuberculosis, directly admit in isolate for airborne disease with the use of PPE, including respiratory protection P3 mask. No more contact

tracing if proper infection control has been completed, including transport by ambulance.

- If unknown or suspected tuberculosis—without correct use of contraceptive measures—see below.

56.4.2.2 Unknown/Suspected Tuberculosis Detected After Admission in the Hospital

The department management determines the patient's infection status in cooperation with infection control personnel and sends a report to the Occupational Health Department/Corporate Health Service with the following information:

- Name of the department, name of the infectious patient, date of birth and address.
- The period the patient was admitted in the department.
- Name and date of birth of staff who have been in close contact with the patient (cared for, examined, treated, been in the same room as, etc.) and total exposure time.
- Occupational health department/corporate health service, etc. conducts tbc tests and follow-up of employees exposed to infection, in collaboration with infection control unit/lung specialist.
- The department management at the relevant department where infection was detected is responsible for informing patients on the same room as the index patient, relatives and other close contact persons and referred to investigation. Contact the TB coordinator in primary healthcare for proven tuberculosis.

56.4.2.3 Follow-Up of Superinfected (BCG-Vaccinated), Infected (Tuberculin Positive, Not BCG-Vaccinated) and TB-Disease Among the Staff

Registration is done by the occupational health department/company health service in cooperation with lung specialist/infection control. Overview of site of infection, number of infected persons and time of infection should be included in the annual report from the occupational health department/company health service.

56.4.2.4 Measures for Patients with Infectious Tuberculosis, Not Isolated from Admission

- The department's responsible physician is informed immediately. Patients with infectious pulmonary tuberculosis should be placed directly in isolation for airborne diseases.
- The patient is placed in a single room if no isolate is available immediately, and the procedure for air isolation should be followed with gloves, protective gown, cap and respiratory protective device, P3 mask. See Chap. 18 on airborne/droplet infection isolation.
- During transport, the patient should use a surgical mask or respirator. The staff should be informed of suspected TB and use adequate PPE (gloves, own, cap and respiratory protection, P3 mask). The ambulance is subsequently disinfected with chloramine 5%.

- The department management records personnel (including ambulance staff) and patients who may have been exposed to infection, i.e. have *not* used adequate infection protection equipment. This is important for the tracing of TB in cooperation with the occupational health services.
- Room disinfection with chloramine 5% is carried out on the patient's room and toilet/bath and other rooms where the patient has stayed. See procedures for disinfection.
- In the case of detected pulmonary tuberculosis, medical devices used in the patient's room should be considered as a possible risk in use for other patients. If the equipment draws air from the room for cooling of the inside engine / electrical parts and cannot be disinfected in a safe way with regard to TB, it should not be used by other patients. Disposed as infectious waste after use.

56.4.3 Contact Tracing of Exposed or Infected Cases

Contact tracing is required among all contacts of a TB-infected patient with infectious lung tuberculosis. Contact tracing is also done for all newly infected cases, superinfected (BCG-vaccinated with a large tuberculin response) and infected (tuberculin highly positive, not BCG-vaccinated)—with and without symptoms. All exposed to infection, patients, visitors, and anyone who has been in the same room as an infectious TB patient, should be followed up.

The department management, in cooperation with the infection control unit/corporate health service, is responsible for infection detection/information in the hospital, as well as information to other healthcare institutions that have had contact with the patient. The local authority/tuberculosis coordinator is responsible for contact tracing outside the hospital (nursing home, healthcare centre, home nursing, etc.).

56.4.3.1 Infectious Lung Tuberculosis

- Patients in the same room as the index patient, visitors to the room, staff who have been in contact with or treated the index patient, and cleaners and other service personnel who have been in the patient's room should—*regardless of length of contact time with the patient*—be tested first [1, 2].
- Tuberculin samples must be made of relevant persons who have been in close contact—in the same room—as the infectious person.
- Tuberculin test should be repeated after 8 weeks in tuberculin-negative and in BCG-vaccinated subjects without significant increases from previous tuberculin tests.
- Screenshot (X-ray) is not applicable initially since early changes cannot be observed by this method.
- In case of suspected findings in personnel or persons with superinfection/infection, refer to the pulmonary clinic/diagnostic station.
- In case of positive findings, TB infection, in a person in the environment around the index patient, the second person's contacts should be investigated further.
- BCG vaccination of tuberculin-negative persons in the TB patient's immediate environment should be considered and is usually recommended.

56.4.3.2 Newly Infected (Tuberculin Test Positive, No BCG Vaccination)

- The purpose is to find the source of infection, i.e. a person with infectious pulmonary tuberculosis.
- In addition to anamnesis (family and person history), lung X-ray examination of close contacts is the most important investigation.
- Tuberculin samples of people in the local contact area.

56.4.4 Special Occupational Groups

When infectious tuberculosis is detected in a person belonging to specific occupational groups like healthcare professionals, sickness leave is provided as long as the disease is considered contagious. The assessment is carried out in collaboration with diagnostic stations and specialists in infectious medicine/pulmonary medicine.

56.4.4.1 Reports and Information [4, 5, 8]

- Tuberculosis is a nominative mandatory (group A disease) to the National Public Health.
- Physicians who detect or suspect tuberculosis should report this to the local authority, the tuberculosis coordinator and the National Public Health Institute. A copy of the message must be kept in the patient's journal.
- Also send a message to the hospital's infection control unit in cases where an infectious person is to be hospitalized or recently been hospitalized or been in other institutions.
- Use the report form.
- Healthcare institutions, polyclinics, laboratories and healthcare centres are also responsible for reporting tuberculosis.
- Nurses, midwives and health sisters who, in their professional practice, suspect that a patient has a contagious tuberculosis are obliged to immediately in writing and orally notify the local medical authority/infection control doctor in the community where the person is staying [4, 5, 8].

56.5 Background Information

Tuberculosis (TB) has increased again since 1975 and is the most common cause of death worldwide caused by communicable disease [1, 2, 13, 17]. One out of 3–4 people in the world have been infected with TB, and about 10% develop the disease [1, 2]. Ten million new tuberculosis cases occur each year; 95% of these are in developing countries in Asia and Africa. More than 1000 new cases occur every hour of the year, more than 3.5 million patients are major spreaders of TB and more than three million die every year of tuberculosis.

Most patients, 60–80%, have pulmonary tuberculosis. TB is caused by a slow-growing, robust bacterium, called *Mycobacterium tuberculosis*. A wide variety of

Mycobacteria called the *Mycobacterium tuberculosis* complex are causing the same severe clinical course as TB [1]. Vague symptoms like coughing, night sweats and weight loss may occur 1–2 years after being exposed to infection in 10% of the cases. The disease is difficult to detect in previously poor and weakened patients in hospitals.

56.5.1 Definitions

- *Tuberculin positive*: person with positive reaction in the tuberculin test (Mantoux). In unvaccinated persons, a positive test may be a sign that the person is infected with TB.
- *Mantoux method*: replaces *Piquet* testing from July 2004 (Norway) and is performed by inserting 0.1 mL tuberculin intracutaneously in the left forearm. Reading will take place after 72 h (3 days). Positive test is induration of 6 mm or more.
- *A newly infected person* is defined differently depending on whether the person is BCG-vaccinated or not.
- *Natural positive*: previously tuberculin-negative, unvaccinated person who has become tuberculin *positive* due to infection.
- *Superinfected person*: enhanced tuberculin reaction as a result of TB infection in a former BCG-vaccinated person.
- *Person with infectious tuberculosis*: a person with clinical signs of tuberculous pulmonary disease or other tuberculous disease that may be contagious. Tuberculosis in other organs other than the lungs is infrequently infectious. Exceptions are tuberculosis in skin and during operative treatment with incision in tuberculous tissue.
- *Vaccinated person*: a person who is vaccinated (BCG) against tuberculosis and after which has a scar in the skin as a result of the vaccination.
- *The BCG vaccine*: probably protects against tuberculosis from the first 4 years after vaccination and may perhaps have a suppressing effect on later disease development [1]. But BCG vaccination does not prevent superinfection, i.e. infection with tuberculosis bacteria and development of primary complex. A number of countries do not use the BCG vaccine but follow up health professionals with regular/annual tuberculin tests. There have been many voices for and against the BCG vaccine, but historically it seems that it has worked in Norway, along with other measures [1, 2]. Due to increased incidence and resistance development, the author recommends the BCG vaccine until a better vaccine is available.
- *MDR-TB (multidrug-resistant tuberculosis)*: resistant to rifampicin and isoniazid as a minimum is widely spread, both in developing countries and in industrialized countries such as Norway, and occurs during incomplete therapy [1, 2, 18–25]. MDR accounts for at least 3–6% of the cases in Europe. In areas with very high incidence of TB, like in Mongolia, treatment may fail in one out of three cases, and MDR-TB occurs during relapses [24].

- *XDR-TB (extensively drug-resistant tuberculosis)*: a rare type of MDR-TB which is also resistant to fluoroquinolones and against one or more of second-line medications against TB [2].
- *Total resistance*: in 2012, totally resistant TB bacteria were detected in India [2, 20]. There are major problems related to how to detect, isolate and treat such cases [1, 2].

In Norway, 300–400 people are diagnosed with tuberculosis each year (5.5–7.3 per 100,000 inhabitants), hence about 2/3 with lung tuberculosis [1, 2], mostly younger immigrants or older Norwegians. In 2014, 327 cases of the *M. tuberculosis* complex were detected against 401 cases in 2013 [3]. Of these, 175 were born in Africa, 98 in Asia, 29 in Europe outside Norway, 2 in America and only 23 in Norway [3]. Nearly 13% of isolates tested were resistant to isoniazid, 3.8% against rifampicin, 2.6% against ethambutol, 10.6% against streptomycin, 7.2% against pyrazinamide and 3.8% were MDR-TB. One case had extended resistance, XDR-TB, against a variety of good medicaments [3].

56.5.2 Risk in Hospitals

In hospitals, an accumulation of patients with undiagnosed tuberculosis may lead to transmission to the environment and to patients, personnel and visitors that are infected (previously not BCG-vaccinated) or superinfected (previously BCG-vaccinated). Many patients with reduced infection defences due to poor general condition may increase the risk of TB spread and development.

Nosocomial infection is not uncommon and is caused by a number of factors such as lack of isolation, improper use of personal protective equipment, improper room ventilation, delayed or lack of diagnosis, extrapulmonary forms of TB, lack of monitoring and follow-up of close contacts and inadequate treatment and control [1, 2, 13–16, 23, 24, 26–35].

TB is a lurking, chronic respiratory disease with cough, night sweats and weight loss. Therefore, the disease is difficult to detect if not thought about.

56.5.3 Transmission

Tuberculosis is transmitted primarily through air (airborne) from a patient with pulmonary tuberculosis and with large amounts of bacteria in the sputum. Transmission can also occur via contact, food, water, milk, waste, etc. In water, atypical mycobacteria are often the most important for patients with reduced infection defences.

Mycobacterium tuberculosis can under favourable conditions live in the environment for up to 1 year, and only one single bacterium is enough to cause infection [1, 2]. An index case with lung tuberculosis can infect about 20 other people, and 10% of them get symptoms, usually within 1–2 years [1, 2]. The other 90% may have a primary complex, usually in the lungs, with live, inactive bacteria, which rarely may be reactivated later in life, especially in patients with severely impaired immune defence.

Reservoir is mainly infected humans, but some animals (pigs, cattle) may also be TB infected; a former very important way of transmission [1, 2]. The bacterium survives in a dry state without access to sunlight (kills the bacterium) and can stay alive outside the human body, for example, in dried sputum, in handkerchiefs, on floors, etc. When a person suffering from infectious pulmonary tuberculosis coughs, sneezes, talks, laughs, etc., small bacteria-containing aerosols of droplets and droplet nuclei are spread in the air; may re-aerosolize via particles, skin cells, dust, etc.; and can stay in the room for a long time. The smallest droplets can reach the alveoli in the lungs after inhalation. In rare cases, infection can be transmitted through basil-containing dust that is inhaled. Tuberculosis in other organs other than the lungs and in the skin is usually not contagious (OBS surgery, rupture of tuberculosis abscesses and the like). *Mycobacterium bovis* may infect through unpasteurized milk. *Mycobacteria* are relatively resistant to a variety of disinfectants but are killed by chloramine 5% for 1 h [1, 2].

56.5.4 Symptoms/Development

- Development from infection to increased tuberculin reaction takes 4–8 weeks, i.e. natural infected or superinfected, but usually not ill. After about 3 months, changes in the lungs can sometimes be seen by X-rays. Ca.10 % develop tuberculosis after 1-2 years, but TB may also develop many years after the time of infection. The risk of getting sick decreases over the years but is present for the rest of life [1, 2].
- Early stage of active pulmonary tuberculosis may proceed without symptoms.
- *Main symptoms of lung tuberculosis* are *persistent cough* (with or without purulent expectorate), *emaciation and night sweats*. Presence of slackness, fever, chest pain (pleural pain), etc. may vary.
- Tuberculosis can later attack many organs in the body outside the lungs, for example, the lymph nodes, bones, joints, kidneys, bowel, skin, pleura and meninges. The symptoms of extrapulmonary tuberculosis depend on the affected organ. In poor general condition, prolonged fever can be the only symptom of tuberculosis, both pulmonary and extrapulmonary.

56.5.5 Diagnosis

X-ray examination, tuberculin test (Mantoux), blood tests and detection of tuberculosis bacteria by direct microscopy and culture of expectorate, bronchial fluid, urine, faeces, pus or tissue biopsies. Cultivation takes 2–6 weeks, but faster diagnostics are performed using genetic technology.

- Suspected pulmonary tuberculosis: at least three expectorate samples, one sample each day for 3 consecutive days.

- Samples are taken from the first sputum in the morning before the patient eats. The patient has to cough up deeply from the chest, preferably promoted by physical therapy.
- The samples are taken on a sterile plastic container without addition and placed in a refrigerator for shipment to the laboratory.
- Pencil samples may also be taken from larynx or via bronchoscopy and aspirate from abscesses.

56.5.6 Airborne Isolation and Treatment

- In case of drug-sensitive pulmonary tuberculosis, airborne isolation regime for the first 3 weeks of treatment and for drug-resistant TB for 8 weeks or more. Infectious pulmonary tuberculosis must be isolated as long as TB is detected in respiratory samples.
- Combination treatment with multiple medications (usually four) is given, and the duration of the treatment is at least 6 months. Further treatment is conducted as DOT treatment, i.e. directly observed therapy.
- For MDR-TB, treatment lasts for at least 18 months with up to eight different tuberculosis drugs. There are at least 1500 MDR cases detected in the European region each year, especially the eastern part [36]. The treatment effect is poor; half of the cases die or has treatment failures.
- XDR-TB bacteria are highly resistant, also against one or more second-line drugs against tuberculosis. A total of 10–15% of the approximately 1500 MDR cases are XDR-TB [36]. Only one in four carries out successful treatment, and many die.
- The expenses for treatment are usually covered by the State.

56.5.7 Tracing Tuberculous Infection in Primary Care [5, 10]

The coordinator for TB and local authority/district physician are responsible for tracing infections in the index patient's family and contacts (work, school, institutions, etc.). Tracing of infection is required when detecting contagious lung tuberculosis or newly infected cases.

56.5.7.1 Infectious Lung Tuberculosis

- Find newly infected among contacts of the index case.
- The nearest contacts are tested first (family, friends, work-colleagues).
- Tuberculin test of relevant persons is carried out.
- Tuberculin test should be repeated after 8 weeks in tuberculin-negative and in BCG-vaccinated subjects without significant increase from previous tuberculin results.
- Natural infected cases or persons with TB superinfection are referred to the pulmonary clinic/infectious disease department for further diagnosis.

- If the person around the index patient has a positive finding, new investigation of this person's immediate contacts is needed.
- BCG vaccination of tuberculin-negative persons in the index patients' immediate environment should be considered.

56.5.7.2 Newly Infected Persons

- The source of infection may be a person with infectious pulmonary tuberculosis.
- Information, X-ray and examination of close contacts.
- Tuberculin tests of close contacts.

56.5.7.3 Professional Groups

If infectious tuberculosis is detected in a person belonging to specific occupational groups, e.g. healthcare personnel and other caregivers, teacher, food producers, military, etc., sick leave must be approved as long as the local authority considers the disease to be infectious. Evaluation is done in cooperation with specialists in infectious medicine/lung medicine.

56.5.8 Today's Situation and the Future

Tuberculosis should be eliminated as a serious fatal disease, already 40 years ago. However, today the disease is still increasing worldwide, and the bacteria are becoming increasingly resistant. The situation has been compared to the early twentieth century, before antituberculous drugs were invented.

The ECDC (European Centre for Disease Prevention and Control) reported in 2015 that 360,000 Europeans developed tuberculosis in 2013: 1000 people every day! [36] There has been a certain decline in new cases in the West of Europe, while there may be an increase in East Europe from 2013 to 2015; see charts from ECDC (Fig. 56.1) [36, 37]. The low endemic countries in the European region report less than 20 TB cases per 100,000 inhabitants per year. North, Western and Southern Europe are included in this group.

ECDC and WHO have defined 18 high-risk countries for tuberculosis in the European region:

“Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan” [36]. These 18 generate 85% of all new TB cases in the European region and also had the most deaths of the 38,000 TB-related deaths in 2013 [36].

56.5.9 MDR-TB

Still, there are in Europe a high number of patients infected with multidrug-resistant tuberculosis; about 1500 cases or more are reported each year, but there may be some reduction from 2013 to 2015; see Figs. 56.2 and 56.3 [36, 37]. In Western Europe, including Norway, MDR-TB is largely linked to immigration [36].

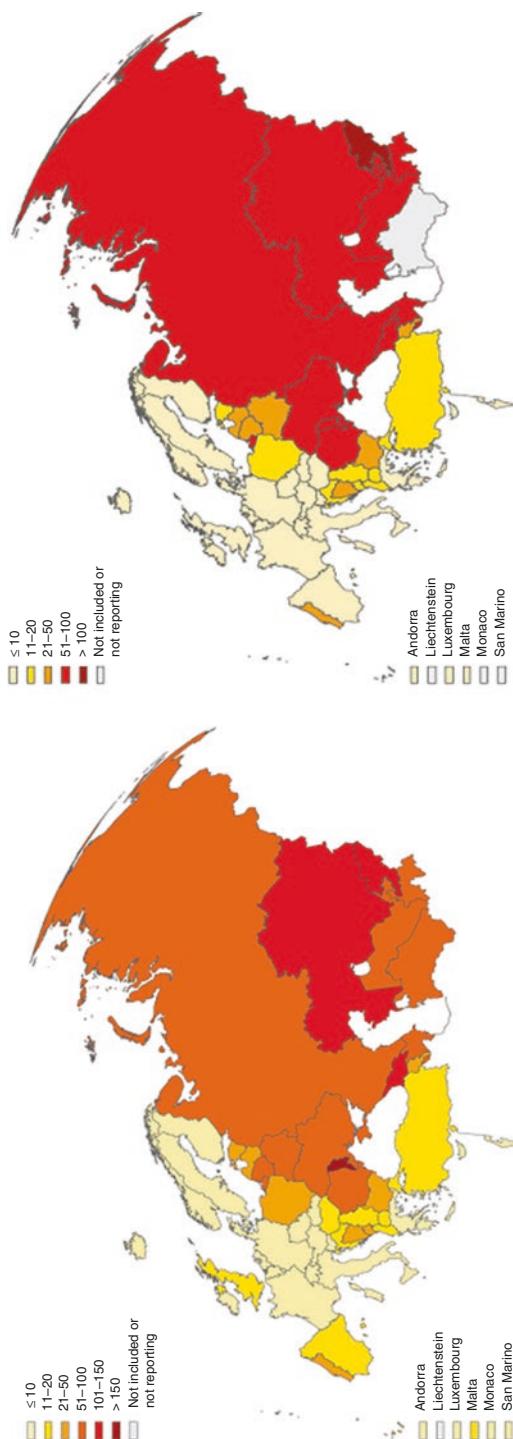


Fig. 56.1 (a, b) Tuberculosis incidence per 100 000 inhabitants, European region, 2013 (left) and 2015 (right). Source: ECDC 2015 and 2017 [36, 37]

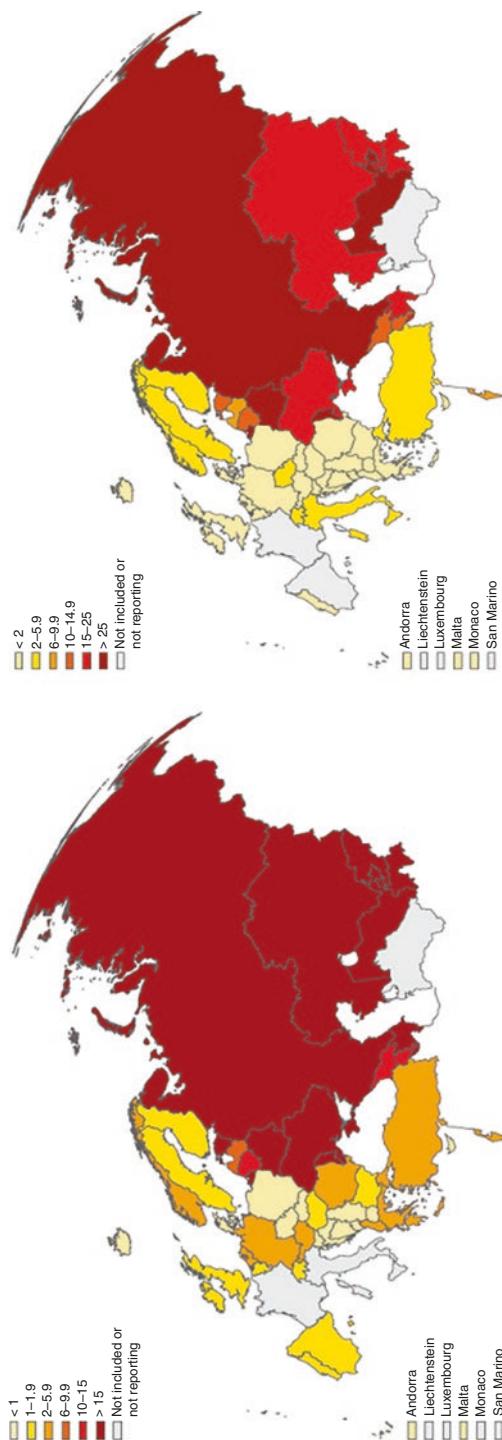


Fig. 56.2 (a, b) Percentage of multidrug-resistant (MDR) cases of tuberculosis among new pulmonary TB cases, European region, 2013 (left) and 2015 (right). Note high incidence in Eastern Europe. Source: ECDC 2015 and 2017 [36, 37]

56.5.10 Increase in Developed Countries Like Norway

In contrast to the general trend in Europe, Norway has some increase in tuberculosis, mostly imported (Fig. 56.4) from ECDC [37]. There is a trend towards failure of treatment, less overview and deaths in cases of tuberculosis in Norway (Fig. 56.4) [36].

With increasing immigration in Europe, the problem will be enhanced if good health control and follow-up are not carried out for new immigrants. Increased travel activity to countries with high levels of resistant TB is a challenge that should be treated with greater attention than today. Hospitals and healthcare in general must be upgraded concerning infection control to prevent further increase of tuberculosis in Europe.

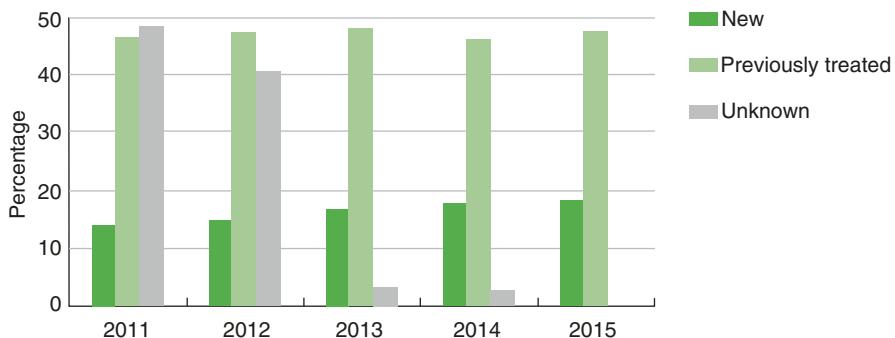


Fig. 56.3 Percentage of multidrug-resistant (MDR) cases of tuberculosis among new pulmonary TB cases, European region, 2015. Note some increase in new cases. Source: ECDC 2017 [37]

a **Tuberculosis cases by geographical origin, 2006–2015**

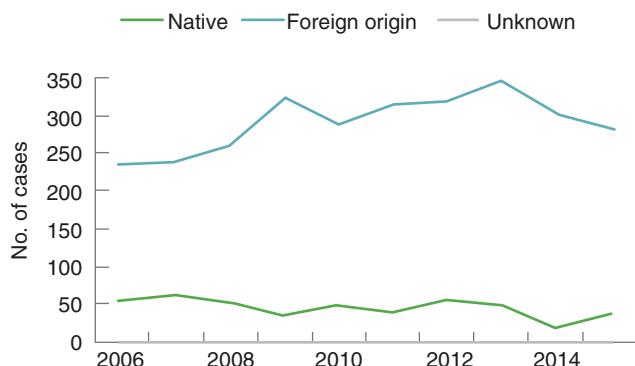
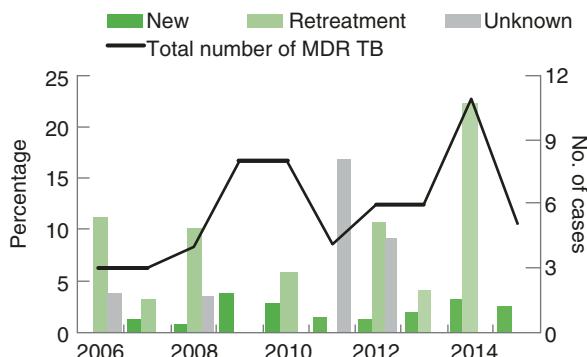


Fig. 56.4 (a, b) Development of tuberculosis in Norway, geographic origin, failure of treatment success and MDR-TB. Source: ECDC 2017 [37]

b MDR TB cases by previous treatment history, 2006–2015**Fig. 56.4** (continued)**References**

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Scabies: Control in Hospitals

57

Abstract

A little skin mite—*Sarcoptes scabiei*—runs on humans and animals and can cause irritable itching, dermatitis and eczema, especially on the hands. Scabies mite is invisible to the eye, cannot fly but has a high speed on warm skin (2.5 cm in 1 min) and may come over from one hand to the next within a few minutes. Outbreaks of scabies may often be large and persisting in institutions, day-care centres, schools, families and long-term institutions as nursing homes. Hospitals are occasionally exposed to infection, and both patients and personnel are infected. The following chapter is focused on practical measures to detect and prevent transmission of scabies in healthcare institutions.

Keywords

Sarcoptes scabiei · Scabies · *Norwegian scabies* · Mite · Itching · Dermatitis Eczema · Hands · Outbreaks in institutions, day care centres, schools, families, long-term institutions, hospitals · Contact infection · Information · Screening Isolation · Decontamination · Environment · Eradication · Nosocomial infections · Infection control · Hygiene · Prevention

57.1 Purpose

- To prevent transfer of scabies/mite to patients, staff, visitors and environment in the hospital.
- The transmission is mainly contact-borne, but biologic materials from humans and animals may be contagious for a period.

57.2 Comprise

- Patients, personnel, visitors, equipment, medical equipment, textiles, rooms and surfaces and the complete environment exposed to scabies.
 - All direct contacts of patients with scabies/suspected scabies and with clothing and equipment used by patients with scabies.
-

57.3 Responsibility

The hospital's management is responsible for the existence of written procedures for the proper control of scabies.

The department's management is responsible for following procedures for infection control and tracing in cooperation with the infection control unit, occupational health services or working environment during outbreaks of scabies.

Personnel are responsible for following current routines and preventive measures and for participating in sanitation/disinfection.

57.4 Practical Measures [1–4]

57.4.1 Inpatient/Outpatient Clinic

- *If known or suspiciously scabies*—directly in contact isolation. No more tracing of scabies in the hospital if proper infection protection has been carried out from the start, including transport in the ambulance.
- *If unknown at the admission/outpatient clinic*—preventive measures; see below.

57.4.2 Scabies: Discovered in Hospitals

The department management cooperates with the infection control unit and the occupational health services/working environment.

- *Contact isolation of the patient* for up to 2–3 days after application of the scab medicament. After treatment for scabies, the patient should have clean clothes, clean bed linen and be placed in a clean room. Personal caring for the patient with scabies is using gloves and disposable gown with long sleeves and cuffs. Room-bound shoes or shoe covers (wear gloves when shoe covers are carefully removed) is applicable. Wash hands after wearing gloves. Use the infectious waste bag in the room.
- *Make sure the diagnosis is correct.* Clinical diagnosis is often easier than microscopic. Itching and itching marks, mite tunnels in the skin, mites, eggs or faeces from mites may be seen [1, 2]. Microscopic detection should be conducted on a minimum of three to five people and preferably all if there are many involved and

many are “itching”. Microscopy may be negative in early stages and by psoriasis-like rashes (*Norwegian scabies*) [1, 2].

- *Disinfection of the room* is applicable during ongoing treatment (floor and horizontal surfaces) and as end disinfection after completion of treatment. This is especially accomplished because scabies dermatitis often is infected with *Staphylococcus aureus* and/or group A streptococci.
- *Furniture with textiles* should be removed from the room, packed in plastic for 10 days (or placed in freezer containers), placed outside if cold weather and replaced with washable furniture.
- *Clothing and laundry* which is used before treatment should be washed at least at 50 °C for 10 min to kill the mites and eggs. Bedding (pillow, quilt, mattress, etc.) may be placed in a freezer (or out in the cold in winter).
- *Shoes and other goods* that cannot be cleaned can be put in a plastic bag for 10 days or placed in a freezer to kill the mite (or out in the cold in winter).
- These measures will be implemented until test samples have shown negative findings for 3 consecutive days.
- *Personnel, relatives and others* who have been in contact with a patient with scabies—before treatment—should be registered and treated, preferably at the same time (avoid reinfection in the environment).
- *Personnel* resumes work after treatment. Personnel who have had symptoms should wear gloves for the first 2–3 days after they return to work after full treatment.

57.4.3 Exposed Patients, Personnel and Visitors

Set up a list of all exposed to the index patient last month and inform about treatment.

The patient, other patients in the same room and anyone with direct (skin) contact to the patient (personnel, visitors, etc.) should be followed up for treatment and control. Remember stand-in personnel, extra staff, priests, service units and others who have been in direct contact with the patient.

Everyone is treated at the same time to avoid reinfection. Make sure that everyone understands that they must follow the treatment to the point. Even those who have not been studied for scabies but have been in contact with the index patient during the last month must be treated.

57.5 Background Information

*A little skin mite—*Sarcoptes scabiei*—runs on humans and animals and can cause irritable itching, dermatitis and eczema, especially on the hands [1]. Mite is invisible to the eye, cannot fly but has a high speed on warm skin (2.5 cm in 1 min) and may come over from one hand to the next within a few minutes [1]. Outbreaks of scabies often have a large extent in institutions, day-care centres, schools, families*

and long-term institutions as nursing homes [1–3]. Hospitals are occasionally exposed to infection, and both patients and personnel are infected [1, 2, 4].

57.5.1 Scabies

Sarcoptes scabiei variant *hominis* is a little skin mite that may cause irritable itching, dermatitis and eczema, especially on the hands [1]. The mite is invisible to the eye, cannot fly but has a high speed on warm skin (2.5 cm in 1 min) and may come over from one hand to the next within a few minutes [1]. Outbreaks of scabies often have a large extent in institutions, day care centres, schools, families and long-term institutions as nursing homes [1–3]. Hospitals are occasionally exposed to infection, and both patients and personnel are infected [1, 2, 4].

A clinically significant variant of the mite causing widespread infection is called *Norwegian scabies* (*Scabies norvegicus*) [1]. This form is the most common cause of scabies outbreaks of long-term infusions since it produces significant amounts of mites. The infection is highly contagious. The skin lesions of the Norwegian clinical variant can be widespread and in part resemble dermatitis or psoriasis and are often misdiagnosed. Also nail beds can be affixed with loss of nails. Atypical courses of scabies are observed relatively often.

57.5.2 Incidence

Every year, about 300 million people get scabies, mostly in developing countries, but scabies is also increasing in industrialized countries, linked to major travel activities, immigrants, poor hygiene in refugee camps, hospitals, etc. [1]. Scabies is a known problem in modern schools, kindergarten, prison and health institutions—especially long-term institutions where there is much contact between patients and between patients and healthcare professionals/relatives [1, 2, 5–14].

Over a year, 17% of 725 long-term institutions in Michigan had proven scabies [5]. In 2015, Kentucky (Federal Government) used fines for at least 20 nursing homes that had problems with scabies and allowed it to spread in several months before anything was done [10]. At last, 45% of patients were infected! [10] Among the five worst nursing homes, the fines were up to 900,000 \$ [10].

Sometimes, scabies may spread in hospitals from infected patients admitted from home, abroad, school, kindergarten, prison, etc., and even from nursing homes/retirement homes. Scabies can often last for a while in the hospital before it is detected as cause of itching and “eczema” between fingers, and such outbreaks can thus be very extensive in hospitals [1, 6, 14–21]. Kidney patients, transplanted patients and others with severe reduced infection defences have usually more widespread scabies than others and serious infections can occur by secondary infection in scabies skin eruptions [21].

- In 2009, 1659 people were exposed to scabies at an intensive care and rehabilitation centre [7]. All exposed persons were screened by a dermatologist, and 1640

was treated, including the household of healthcare personnel. The index patient had HIV and incrustation wounds of Norwegian scabies. The attack rate among health professionals who cared for the index patient was 26–32%. During 7 months, 19 cases were diagnosed, of which 6 were children. Failure to treat, relapse and reinfection in families were linked to too restrictive definition of individuals “at risk”, lack of treatment and limited drug effects [7].

- In 2011, approximately 900 employees at a hospital in the United States were treated after detected scabies in an emergency patient [19]. At least one dozen healthcare personnel who had had close contact with the patient, clothes or equipment were sent home for immediate treatment, and about the same number of persons was infected [19].
- A kidney transplant patient was admitted three times at a hospital in the United States in 2010 before the finding that he had scabies [13]. Many patients and personnel had been exposed to the patient who had been hospitalized by two departments. Rapid infection detection revealed five employees and two patients with scabies. A massive prophylactic treatment was initiated for all at the two departments. One more case was found, and 6 weeks later, the outbreak was declared terminated. The total cost was \$20,000 [13].
- A transplanted patient infected 37 nurses at a cardiovascular intensive department in Halifax in 2014 [20]. The patient was treated there for 2 months. The outbreak led to the cancellation of several operations due to a lack of nurses [20].
- In July 2015 a major outbreak was reported at an intensive department in Alabama, with 19 patients and 99 staff with scabs, of which 46 had pruritus and rash [16].
- In Canada, there was an outbreak of scabies in July 2015 at a childhood hospital in Alberta [21]. Index patients had crusted scabies and approximately 100 people were exposed to infection. All employees, patients and visitors, including their family, were recommended for scab-prophylactic treatment [21].

57.5.3 The Mite's Lifetime and Survival

The scabies mite is—during a period of 30 days—producing eggs, 2–3 eggs a day, while digging a skin tunnel. The eggs develop into larvae within 3–4 days, move on to the skin surface and develop into adult mites within 10–17 days. Most patients who have scabies have at least 10–15 mites who dig a tunnel and lay eggs. Within 2–4 months, the mite society is built up before the actual large skin itching starts [1].

The usual incubation period is approximately 1 month and 1–2 weeks if infected again.

Transfer via direct and indirect contact. The close contact patient/healthcare staff, especially at long-term institutions, is responsible for prolonged outbreaks of scabies if no preventive activity is introduced. In the case of one patient with a scab, up to 50% of other patients and healthcare professionals at the same department can be infected. In case of direct contact with a scab patient, it only takes 2 min for transmission of infection. Personnel working with scab patients who have sores/itching marks between the fingers have 40–70% chance of being infected. In

families, approximately 40% of other family members are infected when one of the members have scabies symptoms. Scabies skin rash that causes skin peeling/eczema/crusts (especially the Norwegian clinical variant) has led to large amounts of mites in the environment of the patient—up to 7600 mites in 2 days is calculated. Mites are living a minimum of 36 h outside the body [1].

Linen, other clothes and equipment in the patient's room may be highly contaminated of mites. Infections may also be transmitted via infected skin creams, etc. and via infected laundry to laundry workers [1].

57.5.4 Diagnosis on Suspicion of Scabies

Scabies diagnosis is: maculo-papular, nodular and/or itchy rashes (especially between fingers) *and* the physician's diagnosis *or* laboratory-confirmed diagnosis (microscopy of skin scraping, mite, egg, faeces). The sensitivity of the laboratory examination is unfortunately only 10–60% and must be repeated to confirm the diagnosis. It is recommended to contact dermatologic department if scabies is suspected (Fig. 57.1).

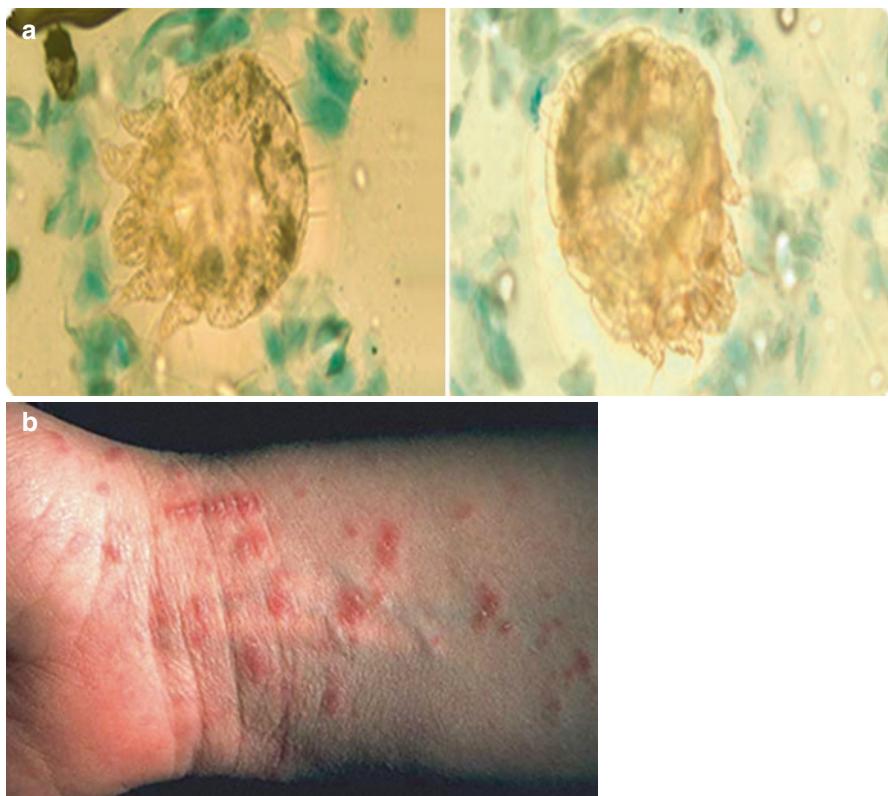


Fig. 57.1 (a, b) *Sarcoptes scabiei* in adult, seen in microscope, and itching marks and tunnels in the skin. Illustration (a) from CDC

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Part XI

Disinfection, Sterilization, Cleaning, Control



Disinfection of Skin and Mucous Membranes

58

Abstract

The skin has rich, permanent and temporary (transient) normal flora of largely harmless bacteria. Mucous membranes in upper airways and gastrointestinal tracts have an even richer and more variable normal flora. A small stick through the skin or mucous membranes is usually harmless and is healed quickly if the wound does not go deeper. In sterile tissue cavities, almost any harmless microbe can multiply and create infection. If a foreign body is placed through poorly disinfected skin or mucous membranes, bacteria may rapidly multiply and become the starting point for a more serious infection. Especially vulnerable are people who have prosthetic or other foreign matters in the body. Skin and mucous membrane disinfection may prevent invasion of microbes and/or contamination of specimens and samples taken. Some disinfectants have better and longer-lasting effect than others. The following chapter is focused on practical measures to disinfect the skin and mucous membranes in healthcare institutions.

Keywords

Disinfection · Skin flora · Mucous membranes · Infection control · Hygiene Prevention

58.1 Purpose

- To reduce microbes on the patient's skin and mucous membranes and thereby the risk of introducing microbes into deeper tissue
- To reduce contamination of samples taken from the skin, tissue or mucous membranes

58.2 Comprise

- All punctures or injections through the skin and mucous membranes
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58.3 Responsibility

Hospital management provides written guidelines for disinfection of the skin and mucous membranes before punctures, injections and operations and is responsible for the hospital's infection control guidelines.

Department management implements routines and reports to the Director if lack of resources (capacity, expertise, infection protection equipment, etc.) may result in infection risk for patients, personnel or visitors.

Staff follows routines. Stick injuries, uncontrollable spill of infected blood/tissue or severe contamination of the skin/mucous membranes upon surgery must be reported to the department management.

58.4 Practical Measures [1–7]

Hand hygiene: Wash or disinfect hands before and after wearing gloves.

Unsterile gloves: Unsterile gloves may be contaminated if taken from an open glove box. Note that in sterile procedures, only sterile gloves are used.

Sterile gloves are used for sterile procedures and as part of sterile clothing.

Sterile gloves, sterile gown, surgical mask and cap and sterile equipment should be used, preferably in an operating room/clean room when performing the following procedures:

(a) Insertion of:

- Central intravascular catheter (CVC)
- Epidural catheter
- Peritoneal catheter
- Arteriovenous shunt
- Venous access port and the like

(b) Punctures for -scopy and other local investigations:

- Organ punctures
- Arthroscopy
- Myelography, etc.
- Angiography, etc.
- Operative treatment—always in an operating room

1. Disinfection before regular blood sampling:

- Chlorhexidine alcohol (70% alcohol with chlorhexidine 2–5 mg/mL)
- Or 70% alcohol
- Or wet liquor compresses with disinfectants (alcohols)

- Working time: 60 s.
 - Do not touch the area afterwards.
2. Disinfection before injections (intramuscular or subcutaneous):
- Chlorhexidine alcohol (70% alcohol with chlorhexidine 2–5 mg/mL)
 - Or 70% alcohol
 - Or *wet* liquor compresses with disinfectants (alcohols)
 - Working time: 60 s.
 - Do not touch the area afterwards.
3. Disinfection before puncture in connection with special investigations/treatment:
- Blood culture, blood to blood bank
 - Insertion of intravascular catheter, central and peripheral
 - Lumbar puncture
 - Punctures of other cavities
 - Organ punctures
 - Introduction of foreign body/fluids
 - Plexus anaesthesia, etc.
 - Chlorhexidine alcohol (70% alcohol with chlorhexidine 2–5 mg/mL).
 - Sterile compresses/gauze pads.
 - Sterile disinfection sets.
 - Working time: 60 s.
 - Repeat disinfection, start centrally and wash within the first area.
 - Working time: 60 s.
 - The skin should be dry between the two applications and before the perforation of the skin.
 - Do not touch the area afterwards.
4. Disinfection of mucous membranes (upper respiratory tract, genitalia, anus) [1]:
- Chlorhexidine 0.5–1 mg/mL in aqueous solution.
 - Sterile gauze pads/compresses.
 - Short shelf life for chlorhexidine in aqueous solution—1 week. Check date.
 - *Chlorhexidine must not be used in the ear!*
5. Disinfection of the skin preoperatively:
- There are many methods of disinfection described (time used, number of applications of disinfectant, etc.): however, they are not well documented [1–3]. Most common methods used are described below:
- Sterile dress for the person that is doing disinfection.
 - Sterile wash kit with sterile forceps and gauze pads/compresses, chlorhexidine alcohol 5 mg/mL.
 - Wash the field thoroughly with plenty of disinfectant, a total of at least five times.
 - A border is first created around the area of operation.
 - The field that is disinfected should be at least 10 cm larger than sterile cover in every direction.
 - The field within the frame must be disinfected.
 - Start centrally and disinfect outwards.

- Allow the disinfectant to work for 1 min each time.
- New application that starts centrally in the operating field. Do not wash as far as last time (contamination from non-disinfected skin).
- Let the disinfectant work for at least 1 min at the end so that the skin is air dried.
- The skin must be dry when covering.
- Do not contaminate when covering the operation area.

See Chap. 35.

58.5 Background Information

The skin has a rich, permanent and temporary (transient) normal flora of largely harmless bacteria such as coagulase-negative staphylococci, diphtheroids and anaerobic bacteria. Gram-negative intestinal bacteria are present around the anus and on the lower part of the body. Bedridden patients have after some days in hospital more gram-negative rods also on upper part of the body, including the face and head, especially after use of antibiotics.

A small break of the skin or mucosa is usually harmless and is healed quickly if the wound does not go deeper, for example, to sterile cavities. In sterile tissue, many skin microbes may multiply and create infection. If a foreign body is placed through poorly disinfected skin or mucous membranes, bacteria introduced may rapidly multiply and become the starting point for a more serious infection, see chapters on intravascular (Chap. 40) and urinary (Chap. 43) catheters, and operative infections (Chaps. 33–35). Especially vulnerable are people who have prosthetic or other foreign matters in the body. Skin and mucous membrane antisepsis removes superficial flora and prevents contamination of specimens and samples taken, which is undesirable by examination of tissue fluid or blood.

By sampling of blood or tissue for examinations, the specimen may be contaminated by normal skin or mucous flora, which is undesirable by examination of tissue or blood. Disinfection removes such superficial flora. However, disinfectants may have varying effects, some short- and other long-term effect [1–4, 6, 7]. At long-lasting operations in sterile tissues, this may be of importance because of the rapid recolonization of bacteria in areas where disinfectants deteriorate and lose effects [8].

Disinfectant is most often chlorhexidine alcohol combinations or different other types of alcohols [1–4, 6–9]. Iodine solutions like povidone-iodine can easily be contaminated with microbes after the vial is broken (use only single use packages). Iodine can cause an allergic reaction to some people.

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Disinfection of Instruments and Equipment

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Abstract

Disinfection is “destruction or removal of all organisms capable of causing infection” and “in practice leads to the removal of all microbes except spores—that is, an approximate sterilization process.” In the healthcare system, instruments and equipment are disinfected with heat, chemical fluids, chemical vapours or gases. Prions are contagious protein sequences that are treated in a special way. Instruments from prion-sick cases are never reused on other patients.

Keywords

Disinfection · Instruments · Reusable equipment · Infection control · Hygiene Prevention

59.1 Purpose

- To remove pathogenic agents, bacteria, viruses, fungi and parasites, from instruments and equipment [1–8].
- To prevent transmission of infection from patients to other patients, staff, visitors or the environment through instruments, technical equipment, fixtures and rooms [1–11].

59.2 Comprise

- All equipment that has been in contact with biological materials.
- All equipment that will come in contact with mucous membranes, skin, secretions, excretions and/or other human biological materials.
- All other equipment/fixtures that may have been exposed to contamination of infectious agents that can cause disease (see isolation regimes, Chap. 14).

- All instruments/equipment disinfected/cleaned before sterilization.
 - *Note!* Equipment/instruments which come into contact with normally sterile sites (mucous tissue, cavities) should be *sterile*.
 - Equipment that comes into contact with (not penetrating) unsterile mucosa (oral cavity, bowel, etc.) should at least be disinfected and preferably sterile. After disinfection, scopes and the like should be *sterilized* because they often may cause lesions of the mucosa. See Chap. 60 on sterilization and disinfection of endoscopes.
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59.3 Responsibility

Hospital management provides written procedures for cleaning and disinfection of instruments and equipment and ensures enough resources, mechanical equipment and competence for proper disinfection.

Department management implements routines, ensures that machine equipment (temperature, detergents, etc.) used is controlled regarding use and disinfection and makes hygienic demands versus equipment manufacturers.

Personnel follow procedures and notify suspected failure of the disinfection process or risk of recontamination of disinfected equipment.

59.4 Practical Measures

Practical measures are based on international and national studies and recommendations concerning use of disinfectants, methods, special treatment of infectious agents, infectious waste and disinfection problems [1–20]. For instance, in Norway, the Norwegian Medicines Control Agency has approved defined disinfectants and methods for technical use in health care in almost 30 years [12, 19].

59.4.1 Removal of Infectious Agents [14–16]

Bacteria, viruses, fungi, etc. are removed in whole or in part by the following methods:

- Cleaning with soap and water: for example, floors and surfaces—environment—fabrics—textiles—cups and vessels. Organic matter, dust and dirt are removed along with most bacteria and other contaminants. The result depends initially on the pollution and cleaning methods.
- Disinfection with chemicals or heat. Machines with fully automatic disinfection cycles remove dirt and organic matter, as well as almost all microbes.
- Sterilization with heat and damp pressure: all common microbes are killed, see separate Chap. 61. All organic matter and dirt must be removed prior to sterilization.

(Autoclaving is also used in the treatment of infectious waste, e.g., from laboratories or in connection with infection isolates.)

59.4.2 Contaminated Equipment and Instruments [14–16, 21, 22]

All equipment contaminated with organic matter should be treated immediately. If transported to a separate treatment area, equipment must be treated as potential contaminated.

- During the cleaning process, most of the organic material is removed. If it dries onto the equipment, it is more difficult to clean, and important contaminants can be left, like prions.
- Bedpans with dried organic materials before the disinfection process may still have residues of biological material on it after washing or disinfection in the decontaminator.
- Operation instruments with dried blood and tissue residues are more difficult to clean in the instrument washing machine than well-rinsed instruments.
- *Machine tools* with internal machine components and electrical wires that cannot be opened and disinfected in liquid or heat are treated according to separate guidelines [9, 11].

59.4.3 Manual Cleaning of Equipment and Instruments [14–16]

- All manual cleaning should be done after disinfection of the instruments, to reduce personnel for exposure to infectious agents. But this process may sometimes be necessary before disinfection, for example, by complicated, combined, fragile instruments and scopes.
- Manual cleaning (regardless of whether the equipment is disinfected beforehand) must take place in defined, well-equipped and ventilated washroom under negative pressure compared to operating rooms and other clean rooms. The entire washing process should take place under the liquid surface, with great care, in a quiet environment to prevent spread of spills or aerosol in the room. There should be plenty of areal for “clean and unclean side,” good light and access to inspect the equipment with magnifying glass.
- PPE: Single-use gown with waterproof front and sleeves, long cuff gloves and surgical mask/cap/eye protection should be used. In case of accident during procedures, infectious agents may spread.
- Brushes for brushing and rinsing narrow lumens, long canals and cavities in the instrument, etc. are recommended as disposable since they are difficult to clean for protein residues.
- All other equipment in the cleaning process itself should be decontaminated after use in the instrument washing machine.

- PPE is placed after use in contaminated waste, with the exception of glasses, etc., which may be decontaminated in the instrument washing machine.
- Washbasins and areas around are afterwards cleaned with soap and water. Finally rinse the washbasin (avoid splashing) with hot water (75°C).

59.4.4 Disinfection [14–16]

- Disinfection is usually carried out before cleaning to protect staff and prevent spread of contaminants.
- Disinfect equipment as soon as possible. The effect reduces if organic materials are left to dry.
- Possible contagious equipment is packaged and labelled.
- Disinfect by moist heat or by chemical disinfectants.
- Heat disinfection is used for all heat-resistant equipment.
- Heat disinfection: boiling in water (100°C) or mechanical heat disinfection in the decontaminator or instrument washing machine.

59.4.5 Boiling (Cooking at $\geq 100^{\circ}\text{C}$) (Usually Not Used Anymore)

Boiling is a simple and safe disinfection method that is checked by inspection.

1. Boiling: in alkaline water, $\text{pH} > 11$ in 5–10 min is an excellent cleaning and disinfection method. Equipment and instruments should not be cleaned in advance.
2. When boiling, the equipment must be completely covered with water.
3. A suitable detergent (alkaline) is added by boiling to prevent adhesive combustion of organic material to instruments.
4. The boiling should take place at 100°C for 5–10 min.

59.4.6 Heat Disinfection by Automatic Machine Systems [14–16]

- Decontaminator is a disinfection machine that use hot water at a temperature of at least 85°C or higher for a certain period of time as part of an *automatic* washing process where organic matter and dirt are removed prior to disinfection.
- *Washing decontaminator* is used to drain the waste, flush and clean equipment with water and soap, and disinfect with a final hot water phase of at least 85°C in more than over one minute. This machine type is intended for urine bottles, bedpans, suction bottles, washbasin, flower vases, saliva cups and the like. Some machines also have a basket for instruments.
- *Instrument washing machine* is used for cleaning and disinfecting of equipment and instruments. There are special instrument washers for cleaning and disinfecting surgical instruments, drainage vials, different scope washing machines, special machines for ventilator equipment, laboratory equipment, etc. First step in the process is a thorough washing process adapted to the special equipment, then rinsing and thermal disinfection at least 85°C for 3–10 min depending on

the machine type/wash program. The heat disinfection lasts for more than 3 min when the disinfection cycle occurs after the cleaning phase and 10 min when disinfection occurs during the cleaning phase.

- Check temperature, filter sand soap according to written procedures and documentation, and check the purity of equipment (blood, tissue, faeces, etc.) before storage.

59.4.7 Chemical Disinfection

Chemical disinfection is only used for equipment that does not withstand heat.

1. Use chemicals approved by the State Medicines Agency [12, 19, 20].
2. Follow the information given on the package about the effect range, preparation, working time and shelf life.
3. Always wear gloves, disposable liquid-proof protective gown, surgical mask/cap and possibly eye protection in direct work.
4. Chemical disinfection must be carried out in good ventilation in a suitable room with a negative pressure and with a separate outlet for chemical vapour.
5. Use suitable disinfectant vessel with a tight lid.
6. Compound equipment is separated as much as possible.
7. The items must be in total below the liquid level in the recommended time.
8. After disinfection, clean the equipment with soap and water adapted to the equipment, and then rinse all objects well under running water (see manual disinfection).
9. The equipment is dried well under clean conditions, stored in clean storage, or continued for inspection, packing and sterilization; see the Chap. 61 on sterilization. This process will not introduce new microbes from the environment.
10. Wash the work area with soap and water—brushes for hollow objects, etc. are used as disposable single use for each instrument, and disinfection vessels are drained, decontaminated and stored clean afterwards.
11. Check for disinfectant, durability, use, storage and accident.

Storage space for disinfected equipment must be clean and dry with written routines for storage and cleaning. Storage space should not be an office or a wet room with aerosol formation.

59.4.8 Disinfectants (Tables 59.1 and 59.2)

- Glutaraldehyde 2% has an effect on vegetative bacteria, mycobacteria, viruses and fungi. The room must have a separate outlet for chemical vapour that is toxic. The disinfectant is inactivated by a high yield of organic material.
- “Virkon,” oxidative agent containing pentapotassium bis(peroxymonosulfate) bis(sulfate), has an effect on vegetative bacteria, viruses and fungi. It is not approved for use against tubercle bacteria and bacterial spores and is inactivated with a lot of organic material. The ppm values for effect against microbes are missing and it is a less stable agent.

Table 59.1 Chemical disinfectant in liquid form

Disinfectant	Effect on	Use concentration	Time min ^a	Shelf life ^a concentrate
ALDEHYDE: for equipment and instruments; effect on most microbes				
Glutaraldehyde	Virus	2%	30	1–2 years
	Bacteria	2%	30	
	Fungi	2%	30	
	Mycobacteria	2%	60	
CHLORINS: for equipment and surfaces; effect on most microbes			Effect time varies	
*Chloramine (12,500 ppm) ready for use.		5%	20–60	2 years
*Chloricide (Sodium hypochlorite, 4.5% active chlorine, 45,000 ppm, in concentrate and diluted 25%– ca 11,000 ppm)		25% ^b	30–60	1 year
*Household bleach (Sodium hypochlorite 5.25–6.15%, 52,000–61,000 ppm, in concentrate), can be used diluted at home		used in 1:10 to 1:100 dilution	30–60	
FENOLE: equipment and surfaces (usually not use)				
Effects on most bacteria, including TBC, but not virus		2%	60	3 years
ETHANOL (alcohols) (Uncertain effect on microbes)		70–85%	2–10	Chlorhexidine-alcohol: 1 week after open
Only for disinfection of clean equipment, surfaces, etc. Do not stand open and evaporate!				
OKSYDATIV disinfectants: for equipment and surfaces				
*Virkon; effect on most bacteria, not TBC and not well documented for virus (Potassium persulfate 50%, sulfamic acid 5%)		1%	30	3 years
*Peracetic acid/hydrogen peroxide (bacteria, spores, viruses)		0.26%	12	24 h
Used in special washers for endoscopes in combination with heat ^c				
*PeraSafe—peracetic acid; effect on most microbes, sodium percarbonate 40–60%		16.2%		2 years
	Cleaned equipment	0.26%	10	
	Mycobacteria		30	

^aRead the instructions on the bottle/jar. After use, solutions must be discarded. Effect time may vary

^b% of concentrate

^cSpecial washing machine with chemical-thermal disinfection

Table 59.2 Disinfectants for technical disinfection: medical equipment, surfaces, fixtures, etc. [5, 8, 16]

Disinfectant	Microbiological effect	Benefits	Disadvantage
Alcohols 70–90%	May affect some bacteria, viruses and fungi, but <i>not</i> all microbes, usually not <i>Clostridium difficile</i> , norovirus and spores	Fast-acting, environmentally friendly. Higher concentrations have better effect	Only on cleaned surfaces. No penetration of protein-rich material. Non-spore killing effect. Evaporates fast, uncertain effect
Glutaraldehyde 2% or more	Very good at right concentration and effect time. Bacteria, mycobacteria, viruses, fungi and spores	All kinds of materials, metals, rubber etc. Well documented. Cheap	Glutaraldehyde vapour irritates respiratory tract. Irritating smell, allergy. Slow effect on mycobacteria: 60 min. Coagulates and fixes tissue to equipment. Observe biofilm formation by poor cleaning of scopes and the like
Ortho-phthalaldehyde-Cidex	Effect of glutaraldehyde/formaldehyde	Quickly acting, very effective. No activation. No irritation. Good material compatibility. Does not coagulate blood and does not fix tissue	Colours on skin, clothing, equipment. Limited experience. More expensive than glutaraldehyde. Eye irritation upon contact. Slow effect on spores. Note anaphylactic reaction in bladder cancer patients
Phenols—used a little today	Gram-positive and gram-negative bacteria, mycobacteria and fungi. Uncertain effect on viruses, especially lipid-free viruses. No effect on bacterial spores	Long shelf life of concentrate	Uncertain effect on viruses, no effect on spores. Slow-acting. Cannot be used on plastic or rubber material. Irritating to skin and mucous membranes and may be absorbed by direct contact. Unfortunate environmental effect. Unstable concentration by inaccurate dilution

(continued)

Table 59.2 (continued)

Disinfectant	Microbiological effect	Benefits	Disadvantage
Peracetic acid	Very good effect and not inhibited by organic/inorganic material. Bacteria, mycobacteria, viruses, fungi and spores	Quick cycle 30–45 min. Environmental friendly end products. Low temperature: 50–55 °C. Fully automated machines. Single-standardized doses. Standardized cycle. Increases removal of organic material. Increases the removal of endotoxin. Most materials tolerate the treatment. Does not coagulate blood and does not fix tissue. The disinfectant fluid passes through narrow canals. Quickly kills spores. Standardization of procedures	Unfortunate for materials like aluminium. Can corrode copper, brass, etc. Only for instruments that can be treated with liquid. Biological monitoring uncertain. Small capacity. Expensive. Eye and skin damage when contacted with concentrated solution. Not suitable for storage of sterile equipment. Unstable in diluted form
Peroxyacetic acid/hydrogen peroxide combination	Good and fast effect. Bacteria, mycobacteria, viruses, fungi, slow effect on spores	No activation. Not irritating	Material incompatibility: lead, brass, copper, zinc. Limited experience. Eye and skin injuries by accident
Chloramine 5% (undiluted: 12,500 ppm) Sodium hypochlorite (chloricide undiluted: 45,000 ppm)	Very good effect. May be inactivated by much organic materials. Effect on bacteria, mycobacteria, viruses, fungi and spores	Well documented. Environmentally friendly. Cheap. Quick effect on dry areas. Effect on biofilm and dried microbes	Inactivated by blood. Material incompatibility: some metals, but not plastic or glass. Irritating vapours
Superoxidized water Hypochloric acid from electrolysed saline and chlorine	Effect like chloramine/chlorine	Depending on the amount of free chlorine. Environmentally friendly. Cheap. Quickly acting, very effective, <2 min	Inactivated by blood. Limited experience. Depending on good concentration of free chlorine >144 mg/L and time
Hydrogen peroxide 6.5–7% liquid substance	Very good effect and little effect of organic/inorganic material. Bacteria, mycobacteria, viruses, fungi and spores	No activation. Increases removal of organic matter. Not irritating. Does not coagulate blood and does not fix tissue. Inactivates <i>Cryptosporidium</i>	Material incompatibility in liquid form: brass, zinc, copper, nickel, silver. Eye damage when contacted

Table 59.2 (continued)

Disinfectant	Microbiological effect	Benefits	Disadvantage
Hydrogen peroxide (HPV) gas/aerosol (5–35%); with (35%) and without water vapour (5%)	Effect on bacteria, viruses and spores. No certain effect on mycobacteria. Increasing documentation regarding antimicrobial effect	Convert to oxygen and water. Effect time: 3–5 h. Suitable for robot disinfection of rooms, surfaces and medical equipment for infection outbreaks and terminal disinfection. Advantage of spore control and ppm control for disinfection effect documentation	Material damage is dependent on concentration of water vapour (35%). For dry HPV gas/aerosol 5%, no material damage to medical devices has been detected. Concentration: ppm <1 before entering the room
Pentapotassium bis (peroxyomonosulfate) bis (sulfate) 50%—Virkon S	Good effect on vegetative bacteria, some viruses, fungi. Uncertain effect on mycobacteria, spores and some viruses	Environmentally friendly. Low toxicity	Corrodes some metals
Sodium percarbonate 40–60%—PeraSafe	Very good effect. Bacteria, mycobacteria, viruses, fungi and spores	Environmentally friendly. Low toxicity	Inactivated by organic materials

From: References [5, 8, 18]

- “PeraSafe,” peracetic acid (from sodium per carbonate and tetra acetyl ethylene diamine), has an effect on vegetative bacteria, viruses, fungi and mycobacteria. It is inactivated with a high yield of organic material. The ppm values for effect are missing. It is used on cleaned equipment, working time 10 min and for *Mycobacterium tuberculosis* 30 min.
- Chloramine 5% and other chlorine compounds such as household chlorine 10% has an effect on bacteria, including tubercle bacteria, fungi and viruses, including hepatitis virus, HIV and norovirus. Chlorine compounds are inactivated by a high yield of organic material and cannot be used on aluminium.
- Hydrogen peroxide 5%, aerosol/dust with defined amount of silver ions, has an effect on vegetative bacteria, spores, viruses and fungi, but not mycobacteria and can be used on all types of metals. Define and monitor ppm values during the process and use spore tests for verification of effect.
- Alcohols (ethanol, isopropanol and disinfectant alcohols) have an uncertain and short-term effect on microorganisms. Alcohol has little ability to penetrate organic material and is therefore only suitable for disinfection of cleaned surfaces.

- Chlorhexidine has limited effect and is only approved for disinfection of cleaned equipment when heat disinfection, other approved chemical disinfectant or liquor cannot be used. It is not recommended as a disinfectant for technical disinfection.
- Several other chemical agents are approved for use in Norway as in other countries [19, 20].

Choice of disinfectant. The hospital should choose one or two clearly defined and documented disinfectants that are easy to handle, easy to understand and easy to throw away after use. The chemicals should not trigger allergies or other illnesses. Chloramine 5% or peracetic acid is recommended in countries with a long tradition of use, especially of chloramine. Hydrogen peroxide dry aerosol can be used for infection outbreaks and as terminal disinfection of isolates after infections with effect on surfaces, air and inner parts of mechanical equipment. No really good documented effect on *Mycobacterium tuberculosis*. By all disinfections using chemical aerosols, the room should be empty of people and checked afterwards for rest gas.

Single-use chemicals. Chemical disinfectants in liquid form should be changed after each use.

Hazardous waste. Small quantities of used chemical liquids can be further diluted with water and discharged into drains under running water. Larger amounts are treated as special waste.

Storage. Concentrates and solutions are stored in enclosed containers in locked cabinets.

59.4.9 Remarks for Chemical Disinfectants

- Follow the recommendation on the product's label regarding durability, range, working time, etc.
- All containers with disinfectant must be covered with a tight lid. Small liquid surface gives less evaporation to the environment.
- Good ventilation.
- Glutaraldehyde steam should be checked with dosimeter and not exceed 0.05 ppm when people are present in the room [8]. Separate exhaust.
- Poor cleaning of instruments can lead to biofilm residues and residues of chemicals.
- Critical symptoms in patients due to glutaraldehyde residues have been observed [8].
- The equipment must be dismantled at maximum, all cavities must be filled, and the equipment must be completely below the liquid level.
- The cleaner the surfaces/equipment, the better effect of chemical disinfection.
- Solutions in use are changed after each use, and the disinfection vial is washed and heat disinfected (decontaminator).
- Brushes for small and narrow instrument canals and cavities are difficult to clean for protein residues; therefore single use.

- These disinfection methods are not effective enough against prions (see under prions).
- Chemical disinfection agents approved by the Norwegian Medicines Agency; see Table 59.1.

59.4.10 Chemical: Thermal Disinfection for Scopes, Etc.

Used for equipment that does not withstand high temperatures. The treatment is done with a combination of disinfectant such as glutaraldehyde or PeraSafe and temperatures up to 60 °C [14–16, 21, 22].

See Chap. 60 on disinfection of endoscopes and other special equipment.

59.4.11 Gas Disinfection with 5% Hydrogen Peroxide, Dry Aerosol [8–11, 23–25]

Medical technical equipment. When cleaning internal parts of medical devices that cannot be immersed in disinfectant fluid, gas disinfection with hydrogen peroxide (5% H₂O₂) may be used. Hydrogen peroxide breaks down to water and oxygen. The disinfection room should be sealed so that gas does not leak out to other rooms while disinfection is in progress. Mechanical equipment is started up, runs and draws the disinfectant gas into the inner parts of the equipment, and the disinfection starts. Nobody should stay in the room during this process. Limit time to stay in a room with H₂O₂ aerosol/gas is <1 ppm in air or up to 15 min at less than 8 ppm.

The gas must be dry so that sensitive parts of internal instruments do not corrode. There are routines for this at special centres for medical technical equipment at hospitals or otherwise decided. Most often, gas disinfection occurs in combination with technical opening for removing dirt, dust and organic matter, which is often abundant in internal parts of the equipment [11]. Always use a spore test and a ppm meter to check the procedure!

Currently there is no gas agent that takes *Mycobacterium tuberculosis* [10, 26]. Therefore, medical devices that have been used in patients with infectious tuberculosis are treated as infectious waste.

Outbreaks and disinfection of rooms. Hydrogen peroxide dry gas (aerosol) can also be used as an alternative or in addition to disinfection with chemical liquid upon outbreak of MRSA, *Clostridium difficile*, multidrug-resistant bacteria, norovirus and other infections. Hydrogen peroxide gas is used for disinfection of rooms, store rooms with disposable equipment that cannot be disinfected with liquid disinfection and which would otherwise be thrown away, textiles that cannot be washed or are difficult to disinfect, and other rooms with storage of a lot of equipment. Afterwards, thorough cleaning of all surfaces and contact points is carried out. The disinfection method with 5% dry hydrogen peroxide gas includes three defined disinfection cycles! Otherwise, the equipment will not be properly disinfected. Spore test placed in the room and on equipment is an important control of effect, together with a ppm—measurer to control the concentration and the procedure.

59.4.12 Surface and Spot Disinfection

See Chap. 65 concerning cleaning of the wards.

59.4.13 Protective Measures

All chemical disinfectants release vapours that may cause health risks (skin and respiratory system, mucous membrane irritation, respiratory distress with asthma, allergy). Avoid skin contact, especially with chemical concentrates. Work in good ventilation and exhaustion (air extraction) and do not inhale! Gasses may be checked by measuring ppm in the air.

59.4.14 After Checking and Storage of Disinfected Equipment

Bedpans, urine bottles, instruments and other equipment must be checked for visual purity and handled with sterile gloves (at least clean) in order not to be recontaminated and are stored or further processed according to their intended use.

Disinfected equipment not further processed for sterilization should be packaged/stored in clean conditions in a clean cabinet with glass door. Cabinets must have regular cleaning procedures.

59.5 Prion Inactivation: Prion Diseases

(Creutzfeldt-Jakob's disease, CJD; variant CJD, vCJD; bovine spongiform encephalitis, BSE; and others—see Chap. 55 on prion disease)

Instruments and equipment cannot be disinfected or sterilized after contamination with prions and should not be reused [4, 27–36]. Contact infection control personnel.

The following decontamination methods are not effective:

- *Chemical disinfectants*: alcohol, formalin, glutaraldehyde, hydrogen peroxide, peracetic acid, iodophores, phenols, chlorine dioxide, and HCl.
- *Chemical gases*: ethylene oxide, formaldehyde vapour, hydrogen peroxide vapour, etc.
- *Physical methods*: boiling, dry heat, UVC, ionised radiation, and ordinary steam autoclaving.

The following decontamination method may have effect, *but not 100% sure!*

- *Chemical disinfectants*: NaOH 1 N for 1 h, sodium hypochlorite 20,000 ppm free chlorine in 1 h or formic acid 96% for 1 h (for histopathology).
- *Physical methods*: burning after autoclaving at 134–137 °C in 18–60 min.

59.5.1 Sterilization of Instruments/Equipment Used in Examination/Treatment of Possible CJD

In particular, BSE/vCJD has thermostable (–resistant) variants—sterilization is not completely effective.

- *Invasive equipment. Use disposable equipment or reusable equipment that can be destructed as infectious waste after use.*
 - Immediately after use, the equipment is immersed for 1 h in a hazardous container with sodium hypochlorite (household chlorine) 20,000 ppm free chlorine for 1 h.
 - 1 N NaOH (40 g NaOH in 1 L of water) for 1 h at room temperature
 - Autoclaving at 134–137 °C for 1 h, packaged as contamination and sent for burning.
- *Non-invasive* multiple-use equipment should preferably be treated as invasive equipment (as described above) or immersed in 1 N NaOH (1 h) or sodium hypochlorite 20,000 ppm for 1 h.
- *Tracking equipment used for CJD.* If, in retrospect, CJD is suspected, previously used equipment will be recalled which will then be processed and destroyed as above. The identity of people associated with this equipment is ensured.

59.5.2 Disinfection of Surfaces/Environment

Surfaces, benches, etc.: Spot disinfected with sodium hypochlorite 10,000 ppm or 1 N NaOH for 1 h and finish with normal disinfection; 5% chloramine (12,500 ppm) for 1 h or 1 N NaOH for 1 h.

59.6 Background Information

Disinfection is “destruction or removal of all organisms capable of causing infection” and “in practice, leads to the removal of all microbes except spores - that is, an approximate sterilization process” [1–8]. In the healthcare system, instruments and equipment are disinfected with heat, chemical fluids, vapours or gases [1–11]. Prions are contagious protein sequences that may be destructed after special methods [4].

“Disinfection” in the form of preventing contamination of food by smoking, salting, drying, etc. has probably been used for several thousand years. Disinfectants as such have been studied since the 1750s. In the nineteenth century, hypochlorite and other chlorine agents have been effective for their special use, first documented by Semmelweis in 1847 and later by Lister who combined hypochlorite with carbolic acid in operative activity.

Many disinfectants have an uncertain effect. Chemical disinfectants are usually less effective if much dirt and organic material are present; some disinfectants may

not kill bacterial spores, fungi, virus and parasites; and others are ineffective against mycobacteria [2, 3, 5, 8–11]. Disinfectants and methods for use are changing in every greater tempo, for increasingly more complex equipment and instruments [1–8]. At the same time, knowledge increases of contagiousness, persistence and survival in the environment; of robust resistance to inactivation by heat, chemicals, UVC and other agents; and of a disturbing development of resistance, both against disinfectants and antibiotics [4, 8, 27–40].

Resistance to disinfectants. Bacteria with a long life in the environment (like MRSA, VRE, ESBL-stains, *Pseudomonas*, *Clostridium difficile*, etc.) are often associated with resistance to antibiotics, infectivity, low infection dose, virulence and resistance to disinfectants [37, 38, 41–44]. *An effective disinfection removes* most common human pathogenic bacteria and viruses, while some heat stable and/or chemically stable microbes survive [1–8]. The most resistant are spore-forming, usually harmless (with exception of *C. difficile*) “dust bacteria” without pathogen significance for others than for patients with reduced infection defence.

- Enterococci may survive in environment for several years and are heat resistant (up to 100 °C in organic materials) and have varying resistance to chemical disinfectants [45].
- Mycobacteria (TB, etc.) may survive in the environment for up to 1 year and are relatively resistant to chemical disinfectants [1–8, 10].
- Norovirus and special pathogenic viruses are robust survivors in the environment—for months—and are often resistant to many disinfectants.
- Hepatitis B and hepatitis E viruses are highly heat resistant, the same with adenovirus, parvovirus and a variety of other virus types.
- Unusually resistant are also certain rare, partially unknown viruses, virus-like particles and infectious proteins; prions (Creutzfeld-Jakobs, bovine spongiform encephalitis (BSE), and other prion diseases). New types and variations of prion disease still occur. The last type is “Shy-Drager syndrome” (multiple system atrophy—MSA) that “raises the question of whether or not also alzheimer and parkinsonism is contagious” [36]. “All chemicals that kill bacteria and viruses do not harm prions” [36].
- Fungal spores and microsporidia are often resistant to chemical disinfectant and high temperatures.
- Parasites like coccidia are highly resistant to chemical disinfectants, as are cysts from *Giardia lamblia*, *Cryptosporidium* and other protozoans [3, 8]. Trophozoites (not cyst form of protozoa) are more sensitive to chemical substances.

Thermal disinfection with moist heat (damp) is in most cases a safe and environmentally sound method of cleaning and disinfection of instruments and equipment.

59.6.1 Chemical Disinfection in Liquid Form

Chemical disinfectants are an environmental stress and can often be both expensive and uncertain. Therefore, chemical disinfection should only be used where heat disinfection cannot be carried out [8, 41, 45, 46].

Chloramine 5% has effects on spores (cortex), bacteria (peptidoglycan/cell wall), viruses (capsid, nucleic acid RNA/DNA, capsule, thiol groups) and fungi (intracellular amino groups)—with varying working time [38]. Effective part: HOCL, free chlorine, can be inactivated with much organic material present.

Chloramine 5% (12.5 g active chlorine)	12,500 ppm
Chloridic undiluted	45,000 ppm
Chloridic diluted 25%	11,000 ppm
Household chlorine (bleach), 5.25%	52,500 ppm
Household chlorine 1:10 dilution	5000 ppm

Inactivating effect on microbes

Hepatitis B/HIV virus in blood spills	5000 ppm
Mycobacteria/TB—60 min	1000–10,000 ppm
Spores >100 ppm kills 99.9% <i>B. subtilis</i>	100–1000 ppm
Other bacteria and viruses	200–1000 ppm
Fungi—varying killing effect	
Cysts—varying killing effect	
Prions—some effect—60 min	20,000 ppm

Glutaraldehyde 2–3% has an effect on spores (core), bacteria (cytoplasmic), viruses (capsid, thiol groups) and fungi (cell wall)—with varying effect time [38]. Proper use of disinfectant dilution and effect time are important. Observe time for durability and check glutaraldehyde vapour in the room with dosimeter: <0.05 ppm.

Alcohol can have bactericidal effects. Effect on hepatitis B virus and HIV, possibly after 2–10 min. Uncertain effect of alcohols, due to rapid evaporation and poor penetration ability in organic materials. Therefore it is used only on clean surfaces and clean equipment. A good virus-killing effect may be achieved by the alcohol mixture 80% ethanol and 5% isopropanol.

Hydrogen peroxide 3–6% in liquid and similar disinfectants are effective for most microorganisms. Six percent or higher concentration has an effect on *Cryptosporidium parvum* and working time of 20 min.

Peracetic acid has good general microbial effect in denaturing proteins: bacteria, spores, viruses and fungi and is used in combination with hydrogen peroxide.

Potassium persulfate (“Virkon”) is effective against most microbes except for mycobacteria and does not have a good effect on spores and is not very well documented against viruses.

Sodium perborate (“PeraSafe”) is effective against most microbes, including mycobacteria.

59.6.2 Chemical Disinfection in Gas:Steam-Aerosol Fogging Form

For more than 100 years, different chemical gases have been used to inactivate microbes, including formaldehyde, ethylene oxide vapour, ozone, peracetic acid vapour, chloricide vapour, etc. Formaldehyde steam and ozone are not active against spores.

Chlorine dioxide gas of 40 mg/L for 30 min at relative humidity 70–75% kills anthrax spores.

Formaldehyde gas moisture “fumigation” is used in poultry production, safety cabinets and laboratories. The effect is >8 log reduction of anthrax spores.

Formaldehyde gas + high humidity (used in ambulances) has no effect on spore tests (author, personal studies).

Ethylene oxide chamber—100% of anthrax spores killed.

Hydrogen peroxide gas/aerosol/vapour/fogging (HPV) is used for disinfection of rooms, surfaces, mechanical equipment, etc. It is well documented for most infectious agents (except for mycobacteria and prions) used correctly and with control of ppm, test spores, leaks and methods and caution with medical technical and other vulnerable equipment [9–11, 23–26]. Wet HPV gas may corrode metal, while dry gas/aerosol does not [9, 11].

Several HPV systems used today may lack control and documentation of efficacy. Disinfection with HPV necessitates control, ppm measurements and spore tests to avoid development of resistance, biofilm formation, adaptation, tolerance or other microbial “adaptations” to biocides [38, 41–44].

Some studies after 2006 are shown below: [9–11, 23–25, 47–59].

- HPV (Bioquell) 30%, effective against environmental contamination with MRSA [23].
- HPV dry aerosol (“mist”) 5% had spore effect but no effect on *Mycobacterium tuberculosis* [9, 11].
- HPV dry aerosol 5%—effect on environmental pollution with MRSA [47].
- HPV effectively against *Clostridium difficile* [24, 48].
- HPV (Bioquell) 30% was compared with VPH (Steris—UK) 31% dry aerosol against bacteriophage. Not properly implemented but effect on a cycle [49].
- HPV (Bioquell) effectively in England against *C. difficile* outbreaks [50].
- HPV (Bioquell) 30% hydrogen peroxide in damp form can be considered more effective than a Sterinis system 5% with silver ions <50 ppm and orthophosphoric acid <50 ppm, from Johnson & Johnson [51].
- Automatic “no-touch” system including HPV can be useful for infection control in hospitals [52].
- VPH (Steris—UK) 35% hydrogen peroxide in steam form—effective in combination with other measures against multidrug-resistant *Acinetobacter baumannii* [53].

- VPH (Steris—UK) 35% hydrogen peroxide in steam form; not completely effective against MRSA—a cycle [54].
- VPH (Steris—UK) 35% compared to Ecasol and Citrox aerosols—VPH's widest effective spectre [55].
- HPV (Bioquell) decontamination and terminal-disinfection intervention: significant reduction of *C. difficile* [56].
- HPV (Bioquell) used in conjunction with standard cleaning reduced risk of MDRO (multidrug-resistant organisms) infection [57].
- HPV (Bioquell) decontamination of sterile packaged equipment [58].
- HPV dry aerosol (mist) and HPV (Bioquell) were both used in the epidemic of multidrug-resistant *Acinetobacter baumannii* in 84 secondary intensive cases infected from patients with intercontinental transmission in a French hospital [59].
- HPV dry aerosol (mist) are proven as effective as active chlorine disinfectant to disinfect rooms and surfaces [60].

59.6.3 Radiation

- UV radiation is effective if the object is not covered [40]. Up to 90% of anthrax spores are killed.
- Gamma radiation; anthrax spores—100% killed.

59.6.4 May Single-Use, Disposable Equipment Be the Future?

Prion-like diseases and new resistant agents like microsporidia and other resistant agents may cause that the focus may be put on disposable rather than reusable, disinfected equipment. This applies especially for devices that come in contact with mucous membranes in the respiratory, oesophageal-gastro-intestinal, urinary and genital areas and which cannot be sterilized [36].

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Endoscopes and Other Special Equipment

60

Abstract

Endoscopic procedures are increasingly used in medicine both diagnostic and therapeutic. Complications and infections are rare, 1 per 1.8 million procedures, but there are no other instruments that are associated with as many infections as endoscopes. This is due to lack of routines, not following routines or lack of competence. An analysis of published exogenous endoscopy-related infections, pseudo-infections and toxic reactions between 1974 and 2004 showed 140 outbreaks where more than 94% of the cases could be prevented by improved decontamination of instruments. Endoscopes are often very complex composed equipment that is difficult to sterilize. They may have combined parts that can be sterilized (high hygienic level) and parts that may only be disinfected (lower hygienic level). In addition, scopes may often have long, narrow lumens, are flexible and may be difficult to clean for organic materials. Still there may be great problems concerning certain endoscopes and other equipment that are difficult to decontaminate. The following chapter is focused on practical measures to disinfect, sterilize and control endoscopes and other special equipment in healthcare institutions.

Keywords

Endoscopes · Heat-sensitive instruments · Reusable equipment · Disinfection
Sterilization · Infection control · Hygiene · Prevention

60.1 Purpose

- To ensure that all products that undergo a disinfection or sterilization process are disinfected or sterile afterwards [1–4].
- To remove pathogenic agents: bacteria, viruses, fungi, parasites, spores, from endoscopes and other heat-sensitive equipment.

- To prevent transmission of infection from patients to other patients, staff, visitors or the environment through instruments, technical equipment.
-

60.2 Comprise

- Endoscope and the like that undergoes disinfection (“high level”) and/or sterilization.
 - All equipment, including endoscopes that have been in contact with biological materials.
 - All equipment that will come in contact with mucous membranes, skin, secretions, excretions, and/or other human biological materials.
 - Endoscopes which come into contact with normally sterile sites (mucous tissue, cavities) should be *sterile*.
 - Endoscopes and other equipment that come into contact with (*not penetrating*) unsterile mucosa (oral cavity, bowel, etc.) should at least be disinfected and preferably sterilized.
-

60.3 Responsibility

The hospital management should ensure enough resources and written routines for modern disinfection and sterilization procedures.

Department management implements routines to ensure that endoscopes and other special equipment are pre-treated, controlled, packed, transported, sterilized, re-controlled and stored in a safe manner. Lack of resources and accidents that constitute a risk of infection for patients or personnel are reported to the Director immediately.

Personnel follow hospital procedures for processing disinfected and sterile goods.

Preparedness in connection with deficiencies/failure (machine shutdown, flood, etc.) regarding sterilization and disinfection capacity must be ensured by planned cooperation with other hospitals and sterilization centres.

60.4 Practical Measures [1–4]

60.4.1 Personal Protection

The personnel working on endoscopy/processing of endoscopes should follow routines for the use of protective equipment for the treatment of patients and unclean equipment. For manual treatment of unclean endoscopes, like washing, drying, etc., it is important to protect the person with the use of gloves, gown (preferably waterproof), cap, eye protection and respiratory protection.

Treatment of *clean equipment* should be done in clean environment/clean room, with clean gown, surgical mask/cap and gloves.

60.4.2 Choice of Purity Level on Endoscope

60.4.2.1 High-Risk Endoscopy: Critical Concerning Sterility of the Scope

- Invasive endoscopes in sterile tissues and sterile mucous membranes
- All instrumentation with risk of lesions in mucous membranes (biopsies, etc.) regardless of sterile or unsterile mucosa

60.4.2.2 Intermediate-Risk Endoscopy: Semi-critical—Concerning Sterility of the Scope

- Endoscope use in unsterile areas like colon. No planned perforation of “unsterile normal mucous membranes”

Invasive endoscopes must be sterile, and all endoscopy procedures should take place in an operating room, with the same requirements for quality of hygiene and infection protection as for surgery.

- *All heat-sensitive endoscopes* like GIT endoscopes, bronchoscopes and nasopharyngoscopes must be thoroughly cleaned and at least undergo a “high-level” disinfection program between each patient [1, 4].
 - *High-level disinfection* destroys most microbes, but there is no good effect on spores, free-living amoebas and *Mycobacterium chelonae* [1–5].
 - There may also be an uncertain effect on *M. tuberculosis*, *M. avium intracellulare*, other mycobacteria and other microbes.
 - Lack of effect may be discovered by biofilm formation, failures in automatic endoscopy disinfection machines and using too short exposure time [1–7].
 - *There is no effect on prions of high-level disinfection.*

60.4.3 Risk Areas in General

- Biofilm formation—in endoscope channels and channels for disinfection machines [1–4, 7, 8].
- Water sources—sterile and non-sterile. Filtered water is not enough [1, 4].
- Other attached equipment—lack of sterilization.
- Disinfectants that fix microbes and organic material to the instrument [1, 4].
- Prion diseases, water amoebas, fungi, enterococci, spores, microsporidies, mycobacteria, *Pseudomonas* and other infectious agents that can survive disinfection process.
- Brush reuse: organic residual material and reuse of damaged brushes that destroy inner scope parts [1, 4].
- Lack of protection of patients and personnel.

60.4.4 Recommendations from CDC [1, 2, 4]:

- IA = A strong recommendation supported by high- to moderate-quality evidence suggesting net clinical benefits or harms.
- IB = A strong recommendation supported by low-quality evidence suggesting net clinical benefits or harms or an accepted practice (e.g. aseptic technique), supported by low- to very low-quality evidence.
- IC = A strong recommendation required by state or federal regulation.
- II = A weak recommendation supported by any quality evidence suggesting trade-offs between clinical benefits and harms.

- *Annual control* of the knowledge and implementation of the endoscope disinfection/sterilization process is recommended: **IA**
- *Protection* of patients and personnel. **IA**
- *Pre-cleaning* of the equipment—immediate cleaning and wiping off most of organic materials—the instrument should not dry up: **IB**
- *Transport*—directly to the laundry room/disinfection room—in a closed container before the rest of the organic material dries in: **II**
- *Pressure leak test* after each use—follow guidelines: **IB**
- *Before manual or automatic disinfection*: cleaning of the entire endoscope and divided into every small component and brushed through and rinsed in all channels and surfaces (disposable sponge)—all under liquid level. Note flaps of the scope that may be difficult to rinse. Check that proper soap/enzyme (detergent) is used. **IB**
- *Use brushes* adapted to channel width, connectors and openings. Means for use during the washing process (brushes, sponges, cloths, etc.) should be disposable (or thoroughly cleaned before disinfection/sterilization between use) and **II**. Should only be used one time (author).
- *Discard enzymatic detergents* every time after use. **IB**
- *Biopsy instruments* that perforate/damage mucous membranes are cleaned, disinfected and sterilized as common surgical instruments. **IA**
- *Ultrasonic cleaning* can be used for problem instruments. **II**
- *Endoscopes in contact with all types of mucous membranes should at least undergo high-level disinfection between each use.* **IA**
- *High-level disinfection systems* for endoscopes must be approved for the current use. **IA**
- *Exposure and time* depend on disinfectant and scope. For example, it is required for use of glutaraldehyde *more than 2%* (2.4%) at 25 °C from 20 to 90 min (FDA). **IA**
- *Use technology* that is consistent with the quality of the scope/manufacturer. **IB**
- *New technology and resources*—ensure approval. **II**
- *The entire endoscope should be immersed under the liquid surface in the washing process.* If this is not done, the scope must not be used. **IB**

- *Automatic endoscope re-processors (AERs) may fail*—must be checked and used in a defined manner relative to machine, disinfectant and scope. **IB**
- *If AER is used*, check connectors and follow the manual so that all internal parts are disinfected. **IB**
- *If the AER process is interrupted*, everything must be reversed. **II**
- *Infection control personnel* should check AER system against manuals and use. **II**
- *After disinfection*, rinse all channels and rinse the endoscope outside with sterile water—the water is removed after each cycle. Finally rinse with 70–90% alcohol and dry with *clean* compressed air. **IA**
- *Inspect the cleanliness* through the process and deconstruct or send to repair damaged scope. **II**
- *Store the scope vertically* for drying (see producer manual). The scope must be protected from contamination. **II**
- *Disinfect the scope before use* if uncertain storage—storage time maximum 10 days. Undefined
- *The water bottle and hose mounted in the suction/flushing system* are at risk and should be washed and sterilized between each use. Only sterile water should be used. **IB**
- *Note name, date, time and scope number* if it needs tracing. **II**
- *Routine testing of the disinfectant* should be performed daily or more often with chemical indicator. **IA**
- *Use disinfectant only once* and follow the manual if this is not done. **IB**
- *Areas for endoscopy and cleaning/disinfection* should provide a safe environment for patients and personnel. Good ventilation and control of chemical gases. **IB and IC**
- *Personnel* who work with scopes must be approved also for the use of chemical substances. Only competent personnel shall participate in the work. **IA and IC**
- *Personal protective equipment, gloves, gown, eye protection, respiratory protection and cap* should be readily available and should be used by all when exposed to blood, tissues and chemical substances. **IC**
- *The endoscope* should be marked for when and where the disinfection process was completed. **II**
- *Microbiological testing of scope and environment*—undefined, but should be done for scopes. Is conducted internationally in many places today.
- *Microbiological testing shall in that case* be made with standard tests. **II**
- *The scope equipment—follow recommendations.* **II**
- *In case of infection outbreak—suspect scope infection or toxic substance*—carry out environmental and scope sampling according to the standard. **IA**
- *Endoscope-related infections must be reported* in the hospital's routines and to relevant health authorities, etc. **IB and IC**

After the outbreak of multidrug-resistant, gram-negative infections associated with endoscopes, CDC recently (March 2015) has tightened the routines for cleaning and inspection—especially of the ERCP endoscope [9, 10].

- The CDC recommends that the following steps should be taken when reprocessing duodenoscopes [9]:
- *Inspection and manual cleaning:* Ensure that the elevator mechanism located at the distal tip of the duodenoscope is thoroughly cleaned and free of all visible debris. The visible inspection is to be done with the elevator in the “open/raised” position as well as with the elevator in the “closed/lowered” position to ensure there is no visible debris above or below the elevator mechanism. Consider to use a magnifying glass (e.g. 10×) to improve detection of residual debris around the elevator mechanism.
- *Drying:* Ensure that the channels of the duodenoscope and elevator mechanism are *thoroughly dried* prior to storage. This should include an alcohol flush followed by forced air drying if these procedures are compatible with the duodenoscope as per the manufacturer’s instructions. If canals and the elevator are not completely dry, bacterial growth can occur, forming a biofilm that is difficult to remove and could result in persistent contamination [9].

60.4.5 Short Version

60.4.5.1 After Pressure Leak Test, Proceed as Follows [1–4]

1. Clean the equipment mechanically—outer and inner surfaces—and brush thorough channels and rinse all channels with water and an enzymatic soap.
2. Disinfect either:
 - (a) Automatic disinfection machine, using glutaraldehyde 2.4% or peracetic acid, perasafe, etc.
 - (b) Manual immersed in disinfectant, flushing with disinfectant in all channels for a defined time
3. Clean: The endoscope and all channels with sterile water—filtered water are not good enough.
4. Dry: Clean/rinse tubes and canals with alcohol and dry with clean pressure air.
5. Store: Protected against re-contamination, vertically or arcuate in a ventilated, clean cabinet [3].
6. This procedure will completely remove *one test* of 10 [5, 6] *Mycobacterium tuberculosis* bacteria in organic matter dried into the endoscope, in a difficult place and in the absence of cleaning [1, 2, 4]. It is documented that this can be done with 2.4% glutaraldehyde, disinfection time 45 min at 25 °C [4].

60.4.6 Problems

Automated endoscope reprocessors (AER) have been used for many years also in Norway [3]. They have great advantages in reducing exposure to organic materials and disinfectants. However, used according to international guidelines, there have been a number of infections and bacterial colonization. This may be due to not following the procedures or that the procedures are not good enough. There have been problems with cleaning, not enough water or not using sterile rinsing water, connectors, micro-organisms and organic materials left in places like elevator wire channel in ERCP, etc. [4, 9–19].

Automatic endoscope machines and use of detergents. There are significant differences with regard to types of detergents—enzymatic and non-enzymatic soaps—both in terms of visible purity and microbiological purity (reduction factor), compared with water control [11]. The requirement is, among other things, that cleaning alone should reduce the bioburden with a \log_{10} reduction of 4. Use defined enzymatic soaps for defined scopes and machines.

Sterile water for rinsing after terminal disinfection is important to avoid recontamination. This should be controlled by routines for microbial sampling [12, 13].

Coupling error for suction duct where the disinfectant does not pass the scope lumen has been reported in connection with outbreak of imipenem-resistant *Pseudomonas aeruginosa* [14]. Coupling systems may be misunderstood by unauthorized personnel.

Biofilm formation in automatic scope machines is a problem that can lead to growth of various resistant microbes, which are very difficult to eradicate [6, 7, 15, 16].

Risk of contamination is present for the light source, knots, hoses, manoeuvres head, biopsy channel, air channel, suction, ocular, etc. The inside of the suction duct, 2.8 mm in diameter, may be contaminated with biofilm formation, etc. and are often instrument design problems [1–4, 9, 10].

In contrast to the CDC guidelines, other countries have used other routines and different types of scope machines. Four main types of endoscope machines have been used in Norway, three of which have a disinfection temperature of about 60 °C and do not reuse disinfectant (glutaraldehyde and peracetic acid/hydrogen peroxide) and one with disinfection temperature of 20 °C and reuse of disinfectant (Table 60.1) [3]. There have been few problems associated with endoscopic use in Norway.

Table 60.1 Disinfection machines for flexible endoscopes used in Norway in 2002, ref. [3]

Machine types	A	B	C	D
Cleaning phase	Yes	Yes	No	Depending on the product
Leak test	Yes	Yes	Yes	Some types
Disinfectant	Glutaraldehyde	Glutaraldehyde	Peroxyacetic acid/hydrogen peroxide	Glutaraldehyde
Drains out the washing water	Program I: no Program II: yes	Yes	No cleaning phase	Yes
Direct connection to endoscope channels	Yes	No	Yes	Yes
Disinfecting time	5–10 min	Decide for yourself	12 min	10 min and 60 min by TBC
Reuse of disinfectant	No	No	No	Yes
Disinfection temperature	60 °C	60 °C	58 °C	20 °C
Disinfection of rinse water	UVC irradiation	>85 °C	Sterile filtration	Someone has sterile filtration

60.4.7 Cause of Infections

- More long, narrow channels—hard to clean.
- Moist or wet scope—increases microbe growth.
- The scope does not tolerate temperatures $>65\text{ }^{\circ}\text{C}$ —do not tolerate heat sterilization.
- Worn out, destroyed scopes with holes in suction ducts, etc.
- Couplings—weaknesses—malfunction of hoses, suction, etc.
- Non-smooth surfaces, sharp angles, “dead ends”, absorbent materials, pits in the material, etc.
- Often few, expensive instruments.
- Manoeuvre head not properly disinfected.
- Lack of disinfection of workplace, light source, etc.
- Too short time for cleaning and disinfection—before new use.
- Contaminated scope washing machines, especially water inlet (*Pseudomonas aeruginosa* and other gram-negative), air intake, soap intake.
- Thick biofilms in scope and in scope washing machine with gram-negative bacteria.
- *Brushes with residues of organic material transferred from scope to next scope!*
Damaged brushes can damage internal parts of the scope.
- Wrong detergent.
- Lack of visual control with magnifying glass.
- Lack of microbiological control at the end of treatment.
- Recontamination during storage of endoscopes in separate ventilated, clean cabinet. After 24 h the scope should be 100% clean inside, and after 7 days this may be reduced to 90% clean [4, 9, 10].
- Contaminated environment, poor hygiene and cleaning between patients and terminal cleaning and disinfection.
- Poor hand hygiene, personal hygiene and attire of personnel working with the patient.

60.4.8 Control: Visual and Microbiological

- By evaluating reprocessing of 89 GIT endoscopes and 3 automatic scope reprocessors in the period 2006–2014 at a hospital in France, 846 samples were taken for microbial growth [17]. French guidelines for treating scopes were followed in 86% of cases, varying with type of scope and seasons. A total of 118 of 846 samples (14%) showed growth of indicator microbes like *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, *Enterobacteriaceae* and *Candida* sp. The result was not satisfactory [17].
- Therefore, microbiological monitoring of automatic scope washers is important for maintaining good practice and for detecting endoscopes that need technical improvement or need to be discarded [11, 17, 18].

60.5 Background Information

Endoscopic procedures are used in a large number, diagnostic and therapeutic, and experience lasts at least 50 years back. Complications and infections are rare, 1 per 1.8 million procedures, but there are no other instruments that are associated with as many infections as endoscopes [1, 2, 4]. An analysis of endoscopy-related infections, pseudo-infections and toxic reactions, 1974–2004, documented 140 outbreaks where more than 94% of the cases could be prevented by improved decontamination of scopes [19].

60.5.1 Cleaning

A proper and thoroughly performed washing processes and selection of enzymatic detergents are central. All organic material must be removed. The disinfection processes does not inactivate prions which is a growing problem. There may also be bacteria, spores and biofilm that is difficult to remove [1–4, 9, 10, 20].

60.5.2 Disinfectant

All disinfectants are inactivated by a lot of organic materials and dirt. Therefore, the instrument must be cleaned for all organic material before disinfection. Do not use endoscopes that cannot completely be immersed in disinfectants. Spores can be detected from all types of disinfection methods.

Glutaraldehyde is widely used, 2% alkaline glutaraldehyde. It is effective, but higher concentrations like 3.3% have some better effect [21]. Concentration decreases over time in disinfection vessels [22]. Glutaraldehyde is well documented, destroys not instruments, is non-corrosive and is relatively inexpensive to use. The downside is slow inactivating effect on mycobacteria, no effect on spores, fixes and coagulates tissue and blood to the metal, must be activated to be effective enough, emits allergenic gases and requires control and protection for users. The smell of glutaraldehyde in the room indicates too high concentration of the disinfectant.

Other disinfectants that can be used are ortho-phthalaldehyde (OPA), hydrogen peroxide, peracetic acid/hydrogen peroxide, chlorine dioxide and PeraSafe.

Do not use these! Iodophores, alcohol, chlorhexidine gluconate, quaternary ammonium solutions, glutaraldehyde (0.13%) with phenol, benzalkonium chloride and hexachlorophene.

60.5.3 Brushes, Sponges and Cloths

All brushes are used once and discarded after use. They can be hardly cleaned for organic matter. Brushes that are damaged at the end can tear up internal parts of the scope. Biopsy elevator (ERCP) must be cleaned with a soft brush [3] (Fig. 60.1).



Fig. 60.1 Endoscope. Source: Kebomed.no

60.5.4 Transmission of Microbes

60.5.4.1 Bronchoscope

- Transfer of infection via bronchoscope is well known [15, 19, 23, 24].
- Until 2007, there were >50 outbreaks with more than 2000 patients exposed to infection and more than 750 patients infected. Dominant agents were *Mycobacterium tuberculosis*, atypical mycobacteria and *Pseudomonas aeruginosa* [19].
- Disinfection of bronchoscope should be at the highest level, really full sterilization. Main problems are inadequate disinfectant, concentration, working time, punctured suction channels, inadequate cleaning, lack of sterilization of biopsy equipment, non-customized duct links, biofilm formation when channels are not well cleaned before disinfection, etc. [8, 15].

60.5.4.2 Gastrointestinal Endoscopy: GIT

- In 1974, 240,000 gastrointestinal (GIT) endoscopies were studied retrospectively, including oesophageal-gastro-duodenoscopy (EGD) and colonoscopy. In all, 24 infections were recorded; two deaths of cholangitis, two deaths of pancreatitis, and it was estimated one infection per 10,000 endoscopies and one death of infection per 60,000 scopies [25]. In 1993, there were 377 published infections following GIT endoscopy or bronchoscopy.
- In 1992, 71 used GIT endoscopes were studied: 23% of inner channels had >100,000 bacteria after full disinfection/sterilization [26]. Unauthorized disinfectants had been used for several of the scopes.
- Bacterial contamination of duodenoscopes is associated with problems with disinfection of “Albaran level”. This is avoided by following validated procedures for recycling processes [27].
- In 2007, >70 outbreaks were reported, and more than 6000 patients were exposed, and more than 400 patients were infected [19]. A total of 70% were caused by *Salmonella* sp. and *Pseudomonas aeruginosa*. The clinical range varied from colonization to death (4%) [19].

60.5.4.3 Endoscopic Retrograde Cholangiopancreatography (ERCP)

- In 1978, complications from ERCP were recorded in totally 1.3% of the cases and 0.7% infections (sepsis, cholangitis), and 1 in 4 died of the infection [28].
- In 1976 was infection associated to ERCP present in 1.1% of the cases; 97/10,425, and 13.4% of infected patients died [29].
- In Canada, 37 hospitals were asked about the reuse and reprocessing of ERCP, as well as microbial sampling form 119 scopes [30]. Microbial growth was found in 7% of cases, and only 43% followed the national guideline cleaning and disinfection. There was a greater amount of protein, carbohydrates and endotoxin with ERCP scopes disinfected with glutaraldehyde than with peracetic acid [30]. There was a lack of immersion of scopes under water for manual cleaning, large enough volume for cleaning, adequate drying before storage and separation of “ERCP valves” from scopes during storage [30].
- In 2015, some failure with ERCP from Olympus in the United States was reported. At least 16 patients were infected with multidrug-resistant carbapenem-resistant *Pseudomonas* bacteria at several hospitals [31]. Resistant *E. coli* (ESBL) outbreaks were reported from other hospitals. More than 500 people are checked for infection, and several patients died due to infections. The problem was not reported to the Food and Drug Administration—FDA—until 2015. The FDA inspected four companies that had Olympus scope in the United States and Japan. The infections came despite the manufacturer’s instructions for cleaning were followed [31]. The scopes had been modified by Olympus with camera and other equipment inserted into the scope—in such a way that it could not be cleaned well enough. The bacteria adhered to inner parts together with residues of organic materials and fluids from other patients, the FDA concluded. The scope modifications were not reported to the FDA. A minimum of 500,000 procedures are performed in the United States in recent years. At some hospitals, the endoscope has been discontinued, and some use ethylene oxide gas sterilization, which results in an additional period of aeration to prevent patients from toxic products [31].
- An outbreak of multidrug-resistant, carbapenem- and cephalosporin-resistant (CR) *E. coli* infection in seven patients in the United States, 2012–2013, was associated with ERCP and non-satisfactory *guideline* for reprocessing of scopes [18]. Among the 35 cases consistent with casus definition, 30-day mortality was 16% and for patients with CR infection 56%. Bacteria were detected in scopes after disinfection (2/8), while environmental samples were negative. Recommended scope product guide was not satisfactory [18].

60.5.4.4 Colonoscopy

Hepatitis C infection is transmitted by colonoscopy [32]. Genetic identical HCV was transferred from a patient to two others being examined by colonoscopy the same day. The source of infection had a high yield—3.5 million genome equivalents—of HCV per ml of blood. The biopsy suction duct had never been sterilized [32].

60.5.5 Types of Infections That Usually Are Transmitted

60.5.5.1 Endogenous Infection

- Microbes may occur in blood (bacteraemia) like enterococci, gram-negative rods, anaerobic bacteria, etc. during the scopy process. For instance, during sigmoidoscopy ca.10% of the cases may have bacteraemia lasting for about 15 min—obs risk of endocarditis/heart affection.

60.5.5.2 Exogenous Infection

- Gram-negative rod bacteria grow in “wet areas” in the endoscope after 14–18 h. *Pseudomonas aeruginosa* growth after ERCP. Other bacteria are *Klebsiella*, *Enterobacter*, *Serratia marcescens*, *E coli*, *Helicobacter pylori* (patient to patient infection), Whipples’s disease (patient to patient infection), salmonella (EGD colonoscopy, patient to patient infection), etc.
- *Mycobacterium tuberculosis*. Patient for patient infection. Culture-positive bronchoscope is detected after 30 min disinfection with povidone-iodine solution. Note especially the suction channel. Other mycobacteria are even more difficult to remove by disinfection, like *M. chelonei*.
- *Clostridium difficile*. Probable patient to patient transmission—by small doses of spores.

60.5.6 Other Microbes More Seldom Transmitted

Fungi: *Trichosporon beigelii*, and others, microsporons

Parasites: *Pneumocystis carinii*, *Cryptosporidies*, *Strongyloides* (Oesophagitis epidemic)

Virus: Hepatitis A, B, C, D (at B carrier), E, HIV, etc. can be transmitted by contaminated scopes.

Recent studies suggest that the infection rates after colonoscopy and endoscopy may be “far higher than expected” [33]. This may partly be due to a not effective drying method [34].

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Abstract

Sterilization means “destruction of all forms of microbial life”. A surgical instrument can be considered sterile if the probability of a single living microorganism is present is equal to or less than 10^{-6} . Use of sterile instruments and other sterile equipment is necessary to avoid infections during surgery and other aseptic processes. Sterility is dependent on a clean surface of the instruments—where all organic materials and dirt are removed, usually by a washing-disinfection process before the sterilization procedure. After this process, sterility may last for a period if handled and stored in a secure way. The following chapter is focused on practical measures to disinfect, sterilize, control, store and use surgical equipment in healthcare institutions.

Keywords

Sterilization · Heat-sensible instruments · Reusable equipment · Disinfection
Sterilization · Autoclave · Infection control · Hygiene · Prevention

61.1 Purpose

- To ensure that all products undergoing a sterilization process are sterile after the process [1, 2].
- To remove pathogenic agents like bacteria, viruses, fungi, parasites and spores, from sterile instruments and other sterile equipment.
- To prevent transmission of infection from patients to other patients, staff, visitors or the environment through contaminated instruments.

61.2 Comprise

- All equipment that is sterilized

61.3 Responsibility

The hospital's management ensures that written routines for sterile work and sterilization processes are available, including routine procedures against prion disease [1–5].

Management at sterile centres implement procedures for pretreating, control, packing, transport, sterilization, after-control and storage of ready-to-use sterile equipment. Resource deficiency that constitutes a risk of infection for patients and personnel must be reported to the Director immediately.

Personnel follow routines for the treatment of sterile and unsterile goods.

Preparedness in connection with deficiencies/failure (machine shutdown, flood, etc.) regarding sterilization capacity must be ensured through planned cooperation with other hospitals/sterile centres.

61.4 Practical Measures [6–12]

61.4.1 Areal

The sterile centre requires “clean room status”—in line with an operating department and is usually associated with operating departments. A sluice for entrance check and dressing is necessary. The same requirements are given for ventilation, air changes and pressure, as well as bacterial amount in the air (<100 CFU/m³).

- The sterile centre usually has a reception area for “less clean”—equipment that is disinfected and washed other places and has to be controlled before further treatment in the centre.
- Clean room for final control and packing.
- Sterilization area—a suitable separate area—without steam and other gases leaking to other rooms.
- Clean and “dry” room for check after sterilization of the goods.
- Storage rooms for ready-to-use sterile goods; clean storage rooms (<100 CFU/m³).
- A separate wash room for transport vehicles after use and a storage area. Transport to relevant departments should be carried out in clean, tightly closed transport vehicles that are cleaned after each use and stored clean.

61.4.2 Pretreatment of Goods Before Sterilization

All equipment coming to the sterile centre should be free of biological material. This happens during inspection, sonication of instruments (dirt and organic material release) and repeated washing in the instrument washing machine [13].

Instruments with residues of dried organic matter constitute a risk of infection (especially prions) and uncertain sterilization results.

61.4.3 Packing and Loading of the Sterilizer

The goods are packed according to defined routines, and the sterilizer is loaded correctly for which goods it is validated. Package material must be permeable to air, steam and any gas while protecting equipment against recontamination after completed sterilization process. Do not load too much goods and fill the chamber evenly each time.

61.4.4 Water Vapour Sterilization: Autoclaving

The method is safe, cheap and efficient. It is used for equipment that can withstand 120–140 °C. The autoclaving procedure treat the goods/equipment in saturated steam at elevated pressure to increase the temperature above 100 °C. In clean saturated water vapour, there is a relationship between pressure and temperature. One atmospheric pressure equals 121 °C, which kills all bacterial spores.

Physical monitoring for two systems:

1. Temperature, 134 °C; effect time (holding time), 4 min; pressure, 2 bar [14]
2. Temperature, 121 °C; effective time (holding time), 15 min; pressure, 1 bar [14]

Biological indicator (spore test) is *Geobacillus stearothermophilus* of other defined spores used for each run [14].

Chemical indicator is placed in different parts of the goods, including outside.

61.4.5 Loading

Packaging must be able to slip through air and steam. The autoclave should be loaded to let the steam circulate freely and to avoid problems with condensation and air pockets. The chamber is filled evenly each time. Too loaded autoclave or almost empty autoclave may give uncertain results.

61.4.6 Treatment Periods

The *preheating* period is the time from which the autoclave is started until the temperature in the chamber has reached the desired temperature.

The *equilibrium* period is the time from which the chamber has reached the sterilization temperature until all parts of the goods have reached the same temperature.

The *sterilization* period is calculated from the time the goods have reached the sterilization temperature.

At 121 °C: 15–20 min

At 134 °C: minimum 5–7 min

61.4.7 Emergency Autoclaving

Sterilization of unpackaged instruments is not recommended and should only be used in emergency situations. Aseptic coverage of the goods and short distance to the user site are a prerequisite. Instruments with cavities can only be sterilized in autoclave with pulsating pre-vacuum. Water vapour sterilization is performed at 134 °C for at least 3 min.

61.4.8 Dry Sterilization

The method uses hot air at 160–180 °C. The method is used where water vapour sterilization is not possible or practical and is suitable for metal and glassware, but not for porous materials such as compresses and textiles. The goods must withstand the high temperatures. The equipment must be completely dry before sterilization. It is packed in suitable packaging paper. The opening is sealed with sterilization tape with colour indicator that changes colour during the sterilization process. The packaging is marked with sterilization date and content.

Sterilization temperature and working time:

- 160 °C for at least 2 h.
- 170 °C for at least 1 h.
- 180 °C for at least 30 min.

The heating time until all equipment has reached the sterilization temperature comes in addition.

Maximum thermometer must be used regularly as a control, for example, every 3 months. Microbiological control with spore samples is done every 6 months. A minimum of six spores are used each time.

61.4.9 Formaldehyde: Low-Pressure Vapour Sterilization (Formalin Sterilization)

Formaldehyde sterilization is used for sterilization of equipment that cannot withstand temperatures with cycles over 65 °C or 70–80 °C. Sterilization takes place at defined sterile departments having competence for this work. The principle is to combine formaldehyde gas and bactericidal capacity from low-pressure saturated water vapour.

The formaldehyde autoclave contains three process steps:

The first step is a moisture and air extraction phase that takes place by means of a vacuum pump and thereafter filled by saturated water vapour into the autoclave chamber.

Second stage is the sterilization process, where formaldehyde and water vapour are dosed in several rounds. During the sterilization process, alternating evaporation and condensation occur within the autoclave chamber in a closed system.

In the third and final step is that formaldehyde is removed by the effect of water vapour blowing through the autoclave chamber. Afterwards equipment is dried in a vacuum, and finally filtered air is sent into the chamber.

61.4.10 Ethylene Oxide (EO) Sterilization

Ethylene oxide sterilizer is used for equipment that cannot tolerate temperatures above 55 °C. The method is performed at defined sterile departments. EO can take place at 37 °C or 55 °C, with relative humidity >60%, pressure 0.8–1.8 bar and holding time 3 h at 37 °C and 1 h at 55 °C [14].

- Biological indicator is usually *Bacillus atrophaeus* used for each run [14].
- Chemical indicator may be placed at different locations in the goods, including outside.

61.4.11 Sterilization Process

A modern EO sterilizer contains three process steps: *pre-wetting, sterilizing and venting* EO from the material. Sterilizers may be differently designed, some with overpressure and others with negative pressure. Results depend on several factors: the concentration of EO, temperature, relative humidity, cleaning before sterilization, packaging material, removal of gas residues from the equipment, loading the autoclave, the time sterilization process takes, etc.

Concentration of EO: The gas concentration varies from pure EO on disposable gas patrons to a mixture of 10% EO and 90% inert gas, e.g. carbon dioxide. The latter is not explosive. Autoclaves that use a gas mixture must work at over-pressure. Autoclaves where clean EO is used, works at under-pressure.

Temperature: Sterilization with EO is preceding from room temperature and upwards. When EO is used for sterilization of heat-sensitive equipment, the most common temperature is approx. 50 °C.

Relative humidity: The bactericidal activity increases with the relative humidity that should be in the range 70–100%. The wetting process should be built into the sterilization process.

Microorganisms: EO is effective both against vegetative and spore-forming bacteria and against viruses. Microorganisms in organic matter can be difficult to kill with EO as the gas has little ability to penetrate dried protein residues.

Cleaning of equipment: It is very important that equipment to be sterilized is satisfactorily cleaned.

Packaging material: The packaging must be permeable to air, moisture and EO gas. Packaging consists of one side sterilization paper and the other side plastic laminate welded together—useful in hospitals (Standard EN 868).

Removal of gas residues from the equipment: After the sterilization process has ended, the equipment may still contain large amounts of EO. The necessary aeration time depends on the temperature, chemic composition of plastic materials, equipment design, packaging and storage. For example, it takes 100 times longer to vent a semihard polyvinyl chloride than a soft one. In a hospital, it is practically impossible to operate with different air times (venting times) depending on the material in which the equipment is manufactured. Therefore, a time is chosen that cover most materials. Equipment is aired at 55 °C in the sterilizer. Then it is delivered after negative spore test.

Loading of the EO—autoclave: As with all sterilization processes, the autoclave should not be packed too tight as air, moisture and gas may otherwise be difficult to penetrate.

Sterilization period: The time sterilization takes depends on the other factors. The lower the temperature, the longer the sterilization time.

61.4.12 Plasma Sterilization

This is also a “low-temperature sterilization method” performed at 45–55 °C. The process consists of a “diffusion period” with injection of hydrogen peroxide (H_2O_2). There are produced free radicals that make the “plasma process”. This is the actual sterilization process. The advantage of this sterilization method is that it does not provide any residual products after the process and hence no work environment problems.

- At a temperature of 50 °C, pressure used is 500 mtorr and effective time is 1 h.
- Biological indicator is usually *Geobacillus stearothermophilus* used for each run [14].
- Chemical indicator may be placed at different locations in the goods, including outside.

61.5 Background Information

Sterilization will destroy all microbial life except for a few infectious substances. An object is sterile when the likelihood for that a single living microbe is present is equal to or less than 10^{-6} . This is the European pharmacopoeia's requirement for sterility. Risk is 0.000001 and the security level is 99.99999%.

All equipment that comes directly or indirectly in contact with body areas that are normally sterile *should* be sterilized. All equipment penetrating the skin and mucous membranes *must* be sterile. All equipment, bronchoscope, tracheal tubes, gastroscopes, cystoscopes, endoscopes, etc.—which come into contact with respiratory tract mucosa, esophagus, urinary tract and genitalia—*should* be sterile or disinfected at high-level disinfection.

Inactivation of microbiological agents is done by burning, autoclaving, boiling in water for more than 10 min, dry heat at 140 °C for more than 90 min and moist heat at 100 °C for more than 10 min.

Nearly complete inactivation occurs by hot water/steam for more than 85 °C for 10 min, chloramine 5% in 60 min, PeraSafe 16.2% for 10–30 min and the glutaraldehyde 2–3% for 30–60 min.

The ability of the various methods to kill microorganisms is expressed by the method's inactivation factor which is the ratio of the initial number of germs to the number of surviving germs at a given time during the procedure. The inactivation factor is different for the individual microorganisms. The inactivation factor that the most resistant microorganism has is important. At a given inactivation factor, the chance of sterility for one and the same period is greater the lower the initial bacterial number is. Thorough cleaning before sterilization will reduce the microbial number and thereby ensure the sterilization procedure.

The most resistant infectious agents are called prions, protein particles that cause Creutzfeldt- Jakob's disease and bovine spongiform encephalopathy (BSE), among others. In such cases, none of our usual sterilization routines are good enough. In case of suspected prion disease, equipment used for the patient is *destroyed* by burning, after autoclaving at 134–137 °C for 1 h and other special treatment (see section on prion disease and technical disinfection).

Sterilization methods current today (Table 61.1):

- Water vapour sterilization at 121 °C for a minimum of 15 min or 134 °C for 7 min or 134 °C for 1 h on suspicion of prions
- Dry sterilization at 160 °C for 2 h or 180 °C for 30 min
- Formaldehyde/low-pressure steam sterilization at approx. 65 °C or 70–80 °C
- Ethylene oxide sterilization (EO) at 55 °C
- Plasma sterilization at 45–55 °C

Table 61.1 Methods for sterilization

Sterilization method	Benefits	Disadvantages
Steam sterilization	Can be used for everything. Non-toxic by-products easy to control and monitor Not harmful to patients, personnel and the environment Rapidly killing effect in microbes Not particularly hampered by organic matter Fast cycle Good penetration through packaging/packages Good penetration through instrument lumen	Heat-sensitive instruments can be destroyed Wet material/instruments can corrode Fire
Plasma sterilization (Hydrogen peroxide gas plasma)	Safe for the environment Non-toxic products Cycle 45–73 min. No airing required (cycle ≥24 min, ref. [1]) Heat- and moisture-sensitive instruments can be treated at <50 °C Easy to control and monitor All types of equipment and instruments Easy to establish	Cellulose (paper), textiles and liquid cannot be sterilized Often small capacity—low volume Limited use of instruments with narrow lumen and long tunnels as endoscopes (cf. producer) Special packaging—synthetic—and containers Toxic border level in the room: 1 ppm should be monitored
Ethylene oxide gas 100% (450–1200 mg/L, tp 37–63 °C, relative humidity 40–80%, time, 1–6 h) ETO	Penetrates all material and instrument lumen negative pressure chamber and good control of the gas All types of material Cycle is easy to control, monitor At increasing temperature and concentration, the sterilization time will be reduced Single dose containers—defined	Aeration afterwards to remove the gas Toxic, carcinogenic and combustible 99.9% of ETO is converted into CO ₂ and water Long cycle and long aeration time Single-dose containers must be stored in fireproof cabinets
Ethylene oxide gas Mixtures	Like ETO	Like ETO

Table 61.1 (continued)

Sterilization method	Benefits	Disadvantages
Formaldehyde—low pressure Vapour sterilization vacuum, saturated water steam formaldehyde	Penetrates all material and lumen Closed system, 65–80 °C All types of material, low temperature Cycle easy to control, monitor Increasing temp and concentration reduce time Particularly useful for heat-sensitive instruments	Small volume Formaldehyde residues in equipment—control Toxic Spore tests every week Long time—cycle and airing Not so efficient at long, narrow lumen
Hydrogen peroxide steam Note—limited experience!	Safe for environment and personnel No toxic residues, aeration unnecessary Fast cycle—55 min Used for heat and moisture-sensitive objects, also metal	Restriction for instruments with cavities Limited use of instruments with narrow lumen and long tunnels as endoscopes (cf. manufacturer) Limited experience with metal damage! Special packaging— synthetic and containers Cellulose (paper), textiles and liquid cannot be sterilized Toxic border level in the room: 1 ppm must be monitored Limited clinical experience Limited experience with microbiological effect!

Source: Rutala WA, Weber Di. Disinfection, sterilization, and control of hospital waste. Principles and practice of infectious diseases. 2015: 3294, and edition 2005: 3331

61.5.1 Infection Risk from Contaminated Sterile Goods

An outbreak of infection among 15 orthopaedic patients who had undergone “clean surgery” was traced back to contaminated surgical instruments [15]. Most patients were infected during the operating season with normal skin flora like coagulase-negative staphylococci and *Bacillus*, and 11 out of 15 had to be reoperated. Microbiological samples from sterile goods showed the same bacterial flora on the inside of the package and on the sterile instruments themselves. Inspection of the sterile centre showed inadequate handling and control of autoclaves and bad hygienic routines. This occurred combined with the fact that surgical personnel did not observe the discolouration of outer parts of the delivered packages with sterile goods nor did good inspection of the sterile goods before opening the instrument packages [15].

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Sterilization: Control and Quality

62

Abstract

Use of sterile instruments and other sterile equipment is necessary to avoid contamination and infection during surgery. Full sterility is dependent on removal of all organic materials and dirt from the instruments, a washing-disinfection process and control before, during and after the sterilization procedure. Definition of sterility is the probability of a single living microorganism present is equal to or less than 10^{-6} . Several practical indicators are used to control the sterilization process and to ensure that the instruments are sterile.

Keywords

Sterilization process · Heat-sensible instruments · Reusable equipment · Autoclave · Infection control · Hygiene · Prevention

62.1 Purpose

Ensure that all products undergoing a sterilization process are sterile after the process [1–15].

To remove pathogenic agents: bacteria, viruses, fungi, parasites, spores, from sterile instruments and other sterile equipment.

To prevent transmission of infection from patients to other patients, staff, visitors or the environment through contaminated instruments.

62.2 Comprise

All equipment that is sterilized.

All personnel working with sterile equipment.

62.3 Responsibility

The hospital's management ensures that routines for sterile work and sterilization processes are available and ensure routine procedures against prion disease [1, 2].

Management at sterile centres implements procedures for pre-treating, control, packing, transport, sterilization, after-control and storage of ready-to-use sterile equipment. Resource deficiency that constitutes a risk of infection for patients and personnel must be reported to the Director immediately.

Personnel follow routines for the treatment of sterile and unsterile goods.

Preparedness in connection with deficiencies/failure (machine shutdown, flood, etc.) regarding sterilization capacity must be ensured through planned cooperation with other hospitals/sterile centres.

62.4 Practical Measures

62.4.1 Check After Each Cycle (Sterilization Process)

- *The goods must be dry.* Wet goods may be due to poor steam quality. Wet packing material does not provide protection against recontamination and growth of bacteria or fungi through the packing.
- *Physical parameters* such as temperature, sterilization time and chamber pressure must be controlled. The EN standards require that all autoclaves have a printer and diagram and that temperature, pressure and time must be printed for each time of sterilization. If a printer does not exist, a standard curve may be used to verify that the curve course is correct. The time can be checked by counting routes on the paper.
- *Chemical colour indicators* provide colour change at certain temperatures, time, humidity and eventually gas. Chemical colour indicators are available as *sterilization tape* or printed directly on the packaging material to show that the individual article has been through the sterilization process. More complex chemical indicators provide change due to temperature, time, saturated water vapour and eventually gas concentration.

62.4.2 Fixed Frequency Control

Biological indicators (BI) (spore samples) consist of certain microorganisms with known, high and stable resistance to the sterilization process [1]. Spore samples are cultures, and it takes time before the result is available. BI is suitable for testing that the sterilizer works properly. The following frequency is recommended for control using spore tests.

- *Water vapour sterilization:* At least every month. International standard every cycle [1].
- *Dry sterilization:* Every other month/every 3 months.
- *Formaldehyde sterilization:* Every other week. Preferably every cycle.
- *Ethylene oxide sterilization:* Each cycle. International standard every cycle [1]. For ethylene oxide you should wait for the result.

- *Plasma sterilization:* International standard—each cycle.

Test organisms may have varied resistance to the sterilization methods used:

- *Bacillus stearothermophilus/Geobacillus stearothermophilus* prepared for water vapour sterilization.
- *Bacillus stearothermophilus* prepared for formaldehyde sterilization.
- *Bacillus subtilis* made for ethylene oxide sterilization.
- *Bacillus subtilis* prepared for dry sterilization.
- *Geobacillus stearothermophilus* for plasma sterilization.

Thermal control is performed regularly by placing three, preferably six, adjusted thermosets, at different locations in the sterilizer to determine if there are places where the temperature does not reach the prescribed level.

Leakage test program can be found on newer sterilizers. The program should run weekly.

The Bowie and Dick test is used daily to test whether air evacuation from the chamber is satisfactory. The test consists of an accurately specified package of towels with a paper sheet with chemical indicator in a special pattern in the middle. The fabric, sterilization, temperature, packing, etc. are precisely defined. If the indicator colour has not been changed satisfactorily, this indicates air collection inside the package.

Working environment: Where gas sterilization is carried out, the work environment is to be checked annually by determining ethylene oxide and formaldehyde in the air, according to the national standard from Directorate of labour inspection (*Occupational Health and Safety*).

Formaldehyde residues in the equipment must be tested regularly by determining formaldehyde residues in standardized filter paper after sterilization. Proposed residue: maximum 100 mg/filter paper.

Maintenance and control: The EN standards require that the staff have special training in the maintenance of sterilizers. In practice, this will probably mean that such equipment should be considered as medical technical equipment. Controls: maintenance and control of printers, temperature gauges, pressure gauge and control of that spore tests are carried out according to specifications.

62.5 Background Information

There is no guarantee that the individual article is sterile after a single control (mechanically, physically, chemically or biologically). Sterility is present combined in a comprehensive quality assurance program.

Loading rate: The sterilizer must be *loaded correctly* and not overfilled.

Correct packing material is important; permeable to air, steam and any gas while protecting the equipment against recontamination.

Temperature, pressure and time must be printed for each sterilization. There are different types of printers. Some have circular sheets and a writing needle that is easily shifted by changing sheets. For documentation, these are suitable as they can be stored after one single sterilization with a control number on the sheet and on the sterilized articles. Other printers are continuous-time typewriters.

Chemical colour indicators: The simplest types produce a colour change when exposed to a certain temperature, time, humidity and eventually gas pressure. The indicator is suitable for showing whether the individual article has been through a sterilization process. Indicators can also be placed inside the packages.

If the specificity is not very high, a high sensitivity indicator will give unacceptably many false positive results for each real positive. If the sensitivity is low, true positive will not be revealed. Goods which should be rejected would be approved.

Biological indicators (BI) (spore tests). The indicator should only provide growth if the efficacy of the procedure has been significantly worse than the European Pharmacopoeia's requirements for sterility.

An advantage of using biological indicators is their ability to measure the effect of all parameters necessary to achieve sterility. The check should be performed at fixed frequency, and the international standard is for each cycle.

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Sterile and Clean Equipment: Storage

63

Abstract

Use of sterile instruments and other sterile equipment is necessary to avoid infections during surgery. Full sterility is dependent on removal of organic materials and dirt from the instruments, a washing-disinfection process and control before the sterilization procedure—and afterwards to not break the sterility of the instrument before use. Definition of sterility is the probability of a single living microorganism present is equal to or less than 10^{-6} . This chapter is focused on the storage of sterile and clean equipment in healthcare institutions.

Keywords

Sterilization · Surgical instruments · Reusable equipment · Disinfection
Sterilization · Infection control · Storage

63.1 Purpose

- To ensure that all products undergoing a sterilization process are sterile after the process and are stored in a hygienic satisfactory manner [1, 2].
- To remove pathogenic agents like bacteria, viruses, fungi, parasites and spores, from sterile instruments and other sterile equipment.
- To prevent transmission of infection from patients to other patients, staff, visitors or the environment through contaminated instruments.

63.2 Comprise

- All equipment that is sterilized
-

63.3 Responsibility

The hospital's management ensures that written routines for sterile work and sterilization processes are available, including routine procedures against prion disease [1–5].

Management at sterile centres implement procedures for pretreating, control, packing, transport, sterilization, after-control and storage of ready-to-use sterile equipment. Resource deficiency that constitutes a risk of infection for patients and personnel must be reported to the Director immediately.

Personnel follow routines for the treatment of sterile and unsterile goods.

Preparedness in connection with deficiencies/failure (machine shutdown, flood, etc.) regarding sterilization capacity must be ensured through planned cooperation with other hospitals/sterile centres.

63.4 Practical Measures [1–6]

63.4.1 Storage Room for Sterile and Clean Equipment

- Sterile equipment is stored in a separate clean room, in its own closet with glass door.
- The storage room shall not be exposed to transit traffic and shall not be used for office.
- Equipment should be stored dry and at room temperature 15–25 °C.
- The ventilation should correspond to an operating department; the following limit values for clean rooms where sterile disposables/sterile disposables/multiple equipment should be stored.
 - Relative humidity: 35–70%.
 - Ventilation: 10–17 air changes per hour.
 - CFU: <100 cfu/m³.
- Avoid strong light to prevent decomposition of material in the equipment and packaging.
- Regular check of the expiration date on the equipment package. Check any dis-coloration of packages.
- Always hand disinfection before handling of sterile/clean equipment.
- Avoid damage to the packaging when handling sterile/clean equipment.
- Outer packaging of transport cartons/packages is removed in a clean place *outside the storage room*, and the equipment packages are immediately placed in the storage room/closet.

- Take out only the equipment you need.
- Sterile equipment removed should be covered before shipping to the place of use.
- Sterile equipment must be traceable.
- The packaging is opened just before the equipment is put into use.
- Inspect the outside of the packaging for discolouration or moisture.
- Sterile equipment removed from the packaging should always be placed on a sterile surface under an aseptic procedure.
- One-time equipment package that has been opened should be discarded. The reusable equipment package that has been opened but not used should always be sterilized again before next use.
- Floor and bench surface in the storage room is washed daily.
- Shelves and cabinets are washed once a month—dry well before equipment is placed back.
- Main cleaning of cabinets/storage rooms at least twice a year.

63.4.2 Durability of Sterile Equipment

- The durability of sterile equipment depends on external factors such as mode of production, sterilization method, packing material, storage conditions, transportation and handling. The durability limit assumes that the product is manufactured, sterilized, transported, handled and stored in a manner that has kept the package undamaged. It is assumed that the packaging has not been opened.
- Generally speaking, two layers of textiles have shelf life 1–2 weeks, paper approximately 3 months, plastic/paper welded 1 year, metal container with filter/sterilization port 3 months. Check production date and date of exit.
- Shelf life limits for *factory-made equipment* are specified by the manufacturer. In cases where the production date is stated, may the product be expected to be durable for 5 years. Single packs are stored in the departments or shelf package, as provided.
- During handling and storage of sterile equipment/sterile disposables, must the equipment/items be protected against:
 - Damage to the packaging. Storage, handling and transportation must be carried out in such a way that the packaging is not damaged, resulting in contamination of the sterile equipment.
 - Humidity. A porous packing material that is moist can easily pass through microorganisms and other particles. Therefore, sterile articles must be stored dry.
 - Extreme temperatures/fast temperature fluctuations. Experience shows that a temperature of 18–22 °C is favourable.
 - Light. Strong light can speed up a decomposition of the material in the equipment and the packaging.
 - Insects must not have access to storage.

- Dust/particles. Each hospital must evaluate the external factors mentioned above and develop guidelines for shelf life for sterile equipment in relation to storage and handling conditions at the hospital.

63.4.3 Storage Types

Rough storage/pallet storage: Here, goods are received and stored in outer packing on pallets, in shelves preferably with adjustable shelves or directly on wheel support. Transport cartons are considered to be contaminated on the outside—often long transport by sea and land and from other continents.

Unpacking room: The outer packaging is removed, and the goods are prepared for further transport. Transport cartons must not be allowed in either clean or sterile store rooms. Outer cartons are often dirty and may contain, for example, insects. Particularly in the grooves on corrugated cardboard, dust and insects can easily accumulate. This room should have negative pressure, separate ventilation and sluice relative to sterile centres. Good access to hand hygiene.

Storage for clean and sterile equipment: Only clean and sterile items are stored, either in single pack or compartment, i.e. clean on the outside.

63.4.4 Warehouse Systems in Sterile Centres

Open shelves: The most widely used system on sterile centres is to store sterile items in open shelves. This is a reasonable solution because the shelves are easy to keep clean and require little floor space.

The downside is that the products are not protected as well as when stored in enclosed cabinets. Open shelves also provide additional requirements for environmental control. There should be a relatively good distance between the shelves so that there is plenty of space to take the items out of the shelves. The open shelves must not be placed so that the sterile articles are lying near the sink, window, door or air valves.

Closed cabinets: When picking up sterile goods from a closed cabinet, it is important to open the door carefully. A “fast” air movement will be able to extract particles and destroy the very purpose of a closed storage system. Closed cabinets are therefore suitable for articles that will be stored for a long time.

63.4.5 Warehouse Properties

When selecting building materials for floors, walls and ceiling, great emphasis must be placed on the possibility of simple and satisfactory cleaning.

Doors: Doors to rooms where sterile articles are stored in open systems should preferably have automatic sliding doors. If it is not possible, it should “turn” out of

the corridor. This is to prevent dust whirling in the room. To protect the doors, it may be convenient to mount a kicking plate on the door. Due to transport vehicles entering the room, there must be no threshold.

Floor: Floors must have a smooth surface, preferably a homogeneous vinyl coating. To avoid dust collections, hollow wedges should be preferred to floorboards.

Wall and ceiling: These should be smooth, strong and painted with 20 gloss paint. Wall coverings should go butt in butt with linoleum.

Lighting: It is recommended 200 lux as backlighting, as well as spotlight at the workplace.

Windows: The windows must be tight and have a simple design. They must not be opened. There should be no curtains in the room, but the room must be shielded from solar radiation. Exterior blinds are preferable.

Washbasins: There should be no washbasin inside the room if it cannot be installed at a satisfactory distance from the sterile items. Here, dispenser with hand disinfectant can be a good alternative. There should be access to the sink at the door to the warehouse.

Cabinet: It is recommended that the cabinets are built from floor to ceiling to avoid accumulation of dust.

63.4.6 Cleaning of Storage Rooms

- Daily cleaning of floors and horizontal surfaces.
- Cleaning of cabinets and shelves as well as baskets and trays at the surgery department and sterile centre should be done once a month.
- In the hospital patient ward departments, corresponding cleaning must be performed every month. Fixed cleaning routines should be developed.
- Main cleaning should be performed twice a year at the storage rooms in the operation units and the sterile unit and once a year at the hospital departments.
- The space on the top of the cabinet (if there is any) should not be used as storage space.

63.5 Background Information [1–6]

Only sterile medical equipment and clean disposable equipment (also clean outside) should be stored in storage for sterile and clean equipment.

Sterile medical equipment, equipment used in aseptic—sterile—procedures.

- Single-use equipment/items: e.g. wound set, catheter/catheterization kit, urine bag, syringes, needles, intravascular catheterization kits, infusion set, compresses, surgical knife blade, sutures, prosthesis, sterile gloves, etc.
- Multipurpose equipment that is sterilized after each use: e.g. surgical instruments and other sterile equipment.

Clean medical equipment: equipment used for diagnostics and clean procedures.

- *Single-use equipment:* e.g. disposable gloves, disposable tongue pad, patch, Q tips, disposable stasis hose, etc. Equipment directly from manufacturer/sterile centre and clean outside.
- *Multipurpose equipment* that is cleaned/disinfected after each use: e.g. stethoscope, blood pressure device, otoscope, ophthalmoscope, multiple stasis hose, atomizer device (with single-use accessory), blood glucose meter (single-use accessory), oxygen device (disposable accessory), bedpan, urine bottle, etc.
- *Multipurpose equipment that is cleaned/disinfected* after each use must be in its own warehouse.
- *Bedpans, urine bottles and similar* should after cleaning and disinfection be stored in a drying cabinet—in separate storage—not in sterile storage room.

Technical large equipment/aids should be cleaned with soap and water between each use and disinfected after use by infection: crutches, wheelchair, seat cushion and so on. This should be on a separate storage for large equipment and never be placed in clean/sterile stock.

According to the separate country's law on trading; there is, for instance, in Norway "Regulations on Registration and Inspection of Medical Disposable Equipment". All products covered by the Regulations should be registered by the "Disposable Medical Device" in order to be traded.

Disease spread through air, contact and blood-borne infection.

Bacteria and other particles (>0.3 mm) are liberated from persons in varying degrees, depending on the attire and the degree of movement. In sitting position approx. 100,000 particles (mostly skin cells) are liberated per minute, while during movement up to 5,000,000 particles are liberated. The size of these particles allows them to penetrate the packing material, thus leading to contamination of the sterile equipment. Training in microbiology and hygiene is therefore necessary to create attitudes for good quality of handling of sterile equipment/products.

Work in "sterile store rooms" includes strict requirements for hygiene to prevent external contamination of the packaging material. Staff stay in the sterile storage room only as long time as they have work to perform there. Equipment or technical aids contaminated with infectious material should not be taken into storage.

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Medicine Storage and Preparation Room

64

Abstract

The medicine storage room is often the “heart” in the ward since nearly all patients at hospitals receive drugs of different types. Medicines are administered in many ways: tablets, fluids or drops, powders or pills, and a large amount of treatment takes place with intravascular, sterile fluids or intramuscularly. All drugs should have a minimum purity requirement, and all medicaments used in sterile areas (intravascular, intramuscular, sterile cavity, respiratory tract, etc.) must be sterile, prepared and administered. The work in medicine rooms is important concerning sterility, exactness and competence in relation to giving the right patient the right medicine. The medicine room should be a restricted area, only used by well-educated personnel, working with medicaments. An increasing incidence of various infectious agents in hospital patients can lead to contamination and spread of disease unless the staff is careful about drug delivery. The following chapter is focused on practical measures concerning storage, handling, use and control of medicaments in healthcare institutions.

Keywords

Medicine room · Medicines · Handling of medicines · Preparation of medicines · Distribution of medicine · Medicine storage · Medicine cupboards · Parenteral fluids · Cleaning · Disinfection · Infection control · Hygiene · Prevention

64.1 Purpose

- Prevent infections and other complications associated with handling of medicines at the hospital wards.
- Ensure good procedures for storing and handling medication at the ward, and in particular ensure that sterile drug treatment, including extraction/additions to

infusion bags by syringes, is carried out in such a way that the sterility of the product is maintained.

- Avoid single-use vials with medicaments used as multi-dose vials.
-

64.2 Comprise

- All who have access to the medicine room and to handling and distribution of medicines, including sterile drugs and fluids.
 - This includes withdrawals from vial/ampoule, addition to infusion bags, handling of antibiotics/cytostatic agents and control of drug and dose.
 - All who brings medications to the patients and ensures that the right dose is given to the right patient.
-

64.3 Responsibility

The hospital's management has (according to law and regulation) responsibility for ensuring that all clinical departments, outpatient clinics and other centres treating patients have defined, well-equipped and spacious medicine rooms for safe storage and space for the work with medicines. The management shall further ensure that written guidelines are available for the function, control, ventilation and use of the medicine room and for the existence of good procedures for the distribution of medicinal products.

The department management is responsible for ensuring that hygiene guidelines are updated, understood and followed for storage, control work, hygiene, distribution and access to medicines. The management is responsible for reporting errors and deviations to the hospital's management, if these can be linked to functional conditions or lack of competence among staff.

The personnel responsible for patient medication shall ensure that current procedures are followed for permanent safety checks and that good hand hygiene and personal hygiene are carried out.

64.4 Practical Measures [1]

The medical room must be located easily accessible with little walking distance for the staff. Several medicine rooms in the same department may therefore be applicable.

Controlled access work on handling and remedying medicinal products shall be carried out in a sheltered area with access only for persons certified for this work and for relevant cleaning staff.

Area should be large enough for two persons to move simultaneously in the room without contaminating the storage of medicinal products and additional equipment for drug delivery. An area of at least 16 m² is required for a bed ward with

approximately 20 patients. There must be cabinets, large enough workbenches, suction hood, washbasin, medicine trolley, medicine trays, sterile liquids (if not stocked in a separate room), etc., and everything must be stored in a way to minimize contamination.

Floors, walls and ceilings must be of robust, washable material that can withstand disinfectants. Simple entire surfaces and cabinets with glass doors make the room more easily to keep clean.

Washbasins according to the standard should be easily accessible beside the door of the medicine room and be at least 1 m from the drug cabinet and workbenches. Avoid splashes when using the washbasin.

Hand hygiene dispenser at the door.

Workbench should be in solid and light washable material that can withstand disinfectants 2–3 m long.

LAF (laminar airflow) bench (hood) for sterile products. Antibiotics and other sterile products are prepared in the LAF bench with a suction hood. It is important that the air is not recycled to the room due to allergy/sensitization for antibacterial agents and other chemicals.

Fridge for storing medicaments (lockable) must be large enough for the ward's needs and should contain only clean medicaments that have not been in contact with patients, and cleaning should easily be carried out (one time/month). Check temperature once/week.

Cabinets and shelves: Clearly set out and easily washable. Avoid too many open shelves, especially at the floor level as dust collection is not avoidable. Prefer cabinets with glass doors. Mark shelves and cabinets.

Unauthorized items: Shoes, bags, patient medicines or samples, other patient items, food and other equipment should not be stored in the medicine room.

Cleaning, workbench and floor are cleaned daily, shelves once a week, closets and refrigerators once a month and main cleaning twice a year. Check and tidy up. Clean trolleys and trays daily and remember trolley wheels.

64.4.1 Storage of Medicines

- Medicines are stored in a separate lockable room/closet.
- Medicinal products that cannot tolerate storage at room temperature are stored at 2–8 °C in lockable refrigerator. Check the thermometer regularly, once a week.
- Medicines are sorted and placed in transparent, marked shelves in the closet/refrigerator.
- The cabinet should have glass doors for visibility.
- Drugs are discarded when the date of expiration is reached.
- The packaging is kept properly closed after each withdrawal.
- Medications taken out of original packaging *should not* be returned.
- Discarded medicinal products are stored in a closed container and are sent regularly to the pharmacy.

- The medicine/medicine refrigerator is checked, cleaned and washed every month.
- If a satisfactory aseptic working technique and work in a sheltered location, the following general guideline for use after opening of the drug- breaking the seal (when not otherwise stated by the supplier) [1-3], is:
 - Nonpreserved solutions: 24 h after opening.
 - Preserved solutions: 1 month after opening, in a refrigerator

64.4.2 Work with Medicines in Medicine Room: Hygiene Measures

64.4.2.1 Tablets, Powder, Crushing of Tablets and More

- Hand hygiene before and after.
- Clean bench, by washing over with soap and water—and disposable cloth.
- The drug is placed in clean cups with clean spoons. Do not touch directly with hands - the drug.
- When crushed in mortars, use clean equipment and wash in a washing machine at 85 °C.
- The drug tray should be clean and washed at 85 °C once a day (preferably after each medicine round).
- Drug cart with tray is cleaned daily. Remember to clean the wheels of the trolley.

64.4.2.2 Intravenous Fluids/Medications

- Hand hygiene before and after.
- Clean bench—LAF cabinets (see below).
- Rubber stoppers/additives on infusion bags *should always be disinfected* before perforating with a needle. Although the stopper is covered with a capsule, it is *not* sterile.
- It is important that hands are not kept straight over the parts of the product to be protected. This is especially important when withdrawing from ampoules.
- When opening a vial for adding medicament to a sterile bag, the date and time and name of the person who performs the procedure should be written.
- Do not work on at the washbasin when setting up intravenously! There may be splashes of gram-negative rod bacteria that are always present in the sink.

64.4.2.3 Use of LAF Benches

- Hand hygiene before and after.
- Find equipment that should be used and place on a clean bench.
- The LAF bench is no storage. The bench must be empty when not working there.
- The LAF bench should stand on continuously (exhaust). Before using the bench, disinfect all the surfaces inside the LAF bench with 70% alcohol.
- Work with calm movements.
- Work at least 15 cm inside the bench.

- Do not have more equipment than is necessary for the work procedure inside the bench.
- When opening a vial/add to a bag, the date and time and name of the person who performs the procedure should be added.
- After completion of work: Disinfect the bench with 70% alcohol. Any spillage may be wiped/washed away, preferably with soap and water before the bench is disinfected. (Spills, like albumin, cannot be washed with alcohol; soap and water must be used.)

64.4.2.4 Cleaning of LAF Benches

Daily: The bench is disinfected with alcohol 70% before and after use. Eventually spill wipes up. Wash with soap and water over the worktop once a day and when necessary.

Weekly: Once a week, wash the whole bench with soap and water. Wash all surfaces inside the bench. For vertical LAF benches (airflow from roof to bottom), lift up the grate at the bottom of the bench and clean well below this.

Note! Avoid getting water into the HEPA filter (sitting behind the lattice in the ceiling on vertical benches and in the back of the horizontal benches). When the bench is dried, disinfect all surfaces with 70% alcohol.

64.4.2.5 Control of LAF Benches

The benches should be checked regularly (once/year + smoke test every quarter) concerning leakage and air velocity. The department is responsible for checking the LAF bench and changing the filter. If there is doubt if the bench has been checked, contact the pharmaceutical department or technical department. Checks are noted on their own form available in the medicine room.

64.4.3 Handling of Medicine Doses and Distribution to the Patients

Drugs delivered to patients should always be checked by two persons.

Good hand hygiene when distributing drugs!

64.4.3.1 General Routines

- *Each patient should have his own eye drops, mixture, cream, ointment, etc.* The bottle/tube should be labelled with the patient's name and date when opened and placed in the patient's room.
- Opened cans, for instance, of laxantia for common use, should be stored in the drug trolley, and the doses should be portioned just before dispensing to the patient. Put the date on the bottle.
- "Possible drug" (medication used when needed) is taken out of the original packaging immediately before it is given.
- Provide time and calm when handling/dispensing drugs.
- *Always check medicine card when handling drug doses.*

- Medicine doses and patient name should be reviewed of two competent health-care workers.
- Always hand hygiene before and after handling medicines.
- Avoid direct contact with medicines such as tablets, etc.
- Avoid to take medicament trolleys into patient rooms, if possible, and not into rooms with known infections.
- Use disposable equipment, like disposable drug vials and disposable gloves (changed if contact with the patient, biological material, patient-related equipment and the like).
- The patient should be advised to take his/her doses immediately/as soon as possible upon distribution.
- Use teaspoon when the patient needs help to take medications in portions and give the patient plenty to drink. The medicine is taken when the patient has swallowed it.
- Drug doses that are delivered but not taken by the patient should be discarded.

64.4.3.2 Eye Drops, Nose Drops/Spray (Aerosol), Oral Spray

- Medicine bottle is marked with the patient's name, date and when opening the bottle.
- The bottle in use must be kept hygienically safe. Keep in mind that some types of medicines must be stored in the refrigerator!
- For patients with infections (upper respiratory tract/eye), the medicine bottle should be placed on the patient's room. If possible, select single use doses, for example, eye drops, nose drops.
- Hand disinfection before handing to each patient, possibly disposable gloves as well.
- Do not let the medicine bottle come into direct contact with the skin/mucous membranes of the patient.
- Any spills on the bottle should be wiped away immediately with 70% alcohol.
- Hand hygiene afterwards.

64.4.3.3 Cream, Ointment

- The bottle/tube is marked with the patient's name and date of use.
- The bottle/tube should be in the patient room.
- The bottle/tube with expired date must be discarded.
- Hand disinfection before.
- Use gloves by application (lubricate).
- Hand hygiene.

64.4.3.4 Suppositories, Klyster

- Hand disinfection before. Use disposable gloves.
- Place the patient in the correct position and protect the surface from spillage.
- Open the pill/envelope and insert the drug into the rectum/vagina.
- Hand wash.

64.4.4 Inhalation of Drugs

64.4.4.1 Inhalation: Fluids

Equipment: Nebulizer (pari—apparatus, atomizer) with nozzle/mask, air hose, nebulizer cups and disposable gloves. Check that the apparatus has undergone proper cleaning and disinfection [4]. Avoid the patient's own equipment used at home is brought to the hospital without proper cleaning at the centre for medical equipment. Use new, cleaned and disinfected equipment. Patients with inhalation treatment should be treated at single room.

- It is important to know the operating instructions for the devices. Check that the parts of the apparatus are properly connected and check that it is functioning properly. No sharing of devices with others.
- Note the medication glass (inhalation fluid) with the patient's name, date and date of use of the glass or use single-dose vials dispensed to each patient immediately prior to inhalation.
- The nozzle and atomizer cup are washed in a dishwasher (85 °C) after each use.
- Mouthpiece/mask and atomizer vials are washed in a dishwasher and rinsed well once a day. Allow the equipment to air-dry. Parts that can withstand heat up to 100 °C may be boiled 6–10 min in water, daily. The air intake filter and the air hose to the atomizer are changed as needed and between patients.
- Hand hygiene before and use disposable gloves.
- Apply inhalation fluid directly into the vial just prior to use by the patient. Instruct and help the patient to use the device properly.
- Hand wash.

64.4.4.2 Inhalation Aerosol

Equipment: Inhalation Chamber

- Each patient must have his own device.
- Check that the parts (nozzle, flask, valve) are assembled properly. After each use, remove the parts from each other, wash them in water, add detergent and rinse thoroughly. Allow parts to air-dry. Parts that can be heated up to 100 °C: boil 6–10 min in water once a day.
- Hand hygiene and disposable gloves.
- Aerosol doses are inserted into the chamber just prior to inhalation.
- Instruct the patient for inhalation techniques and make sure that the patient is breathing properly.
- Hand wash.

64.4.4.3 Inhalation Powder

Medicinal products in powder form are stored in “Turbuhaler, Diskhaler”.

- Each patient should have his own branded turbohaler/dischaler.
- The devices should be used in the patient's room.

- Get to know the operating instructions.
- Hand hygiene before any use.
- Prepare the drug dose (s).
- Instruct patient for inhalation technique.
- The nozzle is washed with soap and water every time after use, eventually in dishwasher/instrument washing machine for high-temperature equipment.
- Hand wash.

64.4.5 Blood Glucose Measurement and Other Control: Risk of Blood Infection and Other Infection

Check that all equipment is clean and that measuring instruments are disinfected between use. Do not expose equipment for blood or other contamination by placing open cotton swabs, patches, plaster and the likes together with the equipment. Single-use, disposable equipment is not used for multiple patients. Create routines that ensure purity and sterility for each patient. All equipment that comes into contact with wounds and sterile mucous membranes must be sterile. This also applies to cotton swabs and bandages that should be sterile packaged. The blood contamination problem and other infections are increasing, especially related to the sharing of reusable containers, injections and blood glucose measurements [5–13].

64.4.6 Medical Equipment to Be Reused to a New Patient

Ensure that the equipment is cleaned and decontaminated inside and outside in routine use with the patient [4]. Make good practices for this. This is especially important for patients with chronic respiratory disease, dialysis treatment, immunosuppression, infusion treatment and wound care.

Be critical of the purchase of expensive medical equipment that cannot be cleaned inside. Make sure that a new user of medical devices gets clean equipment checked and disinfected, for example, at a centre for treatment of reusable medical equipment.

64.5 Background Information

Nearly all patients at hospitals receive medicines of different types. Medicines are administered in many different ways: tablets, fluids or drops, powders or pills, and a large amount of treatment takes place with parenteral with sterile fluids or intramuscularly. All drugs should have a minimum purity requirement, and all medicaments used in sterile areas (intravascular, intramuscular, sterile cavity, respiratory tract, etc.) must be sterile, prepared and administered. The work in medicine rooms is important concerning sterility, exactness and competence in relation to give the

right patient the right medicine. The medicine room should be a restricted area, only used by well-educated personnel, working with medicaments.

64.5.1 Infections: Transmitted by Medicament Treatment

One out of three hospital patients may have infections/colonisation with possible pathogenic microbes. This may be spread to other patients and to the environment, unless staff is careful about hygienic handling and delivery of, for instance, medicines. Personnel responsible for drug administration should be careful, well informed and have competence in hygiene and infection control when handling and administering drugs. It is crucial that personnel do not spread infections to patients though bad hygiene during drug handling or administration.

- Contaminated drugs with pathogenic microbes are a possible source of infection for patients and staff in direct contact.
- Pathogenic microbes can be transferred from one infected patient to another through the staff's hands and equipment used for the distribution of drug doses.
- Pathogenic microbes can be transferred from an infected patient to the staff by direct contact with, e.g. secretions, blood, sore, faeces, etc. associated with drug administration to the patient.
- Reuse of syringes, tips, lancets, intravenous agents, etc., due to time constraints, lack of knowledge, lack of information and training, savings at the hospital, etc.
- Transport, placement and contamination of medicines on patient rooms.
- Where or how the medicines are store and handled.
- Where and how the individual drug doses are handled.

64.5.2 Factors Increasing Risk of Drug Contamination

- More persons and work operations—from the ordination until the patient receives medication.
- Lack of hygiene (environment, equipment and hand hygiene)
- Time constraint and understaffing
- Delegation to personnel without knowledge and responsibility. An increasing problem
- Lack of knowledge and information. An increasing problem

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Part XII

Internal Service



Cleaning of Rooms in Wards

65

Abstract

Cleaning is increasingly relevant as an important factor to reduce spread of contaminants and infections in hospitals and other healthcare institutions. The burden of contaminants, microbes, organic materials, dirt and dust is significantly reduced by cleanliness. The air quality, working environment and comfort increase for everyone by thorough daily cleaning. In addition, the safety of patients increases when potentially hazardous microbes are being systematically and regularly removed both in bedroom departments and in operating departments. A good cleaning results in less contamination of the personnel's uniforms and thus transmission of infection to other patients. Still, cleaning is underestimated and often inadequate—(also in Norwegian hospitals)—due to savings, efficiency requirements and improper use of expertise and resources. The following chapter is focused on practical measures concerning cleaning and control in healthcare institutions.

Keywords

Cleaning of hospital room · Detergents · Cleaning methods · Frequency · Infection control · Hygiene · Prevention

65.1 Purpose

- Prevent infectious spread in the environment, between patients, personnel, visitors and equipment [1–19].
- Reduce microbes, allergenic particles, organic matter, dirt and other contaminations in the room, areas, surfaces and air.

65.2 Comprise

- All floors, surfaces, furniture, sanitary facilities (sink, toilet, bathroom, etc.) and other room-associated equipment, according to the work list.
-

65.3 Responsibility

The hospital management is responsible (according to law and regulations) to make written routines for general sanitation and hygiene at the hospital and ensure that conditions, expertise and resources are in place for a good, systematic and quality-assured cleaning that reduces burden of infectious environment in a proper manner [20].

The department management is responsible for ensuring that correct procedures for cleaning are instituted at all times in the department and followed up in cooperation with the user, the infection control staff and the corporate health service. The department's management is also responsible for communicating to the hospital's management in case of unreasonable poor cleaning that increases the burden of infection on patients and personnel or otherwise reduces the operation, function and safety of the department.

Cleaner management, in cooperation with the department's management, is responsible for ensuring that cleaning is properly carried out in accordance with written guidelines and focused on good infection protection—at all departments. Regular quality measurements of cleaning should also be carried out.

Each cleaner is responsible for quality well-executed work in accordance with guidelines. Cleaners are also responsible for informing their managers and department managers for lack of cleaning due to lack of resources, expertise and/or personnel.

65.4 Practical Measures

A number of guidelines and routines have been established to improve the cleanliness of hospitals [3, 4, 7, 9, 11–23].

65.4.1 Dressing and Personal Protection of the Cleaner

- Cleaners use the hospital's uniform that is changed daily and when contaminated (see Chap. 6).
- Jewellery, piercing, wristwatches, etc. are not allowed.
- Hand hygiene is always important after cleaning in patient rooms.
- Follow the written procedures for use of personal protective equipment (PPE), both during normal cleaning and according to patient isolation regimes.
- Cleaners should be taught hygiene and infection prevention to protect themselves and others. It is particularly important to have knowledge of infectious diseases,

which are commonly observed in the hospital, such as MRSA, ESBL, tuberculosis, *Clostridium difficile*, norovirus and influenza (see Chaps. 14–21 on isolation routines).

- Cleaning and disinfection should be learned from scratch, as well as the use of PPE and how to handle used cleaning equipment in such situations.
- It is crucial to learn how cleaning is carried out at the different levels of cleanliness to avoid spread of infection via the actual cleaning process, for example, from the toilet to the sink.

65.4.2 Equipment for Cleaning

- Mops and cloths should satisfy the requirements for textiles used in hospitals.
- *Moisture mop*, 100% polyester, and *wet mop* in cotton/polyester [13].
- Washcloths and mops should only be used in one place or one area. Used at several sites can lead to spread of infection [24].
- Soap and detergent used should have a defined bacterial number <100 CFU [25].
- Clean equipment is used for each room.
- After cleaning in room/area, washcloths/mops are sent for wash and disinfection in textile washing machines at temperature >85 °C, following guidelines for handling used textiles.
- Other equipment like the wash stick and bucket are cleaned/disinfected in the decontaminator.
- Cleaning cart is cleaned daily.
- Keep the cleaning equipment in a suitable and separate room.

65.4.3 Methods

Studies show that wet mopping and moisture mopping are the best methods for cleaning floors and surfaces [13].

65.4.3.1 Floor

- Moisture mopping without detergent
- Wet mopping with detergent
- Glossing approx. one time/month
- Floor polish as needed

Note! Whatever method used, stains should always be removed! Dry mopping is not accepted at hospitals due to increased dust swirling from the floor.

65.4.3.2 Fixtures and Surfaces

- Dust cleaning with a moistened cloth.
- It is important that all areas that are often in contact with the patient, visitors and staff are cleaned daily such as keyboards, phone, buttons on TV, switches for

lights and calls, bedside lamps, buttons/keyboard on technical equipment, etc. Here are often large quantities of bacteria deposited [26].

- Wash furniture, chairs, tables, bedside tables, etc.
- Use of vacuum cleaner of fabric furniture, radiators, etc. should be avoided or at least in agreement with the department's management, because of spread of particles in the room. Using a dust filter—hepafilter—is necessary.

65.4.3.3 Sink, Shower, Bathroom and Other Wet Areas

In and around all wet areas (bathroom, washbasin, etc.) in the department, there are growth of gram-negative rod bacteria like *Enterobacter*, *E. coli*, *Klebsiella* and *Pseudomonas* [27]. Wash the cleanest part around the faucet and the sink first and then the faucet and around the drain. The cloth is then put into the bag for washing.

65.4.3.4 Soap

Defined bacterial count is <100 CFU, stated by the manufacturer. Soap should be used directly from the manufacturer's container and stored in such a way that it does not get contaminated. Soap can promote bacterial growth, especially of gram-negative bacteria (*Pseudomonas*, *Enterobacter*, etc.) [25].

65.4.3.5 Inspection and Cleaning Equipment After Use

- *Mops* are only used in one room at a time (one mop for the patient room, one new to the toilet, one new to the shower room, etc.). After use put mops and cloths in a bag for textiles, washed at 85 °C and dried and kept at room temperature. Washed mops can be undried if put in a clean bag, held in a clean refrigerator for up to 24 h and used for wet or moist wash.
- For *bucket* and other equipment that can withstand it, decontaminate after use.
- Wash the *nal* with clean water and soap with a clean cloth and wipe over before leaving.
- *The cleaning cart* is washed with soap and water daily.
- *Storage*. The cleaning equipment is stored in a suitable clean room that is cleaned daily.
- *Polish machines and large floor washing machines* are thoroughly cleaned after use and stored in a dry condition and in a clean room to prevent bacterial growth.

65.4.3.6 Special Cleaning

- Main cleaning: walls, ceiling, floor, fixtures, furniture, closets, etc., with soap and water; minimum once a year, depending on department/ward and patient groups.
- Cleaning of ventilation ducts: minimum once every 5 years or more often for valves and long air ducts and valves through the building. Contact technical department.
- Disinfection of rooms and surfaces (see below).

65.4.4 Regular Cleaning: Routine Cleaning [14–16]

Patient room, treatment room, medical treatment offices, ward office, expedition, conference rooms and corridors on the bed wards. All cleaning programs must be written and checked on a regular basis.

65.4.4.1 Patient Room

- Daily cleaned: 7 days/week (two wet mops, five moisture mops).
- *Note! Thoroughly removal of all stains with soap and water!*
- Daily washing of fixtures, all horizontal surfaces, washbasin and wall around the sink.
- Check soap dispenser, towel and dispenser for hand hygiene products.
- Weekly cleaning of lists, including floor lists and lists for patient curtains, as well as shelves and ceiling lamps.
- Valves for air intake/exhaust are washed at least once a month and more often when needed.
- Curtains are sent to wash once a month and more often when needed.
- *Floor* glossing approx. once a month and polishing when needed.

65.4.4.2 Treatment Room, Doctor's Office w/Patient, Conference Room, Ward Office, Expedition and Medicine Room

- Cleaned 5 days/week (one wet mop, four moisture mops). Simultaneous washing and dust drying of fixtures, horizontal surfaces and sink and wall around the sink. If not in use, wash accordingly. If daily use, washed daily.
- *NB! Thoroughly remove all stains with soap and water!*
- Check the soap, towel and alcohol dispenser!
- *Floor* glossing approx. once a month and polishing when needed.
- Valves for air intake/exhaust are washed outside at least once per month and if required.

65.4.4.3 Corridors on the Bed Ward, and Common Room for Patients

- Cleaned 7 days/week (two wet mops, five moisture mops).
- *NB! Thorough removal of all stains with soap and water!*
- *Floor* glossing approx. once a month and polishing when needed.
- Valves for air intake/exhaust are washed outside at least once per month and if required.
- Note that many corridors are under-ventilated and have a bad smell—often because of the coating of organic matter and microbes that decay. Therefore, good daily cleaning is particularly important here.

65.4.4.4 Ward Kitchen and Common Serving Rooms for Patients

- *Daily wet mopping—7 days a week.*
- Valves for air intake/exhaust are washed outside at least once per month and if required.
- Waste bin emptied twice a day.
- Check the soap, towel and dispenser!

65.4.4.5 Wet Rooms (Disinfection of Washrooms, Waste Disposal, etc.)

- *Daily wet mopping—7 days a week.*
- The housekeeper is responsible for daily cleaning in general on the disinfection and washrooms and other wet rooms, window frames, door handles, table and benches and shower and toilet; wash the outside of the decontaminator and of vertical surfaces around the sink.
- Check the soap, towel and alcohol dispenser!
- All of the loose fixtures and special benches for organic waste, infected equipment, etc. in the disinfection room is the nursing staff often responsible for written agreement.
- Valves for air intake/exhaust are washed outside at least once per month and if required.
- Main cleaning at least once a year and documented. More frequency must be agreed with the supervisor.

65.4.4.6 Shower/Bath Room: Attached to Patient Room

- *Daily wet mopping—7 days a week.*
- Clean the shower, remove the lint and hair from shower, and flush the shower inside with warm water.
- Clean shower chairs and all surfaces, sink, mirrors, etc.
- Check the soap, towel and alcohol dispenser!
- Valves for air intake/exhaust are washed outside at least once per month and if required.
- Main cleaning at least once a year and documented. More frequency must be agreed with the supervisor.

65.4.4.7 Shared Use of Shower/Bathroom for Several Patients

- *As above and in addition.*
- After each user, remove the used textiles, clean the shower/bathroom, wash the shower enclosure, bath and shower chair, wipe up from the floor, and the cranes and mirrors should be clear and clean. There should be good ventilation between the patients.

65.4.4.8 Toilets, Common for Patients and Visitors Entering from Corridors

- *Daily wet mopping; twice every day, 7 days a week.*
- Only “inspection” is not enough because most of the microbes and dirt are invisible! The toilet should be clean and tidy all the day—remember many helpless patients!

- Mirror, shelf, sink and toilet are washed in this order.
- The toilet is washed first from the top to the bottom and inside using the toilet brush. The toilet ring is washed with clean mop—top side first.
- The toilet brush is cleaned regularly in the decontaminator at minimum 85 °C, once a week.
- Silicone around the toilet base prevents urine from flowing under the shelf.
- Valves for air intake/exhaust in the toilet are washed at least once per month and if necessary.
- Waste bin emptied twice a day.
- Check the soap, towel and alcohol dispenser!
- Main cleaning of the rooms: two times per year.

65.4.4.9 Toilet for the Staff at the Bed Ward

- *Daily wet mopping × 7 days a week.*
- Valves for air intake/exhaust are washed outside at least once per month and if required.
- Waste bin emptied twice a day.
- Check the soap, towel and alcohol dispenser!
- Main cleaning of the rooms: two times per year.

65.4.4.10 Offices and Corridors Without Patient Access

- Wet mopping × 1/week.
- Moist mopping × 1/week.
- The corridor, door handles and railings (optionally) are cleaned 1–5 times/week depending on the activity.
- Check the soap, towel and alcohol dispenser!
- Main cleaning once a year.

65.4.4.11 Wardrobe for the Staff with Toilet and Shower

- Cleaning 5–7 days a week, depending on use (two wet mops, five moist mops).
- Check the soap, towel and alcohol dispenser!
- Main cleaning once a year.

65.4.4.12 Elevator

- Daily cleaning of floor, girder and control panel.

65.4.5 Special Cleaning

Room disinfection (disinfection and washing) when needed and in consultation with the responsible nurse. Stains and spots or organic materials are disinfected and removed by nursing staff.

Note! Whatever method, stains should always be removed!

65.4.6 Follow-Up and Control Should Not Be Time-Based

Household leaders should follow up and check cleaning at least once a week. Written check, once/month, is logged and reported to the head of the department in which the cleaning takes place. It is pointless to set minutes, etc. for each surface to be cleaned because time spent does not have anything with the quality to do [28]. The most important is that good technique and knowledge are learned and that the cleaner knows the areas that should be cleaned. Control of cleaning together with the person responsible for the cleaning is a good tool in the training process [7, 12, 13, 19, 21, 26, 29–32]. In some cases it may be appropriate to conduct certain environmental tests [33].

65.4.7 Main Cleaning Is Important

The hospital must carry out main cleaning; wash with soap and water, of all walls, ceilings, valves and air ducts every year. In some departments, main cleaning must be carried out at least twice a year: surgery department, intensive and postoperative departments and departments with patients with reduced infection resistance. In case of major outbreaks in an entire department, main cleaning should be considered after the disinfection process has been completed.

65.5 Background Information

Cleaning is an important factor in reducing the spread of infections and contaminants in hospitals and other healthcare institutions [1–10]. Effective cleaning reduces the load of biological material, dirt and dust—that patients, staff, visitors and equipment are exposed to [2, 3, 5–17]. The air quality, working environment and comfort increase for everyone by thorough daily cleaning. In addition, the safety of patients increases when potentially hazardous microbes are systematically and regularly removed both in bedroom departments and in operating departments [5, 6, 8, 11–13]. Cleaning results in less contamination of the personnel's uniforms and thus reduced transmission to patients [18]. Cleaning is underestimated and often inadequate (also in Norwegian hospitals)—due to savings and improper use of expertise and resources [8, 19].

A significant portion of the pathogenic microbes in the environment is reduced by good cleaning and thereby reduction of cross-contamination between patients via contact- and airborne microbes [11–13, 26]. However, 2 h after good cleaning of the floor, approximately the same bacterial load is present on the floor as before cleaning but now with new bacteria. A patient room that is not well cleaned can become an infection risk for the next patient [19, 34–36]. Need for cleaning varies between types of patients [37]. A good hygiene standard is cost-effective in reducing hospital infections. It is also achievable—in contrary to experience with hand hygiene and prescribing antibacterial agents [2].

Cleanliness leads to better indoor environment, healthier air (less organic material decaying) and better working conditions, is aesthetically important and gives patients and visitors a positive impression of the hospital.

65.5.1 Dust and Dirt Contain a Lot of Skin Flora

Most people release 30,000–60,000 dead skin cells from the body per minute, i.e. more than 500 million a day. This happens from patients, personnel and visitors. Dead skin cells are released continuously as small dust particles around the human body and lie as a trace after everyone in the room—and wherever you go. Dead skin cells are the main ingredient (more than 90%) in house dust and in dust in the patient's room. Approximately 10% of loose skin particles contain bacteria in the order of 5–12 per particle. The largest yield of microbes is found on the forehead, around the ears, the head itself, the upper part of the back, the axillary, the nose opening, etc., with gender variation. Also hair and beard can contain large amounts of microbes. Free skin particles will always be shed to the air from bare skin. Good cleaning of the room reduces the load of organic materials, skin cells and bacteria that come with skin shedding.

65.5.2 Area and Equipment

Floor is always coated with a certain amount of dust, skin cells, particles and microbes. A dust particle can contain 5–15 microbes. The larger the amount, the more swirls up in the air by movement in the room. By bed making, shaking out textiles, and dusting with dry cloth, large amounts of dust particles are released into the air. Generally, this is completely harmless to healthy people. However, it is a risk and source of infection for patients with chronic respiratory diseases, respiratory allergy, wounds or with a reduced immune defence/general condition.

Walls are low carriers of dust but can be contaminated with pus/secretion from patients (MRSA, influenza virus, etc.).

Shelves, racks, rails in ceilings and all horizontal objects carry dust and microbes, regardless of height. Movements in the room like bed making and rapid door openings may swirl bacteria-carrying particles up in the air from shelves, etc. and spread it by air currents (re-aerosol) [38].

Washbasins are always contaminated by bacteria, often with bacterial flora of the patient and the personnel who were last in the living room. Gram-negative bacteria grow well with access to water. Water directly from the tap is generally clean enough to drink if it is run for a while before use. But the opening of the crane is often grown with microbes [39, 40]. Some washbasins spray contaminated water into the air.

Toilet seats are always contaminated by the previous user's microbes. As a rule, this is normal skin microbes and/or intestinal flora. Down in the toilet itself, there is always strong contamination of the intestinal flora. In case of heavy water rinsing, aerosols can be released [41].

Air ducts/canals with air brought to and from the room often become contaminated with dust, fungi, bacteria and particles. Especially around openings of ducts for taking air out of the room, large quantities of dust and dirt are generated.

Call buttons, light switches, telephones, radio, TV service channel, door handle and PC are always contaminated with microbes from last and previous users and can be difficult to clean [42–46].

The shower/bathroom is coated on floors, walls and curtains with skin cells and intestinal flora from the last and previous users if not cleaned between each user. Bacteria and most viruses may withstand water temperatures up to 50–60 °C. Special viruses (norovirus, hepatitis E virus, etc.) and bacteria like enterococci and legionella may withstand higher temperatures.

65.5.3 Microbes

The most common microbes in dust and particles are harmless skin bacteria such as coagulase-negative staphylococci, diphtheroids, etc. and fungi.

Occasionally there are *Staphylococcus aureus*, especially in rooms where such patients are treated, and intestinal bacteria (*E. coli*, other gram-negative bacteria and enterococci). Anaerobic bacteria like *Clostridium difficile* and *Clostridium perfringens* form spores that can survive long in the environment and in the dust.

Lifetime in dust and on surfaces if not removed [47].

<i>S. aureus</i>	3–10 months
MRSA—methicillin-resistant <i>S. aureus</i>	Up to 10 months
<i>Enterococci</i>	2–4 months
<i>Vancomycin-resistant enterococci</i>	2–4 months
<i>Streptococci group A</i>	2–4 months
<i>Mycobacterium tuberculosis (TBC)</i>	12 months
<i>Gram-negative rods</i>	Days–weeks–months
<i>Acinetobacter species</i>	10 months
<i>Clostridium difficile</i> spores	Months–years
<i>Hepatitis B/C/HIV</i>	Days–weeks–months
<i>Norovirus</i>	Days–weeks
<i>Influenzae</i>	2–3 weeks

65.5.4 Causes and Factors Concerning “Poor Cleaning”

Some rooms/wards/departments have a bigger problem with cleaning than others, because of:

- Cracks and unevenness in floors and other surfaces that make cleaning difficult.
- Large amounts of wires on the floor/wall, etc.
- Storage of goods on the floor.

- Floor and wall covering difficult to clean/not suitable for cleaning.
- Too much equipment relative to floor space.
- Not understanding cleaning scheme.
- Changed departmental function.
- Cleaning not adapted to patient category/activity.
- Bacteria-infected wash equipment with dispersion [48, 49].
- Poorly completed washing, disinfection, aerosol formation during cleaning and poor design of the rooms, etc. [50, 51].
- Poor cleansing attracts flies and other insects that can carry potentially pathogenic microbes [52].
- Lack of cleaning personnel—infections increases [53].

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Disinfection of Rooms and Surfaces

66

Abstract

Resistant, virulent and infectious microbes lead to increasing need for disinfection of patient rooms and other areas in hospitals. Outbreaks of resistant and dangerous microbes with spread in health institutions results in that the quality of cleaning and disinfection of the hospital environment are being studied with “argus” eyes. In England, the spread of MRSA in hospitals in 2005 was considered so serious that it was taken up in the Parliament and Prime Minister Blair announced a requirement to halve the MRSA cases at English hospitals. Cleaning and disinfection then gained a significant boost.

The following chapter is focused on practical measures concerning disinfection and control of contaminated rooms in healthcare institutions.

Keywords

Disinfection of rooms and surfaces · Disinfectants · Disinfection methods · Frequency · Infection control · Hygiene · Prevention

66.1 Purpose

- Prevent spread of infectious agents in the environment: between patients, personnel, visitors and equipment [1–4].

66.2 Comprise

- Infectious disease/agents; where room, equipment and environment may be contaminated with human pathogenic infectious agents.

- In case of heavy burden of organic materials in the environment, in patient rooms and other areas and where limitation of possible infection is uncertain.
- After defined infectious disease/agents spread by air, contact, blood, food/water, faeces, etc., according to isolation regimens, including strict insolation. See chapter on isolation.

66.3 Responsibility

The hospital's management is responsible for the existence of written procedures for the proper disinfection of rooms and areas affected by possible contaminants and to provide enough expertise and resources to ensure that patients, personnel or visitors are not unnecessarily exposed to infectious agents [5].

The department manager ensures that disinfection procedures are implemented and understood and determine the time, level and extent of room disinfection. The leader shall also inform the hospital's management—immediately—if the necessary disinfection procedures are not followed due to lack of personnel, expertise or resources for such work. The manager should check that the cleaner follows the guidelines for the use of personal protective equipment (PPE) and disinfectants.

Personnel/cleaners follow routines for disinfection, which disinfectant to be used and areas to be disinfected. Follow procedures for taking on and removing PPE.

66.4 Practical Measures [1–4]

66.4.1 Dressing, Donning Personal Protection Equipment: PPE

The person who performs the disinfection procedure takes on PPE:

- Surgical mask and cap covering hair and ears
- Gown—waterproof with long sleeves and cuffs
- Gloves with cuffs
- Room-bound shoes or shoe covers

Follow the recommendation for PPE as outlined in the hospital's *isolation regimes* (see Chaps. 14–21).

66.4.2 Disinfectants

Follow the hospital's routines for selecting disinfectants for rooms and equipment. The most common agents are chloramine 5%, chloricide, household bleach, “per-asafe” (peracetic acid) or “virkon” (pentapotassium bis). *See disinfection of instruments and equipment* (see Chap. 59).

Disinfection process and handling of washing equipment:

- In case of massive contamination, most of the spill is removed with absorbent material, packaged and treated as hazardous waste in defined, yellow waste bag.
- Suitable disinfectant—chloramine 5%—(or perasafe) is applied on contaminated surfaces (table, shelves, floor, wall and equipment such as lamp, door handle, washbasin, etc.) with cloth or sponge that is thrown away after use as infectious waste. Effect time 60 min. Exit the room during this period, but not before disinfection equipment, etc. is taken care of with regard to infection protection.
- Before taking off PPE—doffing—and before leaving the room: the equipment used, mops, cloths, etc., are packaged and treated as infectious. Mops and cloths used are handled further as infectious –brought directly to the disinfection room, put in a washing machine for mops and cloths at 85 °C and washed separately for 10 min.
- Buckets, etc. are emptied and disinfected in decontaminator in the disinfection room associated with the isolate or packaged and brought—as infected equipment—to the decontaminator in the ward's common disinfection room.
- The disinfection cart is disinfected with the same remedy and left in the room.
- PPE is removed at the exit door or in the sluice; learn how to take off PPE! Gown, cap, surgical mask and gloves are treated as infectious waste.
- Perform good hand hygiene in the end.
- Doors are marked with sign and kept closed during disinfection period (1 h).
- After the disinfection period, the infectious agent is destroyed and regular cleaning can be done.

Ventilation after disinfection of rooms: Patient room and disinfected areas are aired approximately 1 h after cleaning.

Larger areas—many room contaminated and/or much disposable equipment/medical equipment.

Larger areas—like in operation departments, intensive units and wards where many rooms/areas may be contaminated, often with a lot of disposable equipment, medical equipment, etc., gas disinfection with dry hydrogen peroxide gas is recommended, with subsequent regular washing [6–10]. Gas method should not be used in case of tuberculosis or other mycobacteria because of lack of effect [9]. Use of robot gas disinfection saves staff to be exposed to chemical fluids over time [6–8, 10].

Check the effect of gas disinfection with the use of spore tests! See chapter on disinfection of instruments and equipment.

Spot disinfection of spills, stains and other organic materials:

- Spot disinfection prevents the spread of possible contamination and organic material (urine, faeces, vomit, blood, sputum, tissue, pus, etc.) from patients to other patients, personnel, visitors and the environment.
- Spot disinfection consists of disinfecting a restricted area of blood spills and stains of organic materials on floors and other surfaces without being known or defined contagious.

The head of the department determines the extent and type of disinfection. The department's nursing staff carries out the spot disinfection immediately, in connection with the accident. It is only necessary to disinfect the area contaminated with biological material.

66.4.2.1 Indication

Limited blood spills and/or biological material on floors and other surfaces without known infectious disease:

- Spill of blood and other organic material is removed with single-use gloves and absorbent material, packaged and treated as hazardous waste.
- Suitable disinfectant—chloramine 5%—is applied on contaminated surfaces/equipment with a cloth.
- Effect time according to recommended of the disinfectant used.
- Chloramine 5% (household bleach, chloricide):
 - 30 min for dried area (removed spill)
 - 60 min for contaminated, spilled surface and if tuberculosis
- Perasafe:
 - 10 min for dried area
 - 30 min if tuberculosis
- Virkon:
 - 30 min for dried area.
 - Virkon does not have any safe effect on tuberculosis.

66.4.3 Spot Disinfection on a Clean Surface

For spot disinfection on smaller surfaces, door handles, switches, chairs, benches, etc., alcohols, 70–85%, can be used.

66.4.4 Cleaning Personnel on a 24-h Basis

There is an increasing need for disinfection of rooms and equipment in patients with different infectious diseases associated with MRSA, VRE, ESBL and other resistant gram-negative rod bacteria, *Clostridium difficile*, norovirus, rotavirus, influenza, etc. This results in additional burden and additional expenses for the hospital. It is important to have an efficient disinfection and cleaning team that remove contamination as soon as possible on a 24-h basis. This may stop more serious epidemic outbreaks and—at the same time—keep going a rational drift of the hospital.

66.4.5 Understaff of Cleaning Personnel During Periods of Sick Leave, Influenza, Etc.

By reduced staffing concerning cleaning, alternative solutions may be made with respect to prevent infections. Patient-directed cleaning and cleaning in visitor areas must therefore be prioritized.

66.5 Background Information

Outbreaks of resistant and dangerous microbes with spread in health institutions results in that the quality of cleaning and disinfection of the hospital environment are being studied with “argus” eyes. In England, the spread of MRSA in hospitals in 2005 was considered so serious that it was taken up in the Parliament and Prime Minister Blair announced a requirement to halve the MRSA cases at English hospitals. Cleaning and disinfection then gained a significant boost.

Infections and microbial agents follow patients, personnel, visitors and equipment to and from hospitals, between departments and wards and between health levels [11–14]. Many of the most resistant and/or infectious microbes have long lifetime in the environment, are robust and persist for months if they are not removed [15, 16]. Periodically, they colonize or infect patients, personnel and visitors and are carried to new areas where new equipment in new rooms is contaminated. The infection is spread through contact and air by dust and skin particles [17–23].

Before the antibiotic era, it was “good Latin” to reduce infections by good hygiene and pertinent cleaning and use of various disinfectants. Today, it is growing recognition again that cleaning, hygiene, disinfection and infection protection are the cornerstones of combating the most resistant microbes. No new antibiotics have been developed for the last 50 years—except for one antibacterial agent that bacteria now are developing resistance against [6–10, 24, 25].

A number of publications show that resistant microbes can survive in the environment after the leave of an infectious patient—for many months. The next patient may thus be exposed to environmental contamination by, for example, MRSA, VRE or multidrug-resistant gram-negative rods such as *Pseudomonas aeruginosa*, *Acinetobacter baumannii* and ESBL-producing *E. coli* and *Klebsiella* [6, 23–27]. *Clostridium difficile* spores may live forever if not removed. Also, norovirus and influenza viruses can survive for a long time in the environment [16, 27]. Microbes are spread in the environment—transmitted through contact with hands, wash-cloths, mops, etc. and by re-aerosols spread to other surfaces [28–32]. Roommates and the next patients staying in the same room have a clear risk of being infected [18–20, 33].

66.5.1 Disinfection of Rooms and Equipment Is a Special Work for Cleaners

There are many disinfection methods: from heat, heat vapours and chemical liquids to different gases and UVC [8–10, 34–37]. Rooms and larger equipment/surfaces are usually disinfected by chemical fluids and increasingly chemical gases are used. See Chap. 59 for disinfection of instruments and equipment.

Disinfectants must have a sure killer effect against microbes and not just “knocking out” so that they develop resistance to disinfectants [38–40]. Ineffective, “microbe-reducing” disinfectants/detergents in common cleaning are used in many countries. This may promote development of resistance [41–43].

Disinfection process or method is often not working [23]. The method itself can transfer microbes further into the environment if cleaning is not carried out in a hygienically thoroughly manner [21–23, 31, 32, 44]. Specially exposed are all contact points in patient rooms: all equipment used as phones, switches, PCs, bed edges, washbasins, toilet, textiles and multipurpose equipment, various auxiliary equipment such as wheelchairs and armchairs and medical examination equipment like stethoscopes and blood pressure equipment, staff’s personal bags, etc. [45–51].

Cleaners must be specially trained for the work with disinfection methods and also taught in the use of chemical disinfectants and in the use of PPE [3, 4, 52, 53]. Using dedicated disinfection teams, there may be a reduction in, for instance, the spread of *C. difficile* [54].

Gas disinfection In case of larger outbreaks with more rooms and larger areas, there is an increased need of more chemical disinfectants in liquid form that may be difficult to work with. Using a robot disinfectant, gas treatment may save a lot of work and exposure to chemicals and may also save costs through decontaminating paper-wrapped disposable equipment in infected rooms [8, 10, 55]. This method is approved and used in different ways around the world [6, 8–10, 37, 55–59]. It is important that spore test are used to document the killing effect on microbes and to know that gas disinfection has no effect against mycobacteria infection [8–10, 58].

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Abstract

The patient's textiles like bed linen are usually contaminated with skin cells and other body particles and may often contain large amounts of bacteria: 10,000 to over 100 million bacteria per 10 cm² textile. Samples from pyjamas and bed sheets after one night may have high yields of both normal skin bacteria and more pathogenic microbes like MRSA, enterococci and gram-negative rods. This is easily transmitted to the staff's hands and uniforms as well as to the environment and can be routed to other patients and personnel. For every day the patient uses the same bedding, the more the bacteria, skin cells and other particles are present on the laundry. The following chapter is focused on practical measures concerning healthcare textiles, laundry processes and transport and storage of textiles in healthcare institutions.

Keywords

Textiles · Bed linen · Uniforms · Laundry · Cleaning · Infectious textiles · Disinfection · Transport · Storage · Infection control · Hygiene · Prevention

67.1 Purpose

- Remove microbes, body particles, skin cells and dirt from healthcare textiles, bed linen and personnel's uniforms.
- Prevent the transmission of microbes from contaminated textiles to clean textiles, patients, personnel, visitors and the environment [1–12].

67.2 Comprise

All textiles used by patients and personnel and all persons who treat clean and/or contaminated textiles.

67.3 Responsibility

The hospital's management has (according to law and regulation) responsibility for written procedures for the transportation, washing and proper storage of hospital textiles and to provide safe areas for the transport, storage, washing and control of clean and unclean laundry. The management shall ensure expertise, resources and personnel for this work so that neither patients, personnel, visitors nor the environment is unnecessarily exposed to infectious agents [13].

Department management shall ensure that procedures for the treatment of clean, unclean and contaminated textiles are implemented in the daily work. Furthermore, the manager shall arrange for the storage of clean laundry in a clean room and unclean and infected laundry in defined unclean units. It must be ensured that unclean and contaminated textiles are handled and sent for wash in a proper manner to avoid exposure to microbial contamination [13].

Head of textile department and transport manager is responsible for all textile treatment regarding sorting, washing, disinfection, storage and transportation of used and clean clothes. It is important to distinguish clearly between the dirty and the clean side of the textile treatment. The manager should also inform the hospital's management—immediately—if capacity, expertise or resources cause patients, personnel, others and the environment to be exposed unnecessarily to infectious agents due to lack of professional textile treatment.

Personnel at all departments follow procedures for the treatment, storage and transportation of clean and unclean textiles.

NOTE! Remove all non-washable items, used needle tips and other sharp objects before textiles are delivered for washing! Empty your pockets and straighten the laundry!

67.4 Practical Measures

67.4.1 Patient Ward [5, 6]

67.4.1.1 Soiled Textiles in the Ward

- From beds, patients, operating clothes, personal clothing, towels, cloths and other textiles
- Protect the uniform when removing used bedding, for example, by a gown that is sent for wash after use. The uniform may easily be contaminated under such and similar procedures [14–20].

- Careful stripping and disposal of used bedding—avoid dispersion of microbes and particles from textiles to the air, hands, environment and equipment [21–27].
- Note that the mattress, quilt and pillow also may be contaminated [28].
- All loose objects must be removed from the laundry.
- Put used laundry directly in a *clean* bag or plastic bag at the user site.
- Hand hygiene.
- Do not carry unpacked, used laundry from beds, etc. out to the laundry collection point.
- Do not sort used clothes at the department.
- After the laundry bag is strapped, it will be transported as soon as possible.
- Wash the bin with wheels daily.
- Perform hand hygiene after handling laundry.

67.4.1.2 Laundry from Patients with Infection/Carrier State

- Use personal protective equipment (PPE): gloves, surgical mask and cap, gown and possibly room-bound shoes. Note that the patient's room and environment are often heavily contaminated by microbes [29, 30]. Follow the hospital's *isolation regimes*.
- Infectious laundry is textiles from patients with infection/carrier state and textiles contaminated with organic materials like faeces, pus, urine, vomit, blood, etc.
- All loose objects must be removed from the laundry.
- Directly placed in defined (yellow) bag that is strapped again, before transport to the storage room for used laundry. Wet, infectious textiles are put in a separate plastic bag that is then placed in a yellow bag for infections.
- In the isolation unit with sluice (anteroom), collecting bags can be stored until it is almost full. Close and send it to the room for used laundry—in clean bag outside.
- Wash the bag with wheels before leaving the sluice and once a day.
- Perform safe removal of PPE and hand hygiene before leaving the patient room.
- See *isolation regimes*—Chaps. 14–21.

Wash of dirty laundry at the patient ward is not recommended [5, 6].

- Not recommended at hospitals or other health institutions due to infection risk

Wash of patient clothing at the department is not recommended [5, 6].

- Not recommended at hospitals or other health institutions due to infection risk

67.4.1.3 Storage of Used, Dirty Laundry

- Avoid storage of laundry bags at the department—send it for wash as soon as possible.
- During up-filling, the sack is stored on disinfection room/garbage disposal, together with waste bags.

- The storage room should have negative pressure and be cleaned daily.
- There should be good routines for collecting used laundry at the hospital.
- Departments with sluices like operating and intensive units shall have storage rooms for unclean laundry and waste in the transition zone between the department and other units and shall be subject to negative pressure in relation to the department.

67.4.1.4 Transport of Unclean Laundry

- The bags must be solid enough to withstand transport. Plastic bags must be solid, minimum P-5. Nylon and textile bags should be of dense weaved fabric.
- Close tightly before transport, and retighten with metal plastic string about 10 cm from the upper edge or otherwise.
- Avoid the use of person lifts, if possible.
- Trolleys/carts used for laundry transport should not be used for clean transport without proper cleaning. All trolleys are cleaned in special washing machines at 85 °C for 10 min.
- Personnel transporting laundry should afterwards change work clothes and wash their hands well before clean transport.

67.4.1.5 Textile Chute for Unclean Fabrics

- Associated storage room for unclean laundry.
- Textile chute and underlying collection rooms shall have negative pressure.
- The chute should not be designed to cause overpressure in the tube under the bag (piston effect).
- The shutters and door to the collection room shall be airtight and should not be opened at more than one place at the same time (negative pressure).
- The chutes should be metal lined and should be cleaned once a year.
- Storage room under the chute must be provided with locks and washbasins and must be cleaned once a day.
- Location of collection room against outer wall with loading ramp outside.

67.4.1.6 External Transport

- *Clean and unclean transport should not be mixed!*
- Before clean transport, car/trailer cargo area must be thoroughly cleaned with soap and water.
- Trolleys must be cleaned properly in the laundry, damp heat of at least 85 °C and wiped dry before packed with clean textiles for transport to user.
- Return transport of used textiles in trolleys and other packaging must take place in an “unclean” car.
- External transportation assumes that all unclean laundry is well and properly packed. If this is taken cared of, cleaning the car’s load compartment is sufficient.

67.4.2 The Laundry [3–6]

The laundry is responsible for all textiles: from arrival as a laundry and until they are deposited clean and in use in the bed wards. The laundry company, in cooperation with the hospital's management, is responsible for procurement, quality, textile types, ease of use and capacity. There should never be a lack of textiles for patients or personnel. If there are too little/too bad textiles, it could reduce the hospital's activity. Infection protection of patients and personnel is more important than the hospital's goal of savings [13].

The laundry staff should be protected against microbes, high levels of particles, large amounts of organic materials, fungi and chemical agents [13]. It is important to have good training in hygiene and infection control and control of the amount of particles and microbial levels in the laundry, both on the clean and unclean side. The laundry must be checked routinely for ventilation, clean air, daily cleaning and main cleaning once a year,—and particle and chemical load.

67.4.2.1 Do Not Store Textiles Outside!

- Do not put textiles unprotected outside due to the general risk and access to birds and animals!
- Textiles that stand outside will be damaged by prolonged wetting where decay and wet rot easily occur, which will propagate to the laundry and back to the patients! There have been several outbreaks due to water-damaged fabrics with bacterial spores that survive the washing process.

67.4.2.2 Unclean Side: Input and Sorting of Used Laundry

- The inlet section—reception of used laundry—is separate from the laundry itself.
- Here there can be a massive concentration of contaminants.
- An effective vacuum with negative pressure prevents contaminants from this area to penetrate to the clean part of the laundry.

67.4.3 Ordinary Unclean Laundry from the Wards

- Sorting unit for textiles is physically separated from the rest of the laundry with separate room and negative pressure.
- The personnel working on unclean laundry side should not work on a clean side the same day due to the danger of cross-contamination.
- All the staff should have wardrobes and canteen.
- Laundry facilities must have a sluice function. In the sluice there should be cap, shoes, gown, gloves, surgical mask or respiratory protection (tuberculosis and particle load), as well as hand wash and shower.

- If the sluice function is not possible, clean donning should be carried out on the clean side and unclean doffing on the unclean side.
- On the unclean side, there must be a separate toilet and sink.
- When sorting, wear protective clothing, gown, gloves, cap, shoes and surgical mask/respirator.
- Wet-wash the floor daily.

67.4.3.1 Infected Textiles: From Patients with Infection/Carrier State

- Treated in separate rooms with separate ventilation and vacuum.
- Infected textiles are treated separately and carefully by staff wearing their PPE.
- Washed in separate machine; do not sort before washing.
- After washing, the laundry can be sorted for regular washing.
- Eventually wash twice at 85 °C.

67.4.3.2 Sharp Objects and Other Wastes Found in Textiles

- Make registration and feedback to wards, if possible!
- Report accidental injury, and contact the manager.
- Note and evaluate actual vaccinations.

67.4.3.3 Clean Side: Clean Treatment of Clean Laundry

- Overpressure relative to the unclean side: look for doors and windows so the pressure balance is functioning.
- Minimal handling reduces the number of microbes on clean clothes!
- Staff with clinical signs of infections should not handle clean clothes!
- Staff should wear clean uniforms every day.
- Good personal hygiene.
- Good hand hygiene and shower (after work on the dirty side).
- The finished and clean laundry is packed clean on clean trolleys for each department.

67.4.3.4 Washing Process: Textiles

- All textiles (patients and personnel) are washed at >85 °C for 10 min.
- All textiles (patients and personnel) are dried in the tumble dryer at >85 °C for 10 min.

67.4.3.5 Surgical Textiles

- Washed separately.
- Control and packing unit for sterile laundry is separated from clean laundry unit due to particle release.
- After checking and packaging, textiles go for autoclaving.
- Allow everything to be done at the textile supply.

67.4.3.6 Cleaning

- Daily washing of floor and dust drying of work surfaces and table.
- Weekly dust drying of pipe hangers, roof beams and shelves.
- Routine for cleaning machines and internal trolleys.

67.4.3.7 Control

- Control of bacteria in the air (CFU/m^3) on the clean side once a year.
- Check particle amount in the air on the clean and unclean sides to check exhaust/air quality every year.
- Control of positive pressure and negative pressure (clean and unclean sides, once a month).
- Control of cleanliness in the working area (ATP and similar) 1–2 times a year or more often.
- Take samples from 100 cm^2 clean clothes on the clean trolley; 10 random samples/year.

67.4.3.8 Transport of Clean Clothes

- Trolley is cleaned before use and closed.
- Transported from the clean side of the laundry by car or trailer with clean and closed cargo area.
- Purity should be checked 1–2 times a year.

67.4.3.9 Patient Ward: Treatment of Clean Laundry

- Store dry and dust free in separate storage room for clean textiles. Only clean textiles should be stored here.
- Always wash/disinfect hands before entering textile storage room.
- No transit traffic through stores.
- The floor of the textile room is not a storage area.
- Daily cleaning of floors.
- Do not store clean textiles in patient rooms! There is risk of infection to the next patient!
- Textiles from the patient's room must not be returned to clean textile storage. There is risk of infection!

67.4.3.10 Personnel's Uniform

- The work suit must be cleaned every day.
- Wash at 85°C for 10 min and dry at 85°C for 10 min, and should tolerate this.
- Winter clothes for ambulance personnel, etc. must withstand washing at 60°C for at least 20 min.
- Work clothes should not be taken home and washed there. It is not allowed due to infection risk.
- Working clothes are adapted to the working situation.

67.5 Background Information

67.5.1 Risk of Infection

Healthcare textiles are often contaminated with blood, tissues and infectious agents and must therefore be packed, transported and washed hygienically satisfactorily so that no one else is exposed to infection or organic matter [1–10].

Microbes survive on fabrics for hours to days and weeks, depending on which agent it is [1, 2, 10, 14, 16, 22]. It is therefore important to change clothes if contaminated with blood, pus or tissue fluids. Depending on endemic or epidemic situations and the patient categories taken cared of, there may be large amounts of microbes on staff uniforms—such as resistant gram-negative rods, MRSA, VRE, *Clostridium difficile*, norovirus, rotavirus, influenza virus, etc. [14–22, 29, 31]. Problems are often that patients with infection are detected late after admission and may therefore contaminate the environment and other patients before the infection is detected [32].

The patient's textiles are usually contaminated with dead skin cells and other body particles and often contain large amounts of bacteria: 10,000 to over 100 million bacteria per 10 cm² textile [1]. Samples taken from 18 patient's pyjamas and bed sheets who spent one night in a hospital showed in a sampled area of 10 cm² different potentially pathogenic microbes [33]. There was a flora varying from normal flora such as coagulase-negative staphylococci, corynebacteria and *Bacillus* spp. to enterococci (9/18 patients), MRSA (5/18), *E coli*, *Proteus mirabilis* and *Pseudomonas aeruginosa* [33]. The amount of bacteria was in many cases up to 100,000/10 cm² [33]. This is reflected in the staff's hands and uniforms as well as in the environment by the patient's care and examination and can be routed from there to other patients and personnel [1, 10, 34]. The more days the patient uses the same bedding, the more the bacterial load and particle load on the laundry increase [1, 10, 33].

The staff in nursing situation in contact with the patient's bedside, bed sheet, duvet, pillows, etc., have a great chance of acquiring a patient's microbes on the front of their own uniform unless patient-bound gowns are used [10, 14–20]. Therefore, frequent shifts and washing of textiles are very important in health institutions. The number of microbes increases on the uniform for each day it is used, and for this reason, the staff have to change outfits every day and more frequently if contaminated [5, 6]. A high degree of safety is achieved by treating all organic material as potentially infectious.

Note! Personnel working with transport and sorting of dirty textiles are particularly exposed to contamination and organic materials if not handled in a hygienically sound manner!

Note! Avoid grading of “contagious”!

67.5.2 The Washing Process

The washing process should remove dirt and contaminants through prewash, main wash and rinse.

- *Patient/personnel textiles* are heat disinfected through a 10-min wash process at 85 °C and corresponding drying process. Then the textiles are free for ordinary bacteria, viruses and fungi, but not sterile. Spore-forming bacteria such as *Bacillus* and fungal spores can survive the washing process and accompany the textiles further to storage. Such agents have become more relevant as a cause of outbreaks in other countries and may be a challenge for patients with severe immune defences, including premature babies.
- *Other fabrics* like curtains, tablecloths, etc. can be washed at lower temperatures (60 °C).
- *Bedside curtain/cloth on display panel* is sent for washing after each patient; there are often large amounts of patient microbes on these textiles [35].
- *Operation textiles* are specially treated and sterilized.
- *Sterile textiles* are packaged in as special textiles and autoclaved.

67.5.3 All Treatment of Unclean, Dirty Laundry: Separated from the Treatment of Clean Textiles

Unclean laundry is a source of infection in all healthcare institutions. Special bedding and patient textiles are often contaminated with tissue fluids, infectious agents and blood. It is important that unclean laundry such as bed linen, towels, washcloths, patient clothing and personnel work clothes are handled in a hygienically sound manner. Remember hand hygiene since contaminated hands can spread microbes between patients, textiles and other equipment and personal clothing [1, 10, 18, 26, 34].

Most microbes can be airborne by swirling from surfaces and bedding by care and nursing, opening and closing of doors, cleaning, etc. [21–27]. Microbes are easily spread to patient clothes and the staff's uniform. Therefore, gowns are recommended for care and washing of patients. Clothes that are contaminated must be replaced. Personnel involved in transportation and sorting of unclean laundry are particularly exposed to contaminants if the textiles are not secured through hygienic treatment.

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Abstract

Beds are important resources for driftin an effective hospital and should be provided with expertise, resources and personnel. Neither patients, personnel, visitors nor the environment should be exposed to infections from contaminated beds or bed equipment. The following chapter is focused on practical measures concerning patient beds, bed equipment and bed linen and washing, transport and storage in healthcare institutions.

Keywords

Patient beds · Bed linen · Pillows · Mattresses · Quilts · Cleaning · Disinfection · Transport · Storage · Infection control · Hygiene · Prevention

68.1 Purpose

- Prevent transmission of infections between patients or between patient and personnel [1–10].
- Remove microbes, body particles, skin cells and dirt from patient beds, mattresses, pillows and quilts.

68.2 Comprise

- Everyone who work with patient beds and everyone who is washing, transporting and storing beds

68.3 Responsibility

The hospital's management has (according to law and regulation) responsibility for written procedures for the treatment and control of the hospital beds and bedding equipment: that there are good procedures for transport, washing and proper storage of beds when not in use. In addition, satisfactory facilities for bed washing and washing of quilts, pillows and mattresses and maintenance of this shall be provided. There must be clean areas for the storage of clean laundry and for bed linen.

The department management ensures that written procedures for the treatment of clean, unclean and contaminated patient beds are implemented in the daily work. Furthermore, the manager shall ensure that clean and used beds are separated and treated in a proper manner.

Head of the textile department and head of transport service are responsible, respectively, for textile processing and transport as regards textiles and bedding.

Cleaning units are responsible for local or central cleaning of beds.

All personnel who treat patient beds are responsible for ensuring that clean bed is not contaminated by others than the patient and that the unclean bed does not pollute the environment or other patients.

68.4 Practical Measures [5–8]

No isolation regime, no suspected contagion.

There are at least two solutions: with and without access to professional washing systems for beds. Either way, bed linen should be treated with care so that no infection is spread to personnel, patients and the environment.

68.4.1 Used Bed: Cleaning on the Patient Room

- Linen is carefully taken off so that bacteria and dust are not swirled up in the air.
- The bed is washed with soap and water.
- The mattress is wiped off with soapy water and cloth.
- Pillow and duvet that are not visibly contaminated are sent to wash approx. Once per month. Wash at 85°C for 10 min, optionally, in bed washing machine.
- Pillow and duvet that are visibly contaminated are packaged and sent to wash.
- After washing the bed, wash hands before putting on a new bed linen.
- Uniform should be clean when bed-making.
- Clean linen is taken from clean textile store.
- The bed is made ready in a clean room, separate from the laundry room.
- The bed is stored covered by clean cover/plastic—in a clean room.

68.4.2 Used Bed: Cleaning in a Bed Wash Central

- In the patient's room, remove the bed linen carefully so that the bacteria and dust do not swirl up in the air.
- Used bed is carefully transported to the bed central.
- If there is a bed washing machine, use this.
- Pillow and duvet that are not visibly contaminated are sent to wash approx. Once per month (85 °C, 10 min).
- Pillow and duvet that are visibly contaminated are packaged and sent to wash. It is done by the person who strips the bed.
- The bed is washed with soapy water at approx. 60 °C and then dried.
- Mattress is washed the same way and is wiped.
- Flushing should be avoided to protect the personnel and environment against aerosols.
- There must be a careful distinction between clean and unclean sides. Clean beds must not be exposed to splashes from washing of unclean beds.
- The bedmaker's hands and clothes must be clean. The bed is covered with clean cover/plastic and stored on clean rooms that are cleaned daily.
- The transport of clean bed takes place as the transport of other clean goods with hand hygiene and clean outerwear.

68.4.3 Infections and Isolation Regimes

- See isolation regimes for contact-, blood- and airborne infections or strict isolation. The type of infection protection is decided by the management at the section/department.
 - The patient's bed and mattress are disinfected in the patient's room.
 - Duvet and pillow are packaged as contaminated and sent as contaminated laundry.
-

68.5 Background Information

Microbes from a patient can survive for hours or days in bed linen and on the bed itself. Also, duvet, pillow and mattress can be infected as found for methicillin-resistant *S. aureus* (MRSA), *Acinetobacter* and other bacteria [2, 9–12]. Cleaners at Good Hope Hospital in the UK were in 2007 told to not wash sheets and bed linen between patients but to turn them over to save 500,000 £ [12]. There was a significant increase of MRSA cases and doubling of *Clostridium difficile* cases: “Is that all the safety of a patient's life is worth? 0.275 pence?” [12]. Therefore, it is important to clean the bed, bed linen and mattress between each patient.

See also Chap. 67.

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Abstract

Waste is produced in large amounts in hospitals: organic and not organic materials, infectious materials, disposable used equipment, outside packing, etc. It is important that waste is handled, packaged, stored and transported to the destruction place without exposing anybody to infectious materials. Patients, personnel, visitors, people who handle waste and the environment should not be exposed to infections from not well-treated, packed or stored waste. The following chapter is focused on practical measures concerning treatment of waste in hospitals: storage, cleaning and control.

Keywords

Waste · Organic waste · Infectious waste · Waste transport · Waste collection
Waste package · Infection control · Hygiene

69.1 Purpose

Prevent contamination from biological waste to patients, personnel, visitors, the environment and others who treat waste from hospitals [1–7].

69.2 Comprise

- All human biological waste (tissue, organs, blood), including sticking/cutting objects used on patients or in experiments
- All microbiological agents and other contaminants from diagnostic or experimental work
- Anyone who treats, packs, stores and transports waste containing human biological agents

69.3 Responsibility

The hospital's management has (according to law and regulation) responsibility for written procedures for the treatment and control of hospital waste - both infectious and non-infectious. This is the case from the waste is generated, through packaging, storage and transport - until left to municipal or central disposal [6].

The department management is responsible for ensuring that proper procedures for sorting, packaging and storage of waste are carried out.

The defined department treating waste is responsible for the proper sorting and transportation of pre-packaged waste, proper storage and delivery to destruction adapted to the waste and providing feedback to each department by deviation. It must also be verified that the infection protection is being taken care of for each individual who works with waste and that it is carefully distinguished between clean and unclean transport.

Personnel dealing with waste should have the knowledge, expertise and time to implement appropriate personal protective measures, including hand hygiene and personal hygiene, with a change of uniform when needed.

69.4 Practical Measures

69.4.1 Department or Ward: Producer of Waste [3–5]

69.4.1.1 Packing of Waste

Practise good hand hygiene and wear gloves when packing. Avoid spill of waste on the uniform. In case of infectious waste, personal protection equipment—PPE—is used.

All waste is packed and closed securely in the user's place, in thick plastic packaging that withstands the weight of the contents and is completely sealed. The packaging should be clean *outside* when carried to the store room. The outside packaging must always be marked. This first phase is the most important part of the waste treatment.

69.4.1.2 Waste Store Room

This room must be suitable for storage of waste. It should have “wet room quality” and preferably with negative pressure to other rooms. If small amounts of waste or frequent collection, the department's disinfection room can be used.

- Washbasins should be easily accessible, preferably in the waste room.
- Daily cleaning of floor and rubbish racks and main cleaning once a year and when needed.
- Large enough room (usually 10–12 m²) adapted to function, with wet room quality of walls and floors and outlet grating in the floor.

Table 69.1 Problem waste; solutions must be adapted to the hospital's own routines and collectors of waste

Problem waste	Package often used
Wastes from infection patients	Yellow sack/container—robust
Highly soggy bandages	Yellow sack/container—robust
Blood soiled waste	Yellow sack/container—robust
Liquid, liquid-filled waste	Plastic can—solid
Biological materials, organs, placenta, amputation, test materials	Plastic can—solid
Sticking/cutting waste	Box/can with lid
Waste that cannot be compressed	Box/can or risk container ^a
Infusion set with the whole set—complete	Box/can or risk container
Medicinal products	Box/can or risk container
Pleur-vac and other closed vacuum/draining systems	Box or risk container

^aYellow thick plastic bag in cardboard box labelled hazardous waste. Remember, label the outer packages. Hand hygiene is very important after handling waste

69.4.1.3 Waste Sorting [3–5]

- Packaged contaminated waste is placed in thick yellow plastic bag.
- Packed other waste is placed in another thick black plastic bag (or another colour).
- Liquid, liquid-filled waste or larger biological parts of biological material are stored in solid plastic boxes with lid.
- Sticking/cutting waste is placed in solid boxes with lid. Before the jar is full, put the lid well in place, and place it in a yellow plastic bag in a labelled risk box. It is important that sticking/cutting waste is placed directly in a tight container at the user site.
- All waste *that should not be compressed* is placed in a yellow plastic bag in boxes labelled hazardous waste or in a thick plastic bag/plastic cap with lid.
- All outer packaging is marked (Table 69.1).

69.4.2 Transport of Waste

69.4.2.1 Check the Packaging

- Wear gloves and gown when handling waste bags.
- Waste bags are closed properly. Secondarily, package is marked outside.
- Make sure that the packaging is not contaminated outside and that there is no hole. Feedback to the department if packaging/sorting fails.
- Handle the bag so that there is no damage to it during transport.
- During transport, waste bags must be free from contamination on the outside and without risk to the personnel.
- In case of special risk of infection, the department shall report on how the waste is to be handled.

- Avoid the use of person lifts, if possible.
- The waste may be collected in larger movable containers, according to the hospital's routines. The containers are closed with a tight lid after use.
- Infectious wastes (yellow bags/cans/boxes) are placed in a separate container for infectious materials. Close with a tight lid and lock.
- Containers are flushed once a week or more frequently if necessary after defined routines.
- Avoid aerosols/water spray on clothing/face during this procedure.
- Wash hands immediately after transport of waste, also after wearing gloves.
- Change uniform when the waste treatment and transport are completed, especially important if clean work is to be carried out afterwards (e.g. transport of clean equipment, patients, etc.).

69.4.2.2 Cleaning and Control

- All trolleys/carts used for waste transport must be thoroughly cleaned before any clean transport (trolley wash at 85°C for 10 min). Otherwise daily cleaning with soapy water. Wear gloves, surgical mask/cap and gown when washing trolleys and carts used for transportation of waste.
- Personnel transporting waste should afterwards change work clothes and wash hands well before clean transport.
- Infectious accident: follow routines and contact healthcare worker in charge for further treatment.
- Problems with infectious waste: contact responsible department or infection control personnel.

69.4.2.3 Note!

Waste containers should not be standing with lock open outside the buildings!

Containers with infectious waste should always be locked and never be compressed—to avoid leakage of infectious materials!

69.5 Background Information

69.5.1 Infection Risk

1. *General risk of infection.* All human biological waste is defined as potentially infectious and must be treated as such in a general protective manner, e.g. blood, urine, other secretions/excretions and tissues. This waste may contain unknown contaminants.
2. *Known/suspected infectious substance.* In some cases, the infectious agent is known, for example, *Salmonella*, *Shigella*, *Staphylococcus aureus*, *Mycobacterium tuberculosis* and other resistant bacteria and viruses like hepatitis viruses A, B, C, D and E, HIV, influenza virus, norovirus, etc. The contaminated waste comes *directly* from the patient (pus, bandages, blood samples, blood, urine, faeces, vomit, expectorate, tissue, organs, etc.) or *indirectly* through contaminated disposables, textiles and other items placed in infectious waste. It

can also be waste from diagnostic or experimental work with microorganisms and other contaminants.

Both groups, 1 and 2, must be secured with good packaging at the user's place (patient room, operating room, etc.) before the waste is packed in a sack/carton/defined packaging for further transport. Packaging for infectious materials/organic material should be defined in consultation with the hospital's health/environment/safety and infection control personnel, responsible for waste in the municipality.

69.5.1.1 Sorting

Due to the large amount of waste per day, it is important that the waste is already sorted at the user site. Secondary packaging should always be labelled. Infectious waste varies from one department to another. Total hazardous waste accounts for 5–10% of total waste. In many hospitals, this percentage is very high (30–75%).

69.5.1.2 Compression

Waste from the hospital is often voluminous and, for that reason, is often compressed before transport. However, this should not happen with contaminated waste or other hazardous waste. Total waste at somatic hospitals in a city like Oslo (500,000 inhabitants) is estimated to be at 2–5 kg/bed/day, corresponding to 16–42 L/bed/day of non-compressed waste.

69.5.2 Destruction of Human Biological Waste

69.5.2.1 Sewage System: Without Treatment

Large quantities of human biological waste, both with and without various contaminants, go directly untreated out in the common sewer system. The dilution effect and microbiological and chemical degradation eventually destroy the contaminants which, in addition, may have a limited life outside the body. The microbes that adapt to sea and brackish water are usually not very infectious to humans; however, this is dependent on climate and type of microbes.

69.5.2.2 Incinerators

In combustion of human biological material, all contaminants are destroyed. However, a serious disadvantage is the pollution of exhaust gases and smoke during the combustion process and relatively expensive transportation costs. Most packaged waste is incinerated—especially organic materials and infectious waste.

69.5.2.3 Other Heat Inactivation of Waste

Large collecting autoclaves can heat-inactivate 25,000 L or more waste per day. This can be run on regular waste disposal site. Such autoclaves can reduce significantly the amount of waste for combustion. There are a number of *disinfection machines* for heat treatment of waste.

See also Chap. 59 on disinfection.

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Abstract

Hospital patients are highly dependent on a good food control, clean kitchen and clean food.

Practical measures concerning food and other nutrients; cooking processes, serving, transport, storage and control are central in healthcare institutions. The following chapter is focused on kitchen hygiene; practical measures to handle, prepare, cook and serve food and beverages in hospitals in a safe way; and how to treat and wash dishes and cutlers to avoid transfer of infections between patients, personal and environment.

Keywords

Food · Nutrients · Beverages · Cooking · Preparation · Serving · Dish washing · Transport · Storage · Food supply · Control · Water · Hygiene

70.1 Purpose

To prevent transmission of infectious agents via food, other nutrients and beverages to patients and staff [1–5].

70.2 Comprise

- All serving that takes place at the ward, clinic and outpatient clinics, patient hotels and at cafeterias
- Everyone who is offered food and beverages at the hospital: patients, personnel and visitors

70.3 Responsibility

The hospital's management ensures that official, national written requirements for food hygiene, nutrients and handling/serving of food are available and followed [1–6]. In Norway, the Norwegian Food Safety Authority regularly check the hospital regarding the preparation and supply of food, as well as hygiene around the kitchen, ward kitchen and food serving [1–6].

The central kitchen's management and preparation of food follows national guidelines and orders and ensures that patients, personnel, relatives or visitors are not exposed to food contamination [6].

The department management facilitates the serving of food in a hygienically safe manner to the patients. The national guidelines and instructions should be followed by the ward kitchen, which has no admission for visitors or patients.

Everyone who handles food, dishes, etc. must follow the hospital's routines. Personnel responsible for the production and presentation of foodstuffs must not have infections or be carriers of infectious agents [7].

70.4 Practical Measures [8–10]

70.4.1 Personal Hygiene

- Wash hands before and after handling food/serving.
- Use clean uniform, do not use jewellery or piercing, and long hair should be covered/set up.
- Perform hand hygiene before and after helping a patient to eat.
- Wash hands after handling unclean dishes.
- Personnel with gastrointestinal infection should be on sick leave until healthy/no-carrier state (see gastrointestinal infections).
- In case of infections on the hands (herpes simplex, staphylococci, streptococci, etc.), go on sickness leave.
- Small wounds/scrapers must be covered with waterproof plastic (optionally with gloves on the outside).
- Avoid unhygienic habits (contact with the nose, mouth and hair or sneeze over food).
- Do not cough in the bend of the arm or other places on the uniform; use a paper towel and wash your hands afterwards.
- Potted plants and other plants should be removed from the kitchen.

70.4.2 The Patient

- The patient is offered to wash or disinfect hands *before the meal*.
- Ask the patient not to use the phone during the meal as it is often heavily contaminated with microbes (wipe over with a cloth and disinfect afterwards).

- The food is placed on a clean table or bedside table. Make sure the surface of the board is clean. Wash with soap and water if necessary.
- Food is best taken in clean, proper surroundings.
- Offer hand hygiene *after the meal*.
- Do not allow the patient to touch food/drink or equipment/service that others should eat/use.
- Open, self-service buffets where patients and visitors can touch directly the food are *not acceptable!* Everything (slices of bread, cheese, jam, etc.) must be packed separately.

70.4.3 The Food, Nutrient and Beverage [1–5]

- Do not let hot food stand at room temperature over time. Bacteria can grow and form toxins. If the food is not eaten immediately, it should be cooled quickly and warmed up immediately before it is eaten. Keep the food covered. Particularly “bulk food” in large portions is subjected to growth of microbes and toxin production over time when there is a slow cooling (*Clostridium perfringens*, *Bacillus cereus*, *Staphylococcus aureus*).
- Lightly decaying foods must be quickly placed in a refrigerator (never more than 2 h at room temperature).
- Warm food should be kept above 60 °C and the time limit for eating is maximum 2 h.
- The food trolleys should be clean outside and inside when loaded from the central kitchen.
- Food trolleys/cabinets/and dispensers should be checked regularly to ensure that they maintain proper temperatures and are clean.
- The food trolley should be brought to the ward kitchen. It is not allowed to ladle out the food from the food trolley on the corridor.
- All cold foods are stored in the refrigerator at –1 to +4 °C or freezing at –18 °C or colder. Thawing of frozen foods should take place in a refrigerator.
- Food to be served must not be mixed with food that has been served.
- Make sure the food is served in a hygienic and aesthetically satisfactory manner (clean bedside/board, clean surface).
- Do not touch directly on food or on the used parts of the dishes!
- If food is made at the ward kitchen, good hygiene must be carried out. Check the expiration date of the foods. There should be adequate bench space and washing facilities.
- *Do not serve the patients food like unpasteurized cheeses, milk or other foods made from unpasteurized milk or other foods that may—due to food source, production, storage or limited shelf life—contain Listeria or other pathogenic microbes!*
- See the health institution’s official food procedures, where there should always be a list of foods that are *not suitable* for serving patients.
- There must be a log and report on cleaning and temperature control of the refrigerator.

70.4.4 Portion for Microwave/Heating

Portion packs for heating/microwave are treated as easily decaying products and placed in refrigerator at maximum +4 °C until use. When heated, the temperature should exceed 72 °C. The portions are sealed and must be broken first during serving.

70.4.4.1 Food Waste

- Food waste must be handled in a hygienically safe manner.
- In the case of a board serving, food waste must be returned to the central kitchen or processed according to custom routines.
- Infectious waste should be taken care of at the department.
- It must be ensured that the waste does not contaminate other foodstuffs and that it does not bother in other ways (smell, attraction of pests, etc.).
- Local solutions are followed.

70.4.4.2 Infected Patients: How to Treat Food Waste and Dishes—See Isolation Routines

- *Contact-borne agent/blood-borne agent:* Tray/board with food waste after use is treated as infected. Equipment from patient, contaminated with blood/tissue fluids, etc., is heat disinfected (dish, cup, cutlery, tray, etc.) in the decontaminator (decontamination room) before being treated as normal used dishes.
- *Airborne agent/strict isolation:* All equipment is thermal (heat) disinfected in the isolation unit before treatment as regular washing.
- *Heat decontamination:* takes place at a minimum of 85 °C for 10 min (eventual autoclaving when strict isolation).
- *Regular decontaminator* can be used, where another machine is not available. It is assumed that the goods are properly placed (e.g. in the basket) and do not disappear into the machine.

70.4.4.3 Washing of the Dishes, Service Sets, Equipment, Trolleys/Carts/Trays, Etc.

- Dishes and cutlery are washed at the central kitchen in a dishwasher (rinse at 40 °C, wash at 60 °C and steam treat at 85 °C); at least 85 °C for 5 min with final rinsing and at least 85 °C if measured between cutlery/plates. Local solutions.
- Trolleys and steel boxes can be returned to the central kitchen for cleaning. Local solutions.
- Clean and unclean tableware must be treated completely separate, i.e. storage of clean equipment must be well spaced—at least 2 m from the washing area and put in a closed cabinet.
- Avoid open rinsing and prewashing of dishes, etc. which cause aerosol formation. In such cases, washing should be carried out in a separate room—separate from storage of clean equipment.
- Wash hands after touching unclean equipment and before touching clean equipment.

- If the dishes are washed at the ward kitchen (post-kitchen), wash them in a dishwasher with the same temperature requirements as above. The hot water from the tap does not meet the requirement for temperature. This also applies to the kitchen equipment for the staff.
- Remember washing cans, thermo-cans and serving tables on the corridors! This is very important since it is a contact point between patients and visitors with risk of transmitting infections. During outbreaks, serving on corridors in hospitals should be prohibited.

70.4.4.4 Kitchen Hygiene

- Daily cleaning is important: benches, stove and floor.
- Weekly cleaning of drawers, cabinets and refrigerators.
- Use clean cloths and clean towels, and send them for laundry at each shift or more often when needed.
- There should be a separate hand washbasin in the kitchen and preferably a utility sink.
- Coatings on benches and floors should be complete so that cleaning can be effective.
- If used dishes are brought back the kitchen, separate the clean and unclean side carefully.
- Check cleaning of exhaust valves and possibly fan and filter in the exhaust fan every month.
- Cutting machines that cannot be heat-treated are thoroughly cleaned after each use and every day. Afterwards, disinfect with 70% alcohol.
- The microwave must be clean—it loses the effect when dirty. Remember the lid placed over the food tray is put in the dishwasher after each use.
- See separate routines for cleaning of ice machines.
- The dishwasher is cleaned inside each week and temperature control weekly.

Employee food (packed lunches, cakes and the like).

These should be stored in a separate refrigerator and should not be mixed with patient food.

70.4.4.5 Family or Visitor's Food

Visitors who bring food to the patient should not enter the ward kitchen, and the food should not be mixed with the hospital's patient food.

Food traded outside the hospital, for example, directly from a ward or department:

Do not take this to the ward kitchen and do not mix in with the hospital's patient food.

70.4.4.6 Canteens for Patients

- It should always be kept clean and tidy, also at the cafeteria's kitchen.
- It should not be self-service or buffet style.

- Work in the canteen is dependent on good personal hygiene, clean uniform and cap that effectively cover the hair.
- All types of food served must be wrapped in/covered separately to avoid transfer of microbes between patients.

70.4.4.7 Food and Beverages on the Corridor, Living Room, Etc.

- Food services (meals) on the corridor for patients are not hygienically acceptable.
- Juice, hot drinks, water, etc. may be served in periods but should be omitted.
- Cans, etc. are cleaned daily and all equipment is replaced daily.
- Avoid that patients/visitors are touching food that others should eat—separate wrapping of cake, biscuits, etc.
- During outbreaks of gastroenteritis, norovirus or other contagious agents at the department, the corridors are emptied and food/beverages are served directly from the kitchen.

70.4.4.8 Internal Control: Food

Follow the hospital's IC food procedures.

70.5 Background Information

Hospital patients are highly dependent on a good food control, clean kitchen and clean food. Globally very large exchange of food and beverages, and a serious lack of food control, constitutes a high infectious risk, especially for patients and personnel in healthcare.

70.5.1 Food Control, For Example, Norway

Even well-developed and rich countries, like Norway (ca 5 mill inhabitants), have been haunted by many and extensive food- and waterborne epidemics, also in hospitals. Typhoid fever, bacterial dysentery and cholera from food and water were common until the twentieth century and epidemics of streptococci, diphtheria and tuberculosis via unpasteurized milk, ice cream and other foods; milk-borne epidemics were common in the middle of the last century. Contagious jaundice virus (hepatitis A) and poliovirus in food and water were at risk until the 1960s. In Norway, the *Health Act* came in 1860 with local food control, followed by the *Slaughterhouse and Meat Control Act* (1924), the *Food Control Act* (1933) and the *Coordinated Nutrition Control Act* (1978). Good hygiene eliminated most infectious diseases related to nutrition, anchored in health management with *health and integrity* in focus [11].

The *Norwegian Food Safety Authority* (“Statens næringsmiddeltilsyn-SNT”) (1988) was the first control line of public and private enterprises. Accredited laboratories controlled microbiology, resistance patterns, chemical agents, additives,

pests and other indicators of foodstuffs, including water and supervised food producers, serving places and grocery stores. All imported food and beverages were checked. *SNT* was later on (2004) replaced by national food supervision (“Mattilsynet”), responsible for control of food, seafood, animal health and agricultural surveillance. The anchor to the health administration disappeared, and the industry and manufacturers got into the public food control [11, 12]. *Self-declaration and random sampling* were introduced instead of a routine control of all imported food [11]. Lack of control contributed to a variety of food scandals. Antibiotic-resistant bacteria increased in fish, animal and poultry herds and also in animal and fish feed and entered the food production [12–14]. A new type of contagious jaundice (hepatitis E) is spread among pigs and transferred to humans. Blood donors are still not tested for hepatitis E [12].

Today, the Norwegian Food Safety Authority reports annually 1400–1800 food-borne bacterial intestinal infections, infected in Norway, and this is the top of the iceberg. The Authority conducts infection detection at outbreaks and places the preventive responsibility on the manufacturer: “The individual food business that produces or markets food is responsible for ensuring that food is safe and that this is indeed the case. The Norwegian Food Safety Authority is responsible for supervising that food business is in compliance with its obligations” [11].

However, it is impossible to control food producers in other countries. Requirements for training in hygienic and proper animal husbandry have been removed or reduced, also in Norway. This leads to an increased incidence of serious infections among animals such as listeriosis from bad silo feed and other feed. About 50% of animal feed is imported and assessed by the Norwegian Veterinary Institute as “both biological and chemical risk” [12].

70.5.2 Bacteria: Food-Borne [12–28]

Dangerous *E. coli* bacteria (EHEC; entero-haemorrhagic *Escherichia coli*) infected 18 children with 1 death in Norway in 2006 [12, 15]. The source was slicing sausage from Norwegian animal herds. Food control would probably have prevented the outbreak. On May 2014 there was an outbreak of EHEC in England in connection with visits on animal farms, “lamb petting zoo”, and the same is observed in the United States and in Denmark. Infected sprout seed from Egypt, grown in Germany, infected 4000 patients; hence, 900 with haemolytic uremic syndrome (HUS) and 60 died in 2011. The bacterium was in addition antibiotic resistant (ESBL). Import control would have prevented the outbreak [15].

Drug-resistant *E. coli* (ESBL) is detected in Norwegian-produced chickens, as a result of uncontrolled imports.

Salmonella outbreaks from food increase in Norway as in other developed countries. From 2004 to 2013, the National Institutes of Health registered at least 13 outbreaks with more than 420 infected persons. Outbreaks were traced back to imported foodstuffs such as Italian rucola salad, frozen minced meat from Poland, Italian salami sausage, catering company serving food from abroad, Spanish bacon,

alfalfa sprouts with contaminated seeds from abroad and minced meat from Sweden, which came from Danish meat companies [14, 16].

Salmonella was also detected in imported animal feed in 2012, such as soya, meat-bone flour, animal fat and flour and also in fish feedstocks (16 of 827 samples) [13]. *Salmonella* was detected in 2 of 690 investigated chicken flocks [13]. One of 198 samples from fish-contained salmonella was imported from Vietnam [13].

Salmonella diarizonae is found in almost half of samples from sheep [13]. Norway is special globally by the wide spread of this bacterium. *S. diarizonae* is usually detected in reptiles (snakes, lizards and turtles as pets) and in fish, but in Norway, they have come across to sheep. It's not normal either in sheep or humans. In sheep it produces diarrhoea and lamb foetal dead, and in humans it has been registered as increasing cause of severe infection in blood, urine, respiratory tract, etc., in patients with impaired resistance against infections. *S. diarizonae* can be a challenge for young children and patients with immunodeficiency [12, 17].

S. diarizonae is now found in up to 45% of samples from sheep and described as an endemic, under-reported zoonosis in Norway [12, 17]. It is the second most frequent cause of abortion in sheep and can induce diarrhoea in all animals. The spread in the crews must be limited by, among other things, routine control of animals and of imported feeds.

Shigella bacteria imported via fresh sugar peas from Africa started outbreaks of diarrhoea both in Denmark and Norway during spring 2009 and were also registered in other outbreaks [14, 18, 19]. *Shigella* in food products is not registered in Norway.

MRSA in food production comes with uncontrolled import of livestock/animal and foodstuffs and poses a risk of food-transmitted disease in Norway [14]. Pig production in the Netherlands and Denmark is most often infected with MRSA [20–22]. In 2012, animal-associated MRSA (LA-MRSA) was the second most common cause of human disease in Denmark, and in 2013 it completely dominated. In Danish pig farms, 16% were infected with MRSA, 44% infected at the slaughter and 77% of all animals brought to the slaughterhouses [20–22]. It is estimated that at least 30–40% of Danish pork for sale is MRSA-infected, which Norwegian importers now take into account. The infection is also detected in chicken meat and in milk tanks in Denmark, the Netherlands and England [12, 22]. In Denmark, children are warned of “visiting farms” due to infection [20]. Denmark’s food minister launched a five-point plan in the summer of 2014 to reduce MRSA among animals [21]. Norway is moving towards the same development, but all pig farms are negative today concerning MRSA.

Listeriosis [12, 23–28]. The food scandal in Denmark in 2014, where 38 people were infected with listeria bacteria from Danish roll sausage (Deli meat), resulted in 15 deaths [23]. The food control was poor. Caramelized apples led to listeria disease in 32 people in 2014, of which 6 died in 11 states in the United States [24]. In the autumn of 2007, there was an outbreak at a hospital in Oslo (Rikshospitalet) in Norway with a total of 11 patients infected from Norwegian-produced soft cheese. There are still many outbreaks of listeriosis, and particularly vulnerable to this type of infection are patients with impaired resistance to infections, pregnant women and persons with pathological conditions in the intestine (cancer, diverticules, etc.) [25–28].

70.5.3 Virus

The hepatitis E virus (HEV) that infects animals (pig and chicken—zoonosis) is robust with great ability to survive in the environment and can withstand temperatures up to 70 °C for 20 min and 60 °C for 1 h [29]. The virus is closely linked to animal food production and poor animal hygiene.

The hepatitis E virus was rare in Europe. However, from 2009 on, HEV has been widely distributed in pig production in Denmark, Sweden, the Netherlands, Italy (50%) and Spain (40%) [12, 29]. A total of 85% of British pigs are infected while at the same time infecting the population. It is believed that one in ten British sausages and pork meat is infected with the heat-resistant virus [30]. It is therefore now recommended heating for 20 min at 70 °C or higher temperature to destruct the virus [30]. Let the sausage/meat lay for a while after the warming—before eating [30]. The virus that spreads in pigs is also in Norway [12]. HEV is most serious (liver affected) for pregnant women—especially during third trimester—and for people with affected liver or severe immune defences [31].

Widespread HEV infection among pigs, combined with poor kitchen hygiene, increases infection in the population. The Netherlands calculates a HEV-positive blood transfer every day since they do not test blood donors. In Norway HEV infection is present in pig farms; the extent is unknown nor is it tested in blood donors.

Norovirus is associated with contact and airborne transmission and causes outbreaks from contaminated water and food [32–37]. It is resistant to high temperatures and to chemicals, survives up to a year in the environment, has very low infective dose (one to ten virus particles) and gives almost no immunity. A high proportion of the population globally is infected every year.

70.5.4 Parasites

Toxoplasmosis infects half of Norwegian sheep farms and can cause serious infection to animals and humans [38]. The parasite survives drying, salting, smoking and partly freezing and is in a red risk area for humans and domestic animals [38].

70.5.5 Reasons for Spreading Resistant and Dangerous Microbes via Food

- *Lack of hygienic import control and national control.* Animals, feeds, food and other foodstuffs. For the last 10 years, no food has been routinely controlled. When the hygiene control is out, there is often a lower level of hygiene in the production of food [12].
- *Poor hygiene in agriculture and slaughterhouses.* Large-scale drift and robotization lead to major contamination in animal—living areas with production of large amounts of dust-bearing bacteria and with special requirements for good hygiene [12]. The same happens in slaughterhouses and can be followed further

up in the food chain. Infection via milk, milk products and meat products with, for example, salmonella, MRSA, *Listeria* and resistant bacteria is also a fact in Norway. Large animal herds, increased animal density, poor hygiene and trading with livestock and pigs/calves are increasing risks for spread of infection. Antibiotics for animals and fish and growth promoters (pleuromutilin, copper, zinc, etc.) also select for antibiotic resistance in the herd. One third of Norwegian chickens carry antibiotic-resistant bacteria [12].

- *Infectious spread from cattle.* MRSA can be detected in the air up to 150 m from infected cattle and can be spread from colonized animals on pasture with dirt—via air to people passing through the pastures, as recently shown in Pennsylvania. Such contamination creates major problems for the entire animal production with cleaning and disinfection, ventilation systems and the building as a whole. Farmers and families are particularly vulnerable to infection, which in turn can affect the work situation and health.

70.5.6 Measures to Reduce the Rate of Food-Borne Infections

- Establish a solid and effective food control, control of all production units—both domestic and imported. Animals and poultry with MRSA or other serious infections (resistant bacteria, hepatitis E) may not be imported to the country. Visits at farms abroad must lead to a number of preventive measures. Infected flocks must not be able to spread the infection (infection control measures), and infected animals must not be delivered to the open market [12].
- Good hygiene—washing and disinfection and personal protective equipment (PPE) must be used properly. Butchers, veterinarians and production units must be followed up with regular hygiene and infection controls. Good and local animal welfare in spacy and hygienic areas will lead to less infection.
- Kitchen hygiene, including kitchen hygiene at health institutions, must be placed on a higher level than today. The bacteria present on the surface of the meat die by cooking and frying, while the virus usually sits inside the meat and will withstand more heat. Pre-cooked foods should not be contaminated by using the same equipment on raw and cooked foods. Raw and cooked/fried foods should not be mixed. The salad should be washed separately [16]. Good kitchen hygiene includes good hand hygiene, dishwashing with high enough temperature and good cleaning.
- *Better food control* would lift the food control back on a more correct track for *health and integrity* over profit and bad and unhygienic animal care [11, 12].

70.5.7 Nosocomial Infections via Food and Beverages

70.5.7.1 Hospital Microbes

After a day in hospital, the microbial flora in the intestinal tract and in the oral cavity is somewhat displaced by “hospital flora”. It comes with food, water, equipment,

other patients, personnel and the environment around the patient. In most cases this is not important for the patient's hospital stay. However, if the hospital environment is loaded with resistant or virulent (pathogenic) microbes, "hospital microbes" may pose a risk, especially for surgical and intensive patients and in immunosuppressed patients.

Resistant bacteria like gram-negative rods (ESBL), VRE and MRSA can easily be spread into the environment via contaminated food and water. In order to prevent the spread of hospital microbes, it is particularly important with a high level of hygiene concerning serving food and beverages at hospitals.

Intestinal Pathogenic Microbes in Hospitals

- Intestinal pathogenic bacteria, like *Salmonella*, *Shigella*, *Campylobacter*, *Yersinia* and pathogenic strains of *E. coli*, rarely occur as a hospital infection, but may spread in hospitals during lack of infection control [39–41]. The greatest risk may occur outside hospitals, during holidays and travel activity. A total of 75 persons—mostly patients—at a hospital in Southern Norway were infected with *Salmonella infantis*, an outbreak that started from the central kitchen [15]. The workers at the kitchen had recently been for holidays in the South of Europe, got some stomach problems there, but were healthy carriers when returning to job. *S. infantis* was found in food and in the kitchen environment [15].
- *Listeria monocytogenes* is an actual hospital bacterium for special patient groups. *Listeria* is normal flora in animals, associated with contaminated foods such as unpasteurized dairy products and other refrigeration products, cold cuts and fish toppings, grows in the refrigerator and is living in water amoebas, thereby surviving chlorine treatment of water.
- Intestinal pathogenic viruses such as noro-, sapo- and other caliciviruses, as well as rotavirus, are frequently transmitted via contaminated water and food and can be spread by healthy carriers working with food and beverages.
- Hepatitis A can be an epidemic problem, especially if a healthy virus carrier is working in central kitchens.
- Hepatitis E may probably be a new and underestimated virus brought into hospitals via infected food and beverages.
- "Food poisoning" occurs in response to toxins in the food (re-heated food). Good healthcare and kitchen practices today make such episodes rare.
- *Clostridium difficile* often causes antibiotic-associated diarrhoea (colitis) in patients treated with antibacterial agents. The bacterium is a resistant, spore-forming microbe that easily infects other patients. It is the most frequent cause of acute diarrhoea in hospitals. Spores of bacteria may be transferred via salads, other food, beverages, etc.

70.5.8 Spread of Infections

Lack of hygiene control concerning food and beverages may increase the risk of carrier status or infection of resistant and special microbes. This problem is very

relevant for hospital patients. Infection is most often transmitted from a healthy carriers or a person in the recovery phase.

Visitors', relatives' and/or patient's participation in cooking and serving and using "patient refrigerator", ice machines and other kitchen equipment is a risk of infection that is to be avoided. Resistant bacteria may be brought to hospitals via contaminated meat, fish and other foodstuffs—delivered to the central kitchen and post-kitchen at the hospital [42, 43].

Infection from contaminated equipment, dishes and cutlery may occur in case of failure of routines or technical faults on the dishwasher. Temperatures $>85^{\circ}\text{C}$ kill most bacteria, viruses, parasites and fungi, while some microbes survive 75°C [1–5].

Infection via drinking water may cause major epidemic outbreaks. Visibly clear drinking water may contain up to 10,000 bacteria per mL.

Ice machines that never are cleaned, with ice baler that rarely is cleaned and with free access from all users, patients and visitors, constitute a high risk of contamination and growth of bacteria, especially *Pseudomonas aeruginosa* [44–48]. Also parasites and fungi survive here (*Pneumocystis carinii*, *Giardia lamblia*, *Cryptosporidium*). The area around the opening of the machine is easily contaminated. Ice machines, impossible to clean inside, should not be used. The entire interior of ice machines must tolerate disinfection, for example, with chloramine 5% once a week. Ice machines should not be used in case of infectious outbreaks in the department.

1. When purchasing a new type of ice machine, contact the technical department, the kitchen management and infection control personnel. Ice machines may be registered at the technical department. It is recommended to use ice machines with closed systems where no one is in contact with the ice.
2. The machine must be directly connected to a water outlet, no recirculation or backflow in the system. The machine is placed in a clean place in the kitchen.
3. The machine must be easily accessible for cleaning all parts that are in contact with ice water.
4. Daily cleaning in the dishwasher of equipment (cans etc) used to pick up ice. Ensure that this is not contaminated during use. Wash hands before ice is collected. Patients/relatives should not handle the ice machine.
5. Weekly cleaning with soapy water. Rinse with clean water and finally with chloramine; 40 mL of chloramine 5% are added to 5 L of water. Rinse with clean water.
6. Every quarter, a more comprehensive cleaning and inspection of the system should be carried out; refer to the instruction manual for each ice machine registered.
7. Maintenance and inspection should be routinely performed by the technical department and recorded.
8. Patients with severely impaired infection defence should not use ice from the ice machines even if the machine is well controlled and cleaned. They should always use frozen sterile water.

See Chap. 71 on water.

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Water and Water Systems in Hospitals

71

Abstract

Drinking water is generally clean enough for use by healthy people in most countries. However, breakage of sewage pipes into drinking water may happen, or the actual drinking water source may be heavily contaminated by accidents. Floods and natural disasters cause global problems with regard to drinking water; with outbreaks of cholera, other bacteria and hepatitis A and E; and with norovirus and other viral types, protozoans and a variety of other microbiological agents. Legionella has often been linked to outbreaks in healthcare institutions. The following chapter is focused on practical measures concerning water and water systems in hospitals: source, use and control.

Keywords

Water · Water systems · Drinking water · Ice machines · Bacteria · Fungi · Parasites · Hygiene · Infection control

71.1 Purpose

There may still be rather large, waterborne outbreaks on in industrialized countries like Norway, in spite of being a country exceptionally rich on clean water [1–3]. However, water and sewage systems may often be old, damaged by building activities and not well maintained.

- Therefore, it is very important with preventive measures to prevent transfer of microorganisms from water systems at the hospital to patients, personnel, visitors or the environment.

71.2 Comprise

- All water systems for clean water—from water source through hospital intake (piping systems, central hot water units) and for washing (all types), showers, bathrooms, toilets, pools or machines (instrument washers, decontaminators, dishwashers, laundry dishes, autoclaves, machines that are cooled by water, machines for drinking water, ice machines, coffee machines, etc.).
- All wastewater systems—from the sink, shower, bathroom, toilet, etc. through collector's pipes back into the sewer system. Especially older hospitals are exposed to flooding of sewage from old, broken sewage pipes or incorrect treatment of wastewater.
- All patients, personnel, visitors, equipment and environment at the hospital.

71.3 Responsibility

The hospital's management provides written guidelines for water treatment and use and control of water and sewage in the hospital and that patients, personnel and visitors are not exposed to contaminated water [4].

Technical department follows procedures for water treatment and control and reports to the director—immediately—in case of serious risk of infection. Notices from local water authority about contaminated drinking water shall be communicated immediately to the director, infection control unit, chief of the central and ward kitchens and after local agreement.

Property/building department shall ensure water and drainage.

71.4 Practical Measures [1, 5–9] (Tables 71.1 and 71.2)

71.4.1 Aerosol-Producing Devices

“Plumbing systems at hospitals and other healthcare institutions constitute a significant risk of spread of infection. It is therefore important that preventive measures are determined and implemented on the basis of thorough risk assessments” [8].

Table 71.1 Cooling tower: control

Cooling towers	Drain off and cleaning Control of growth and biofilm	Full-year operation: ×2 Part-time operation: ×1
	Disinfection	Risk assessment determines how often the system is disinfected (legionella growth/other growth)
	Monitor and measure inhibitor level	Monthly
	Colony count tests Legionella test	Monthly (weekly with dip slide) + 1 week after cleaning At outbreaks—and preferably once a year

Table 71.2 Water distribution network: control

Internal water distribution network	Shock heating Control of growth and biofilm	Full-year operation: ×2
	Disinfection with chlorine (replacement or addition to shock heat)	Risk assessment
	Water temperature minimum in – Water heater: 65 °C – Regular tap points: 55 °C after 1 min	Monthly
	Colony count test Legionella test	Monthly At outbreaks—and preferably once a year
Shower heads and hose	Clean	Quarterly
Drains rarely in use	Rinse trough with hot water	Weekly

Source: Guidance for the prevention and control of legionella infection. Public Health Institute 2003, updated 2010 and 2013 [7–9]

Legionary disease was discovered in 1976. The disease causes many outbreaks around the world, linked to the cooling tower and to hospitals [1, 5], see Table 71.3. *Legionella* is an environmental bacteria that “survives everything and can withstand everything”—even high temperatures [1, 5–16].

In Norway, few cases have been registered each year, but without preventive measures against legionella growth in the plumbing systems, infection risk is considered to be significant [7–9]. The basis for risk assessments is described [8].

71.4.2 Risks: Especially for Legionella Infection [1, 6]

- Cooling towers and scrubbers or similar are predominating; see Table 71.3 [1, 5–9, 12–28].
- Travel and foreign stays [16, 17, 22].
- Irrigation systems in agriculture, for vegetables, shops and moisture systems for patients [29, 30].
- Electronic sinks, splashes and aerosols around sink and stationary water systems [31–34].
- Failing control of water systems in hospitals [25, 26].
- Window cleaner systems with growth in flushing containers [18].
- Soil, dust and plant products [1, 6].

71.4.3 Internal Water Distribution Network: Citations from Norwegian Water Report 115 [7–9]

- The temperature in the circulation pipes for hot water should be kept constant above 60 °C, and the hot water at all tap points should reach at least 60 °C within 1 min of opening.

Table 71.3 *Legionella* species

Some outbreaks of legionella infections associated with water systems or unknown						
Place		Year	Number	Died	Infection source	Comment
America	USA, Philadelphia, VA	1976	221	34	Cooling tower, hotel	“Veterans” <i>Legionnaires’ disease</i>
	USA, Oklahoma	2004	66		Hotel	Pontiac fever—tourists
	USA, Pennsylvania, VA	2012	21	5	Water distribution	Control failure, hospital Identical to 1976! CDC
	USA, Ohio	2013	35	5	Cooling towers	Nursing homes
	USA, Wisconsin	2013	31		Source unknown	
	USA, Alabama	2014	9	2	Water distribution	Control failure, hospital
	USA, New York City	2015	128	12	Cooling towers	Lack of control, CDC
Europe	Canada, Toronto	2005	127	21	Cooling towers	Institution for elderly
	Canada, Quebec	2012	176	11	Cooling towers	
	United Kingdom, Stafford	1985	175	28	Cooling towers	Hospital
	England, Hereford	2003	26	2	Cooling towers	Cider production
	United Kingdom, Edinburgh	2005	100		Cooling towers?	Wind direction
	United Kingdom, Edinburgh	2012	100	3	Cooling towers?	
	England	2014	1		Birth under water	Home birth
	Spain, Murcia	2001	800	3	Cooling towers	Hospital cooling tower
	Spain, Zaragoza	2004	28	2	Cooling towers	Hospital cooling tower
	Spain, Catalonia	2012	8		Cooling towers	Tourists
	Spain, Catalonia	2013	14		Unknown	
	France, Pas-de-Calais	2004	86	17	Cooling towers	Noroxo factory
	Norway, Stavanger	2001	28	7	Cooling towers	Many passed by
	Norway, Nesodden	2003	10		Whirlpool	“Pontiac fever”
Australia	Norway, Fredrikstad	2005	103	11	Air scrubber, cleaning	Borregaard factory
	Norway, Radiumhospitalet	2013	5	1	Water distribution	Control failure, hospital
	Australia, Melbourne	2000	125	4	Cooling towers	Aquarium
	Australia, Victoria	2013	5	1	Cooling towers	
	Sum		2428	169		
Died				7%		

Source: Promed—mail, [1, 5, 6]

Cooling tower is often associated with outbreaks

- The temperature of the cold water system should not exceed 20 °C.
- Regular or continuous treatment of the hot water system must be carried out.
- Blind pipes should be removed, and if this is not possible, drain valve should be mounted so that regular flushing can be performed. There should also be routines for regular flushing of other slightly used tap points.
- Flushing the shower with water that holds 70 °C, some repeated times each year will prevent legionella growth.
- To prevent growth of legionella bacteria, shower hoses and shower heads should be regularly flushed with water holding at least 70 °C for 5 min.
- A program must be developed for checking the technical facilities, like including temperature recording.
- A program for sampling and analyses of germ numbers and *Legionella* spp. must be prepared [8].

71.4.4 Preventative Measures [1, 5, 6]

- Heat >75 °C (heat resistant). Central hot water heaters should be set at least 75–85 °C to inhibit growth of the microbe.
- Avoid uncontrolled use of the cooling tower. Check that venting from the cooling tower is not drawn into the nearest air intake. Avoid local air cooler/heating systems that can promote the growth of microbes in condensation water and spread it into the room on collected dust particles. Follow routines that prevent such spread (such as cleaning routines).
- Chlorine has good disinfecting effect on bacteria in water. Chloramine 5% disinfectant (less effect if a lot of protein is present). The bacteria are also rapidly killed by 70% alcohol.
- Hot water (>75 °C) for flushing pipes approximately in 30 min is effective.
- Control of water systems, cooling towers, water distribution networks, hot water, humidification systems [30], cleaning systems, showers, baths for birth [27, 28], irrigation systems, etc. All stagnant water, growth inside pipes, biofilms, etc. provide a basis for legionella.
- Colony count test (most often number of coliform bacteria) from defined taps (growth at 36 °C)—preferably monthly to quarterly. The number of bacteria (most often gram-negative rods) should not exceed 100/mL clean drinking water [1, 5, 6].
- At high germ numbers, flush with warm water for 15–30 min. Then check the test.

71.5 Background Information

Drinking water is generally clean enough for use by healthy people in most countries. However, breakage of sewage pipes into drinking water may happen, or the actual drinking water source may be heavily contaminated by other accidents. Floods and natural disasters cause global problems with drinking water, causing

outbreaks of cholera, other bacteria and hepatitis A and E and norovirus and other viral types, protozoans and a variety of other microbiological agents. Legionella has often been linked to outbreaks in health institutions.

There are still large, waterborne outbreaks in industrialized countries like Norway, in spite of being exceptionally rich on clean water [1–3]. However, water and sewage systems may often be old, damaged by building activities and not well maintained. During Christmas 1978, several hundreds were sick of *Shigella sonnei* in two communities in Norway (Brandbu and Røyken) due to contaminated drinking water [1]. In 2000, hundreds of people were infected with *Campylobacter jejuni* via contaminated drinking water in Skjervøy in northern part of Norway [2]. In Bergen 2004, approximately 5000 were infected with *Giardia lamblia* from contaminated drinking water source, hence many with long-lasting effects [3].

71.5.1 Other Waterborne Microbes That May Be Pathogenic

Most gram-negative rod bacteria grow and propagate unharmed in water, such as *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Klebsiella* sp., *Citrobacter*, *Serratia*, *Acinetobacter*, *Burkholderia*, *Stenotrophomonas*, etc [31–43]. In New Delhi, multidrug-resistant gram-negative bacteria are detected in drinking water cisterns—even *Vibrio cholera* with NDM-1 super-resistant gene [34, 43].

In southern parts of Europe, the incidence of mycobacteria in water increases and is associated with infections during surgery and infections among patients with highly impaired infections [44]. Outbreaks may also occur due to improper location, design or use of washbasins, too close to patients, electronic water mixture on too low temperatures and use as sinks for sewage [31–34, 41].

Large collectors under the sink, plumbing traps or “gypsum knee”, where the container is containing sewage that becomes a growth of many types of gram-negative bacteria, are a risk [34, 37, 45].

- A nosocomial outbreak of multiresistant *Enterobacter cloacae* among patients after heart surgery and among leukaemia patients at Tromsø Regional Hospital, Norway, was linked to contaminated plumbing trap of a sink made for collecting used plaster (gypsum) in the operation department (1989) [34, 37, 46].
- Multidrug-resistant *Pseudomonas aeruginosa* in the tap water at the intensive care unit at Akershus University Hospital, Norway, led to several outbreaks and deaths among patients (2002) [38].
- Aerosols generated from a washbasin placed too close to patient's beds caused contamination, colonization and infection with multidrug-resistant *Pseudomonas aeruginosa* [41]. Aerosols with bacteria contaminated the environment at a large distance around the sink (2009) [41].
- A washbasin in an intensive care unit was the reservoir and source for an outbreak of multidrug-resistant *Acinetobacter baumannii*—which also contaminated the entire drainage system (2010) [42].

- For an 18-month period, there were 84 secondary cases of multidrug-resistant *Acinetobacter baumannii* at an intensive department in France (2013) [33]. The outbreak started with two index patients from abroad transferred to the department with *A. baumannii*, which was further spread through the staff's hands, by air, poor hygiene and splash of contaminated water in the sink [33].

Biofilm and heavy growth in water systems, as well as a lot of humus, protect bacteria and keep the growth at the same rate. Persons with severely impaired immunity defence should not drink tap water, and open wounds or urine catheters should not be rinsed in running water!

In hospitals, in addition to regular legionella control, a routine control of water is important for detection of germ numbers (numbers of gram-negative rod bacteria). Water systems with a higher yield of coliform bacteria than 100/mL water should be treated by flushing with hot water.

In case of outbreak of legionella, start tracing of the infection with the cooling tower and “dead ends”—if there exists! [46, 47].

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Technical and Medical Technical Equipment

72

Abstract

Hospitals have large amounts of medical technical and other larger and smaller technical equipment that need routines for cleaning, maintenance and repair. The technical devices may be used in patient rooms, operation departments, laboratories, examination rooms, intensive units, etc. and may be shared by many users and moved between departments and rooms. Microbes usually follow these devices if no hygienic measures are used. Large systems for water and drainage, ventilation, air pressure conditions and heating should be cleaned, maintained, repaired and treated so that patients, personnel, visitors or the environment is not exposed to infection.

Keywords

Technical equipment · Medical technical equipment · Hospital · Water sewage system · Ventilation · Air filtration · Air pressure systems · Room heating Hygiene · Infection control

72.1 Purpose

Protect technical and medical technical personnel, other personnel, patients and visitors against infection from medical and other equipment and against contamination in connection with building and ventilation measures [1, 2].

72.2 Comprise

- All equipment, medical devices and technical installations in direct/indirect contact with human biological material and/or microbes.

- *Medical technical equipment* is defined as any instrument, device, aid, material or any object used to diagnose, monitor, treat or alter the patient's anatomy or physiological process. Laboratory equipment where the answers are used for diagnostics of patients is defined as medical devices.
 - *Other technical equipment* that comes into contact with the blood or other tissues should be *handled in a similar manner*. This also applies to decontaminator, instrument washing machine, dishwashers, other disinfection machines, autoclave, sewage systems, ventilation systems, outlet and extraction systems, etc.
 - Be aware of the possibility of spreading contaminants via pipes, slides over ceilings and ventilation and through elevator, lift shaft and technical routes, by accidental pressure changes and diffusion.
 - Respiratory equipment—see separate Chaps. 29–31.
-

72.3 Responsibility

The hospital's management provides written procedures for the purchase, maintenance, repair and use of technical equipment and medical equipment and for clear and defined hygiene and protection requirements for the equipment [2].

The department's management contacts the infection control unit and medical devices unit *before purchase* for evaluation of hygiene and infection prevention in terms of cleaning and use.

All users requiring maintenance, repair or checking of above-mentioned equipment, either at their own department or sent to the technical department or any other entity, shall ensure that the equipment is properly cleaned and disinfected if necessary—or treated at another secure way.

Departments that have practical responsibility for the maintenance, inspection and repair of technical equipment follow procedures for personal protection and hygiene during supervision, repair, inspection and maintenance of medical devices/equipment and when working with connections of decontaminator and similar equipment to water and drainage.

72.4 Practical Measures [3, 4]

Disinfect equipment as much as possible.

All medical devices must be disinfected before being sent for repair. Those who "own" the equipment and order the work must ensure that the equipment is disinfected or chemically disinfected before it is sent for repair, maintenance and evaluation.

72.4.1 Infected Equipment

If disinfection of the equipment is impossible, this is reported in writing on the equipment. Carefully clean the equipment on the outside and pack it in yellow plastic bag before sending. On the label, set "Infected".

72.4.2 Hand Hygiene

When receiving equipment for repair, hand hygiene is important before and after technical work. Wear gloves where the equipment seems unclean, even if it is cleaned from the sending unit.

72.4.3 Work Attire During Normal Work with Cleaned Machines/Equipment

- Use the hospital's work outfit. Private clothing should not be used due to the risk of infection.
- Work clothes are changed daily.
- Visor/exhaust hood if splash and dust.
- Wear gloves when needed and always when equipment is contaminated. Perform hand hygiene after removing gloves.
- Remove the workwear before leaving the room, during dinner break, etc.
- Do not eat or drink in rooms where technical equipment is repaired.
- Always practice good hand hygiene after leaving the machine/equipment.

72.4.4 Work Attire When Working with Possibly Infected Device

In case of possible infection, work in a separate room or distance from others. Avoid blowing/suction. Consider whether the equipment should be gas disinfected before cleaning and repair.

- Use the hospital's uniform. Private clothes must not be used.
- Learn to take on and off personal protective equipment—PPE!
- Wear surgical mask or respiratory protection, P3 mask, if there is airborne infection or a lot of dust.
- Use cap that covers the hair and ears.
- Use eye protection.
- Wear gloves with long cuff.
- Use gown with long cuffs, waterproof if splashes.
- Exhaust hood if splash and dust.
- Perform hand hygiene after removing gloves.
- Remove the gown and other PPE before leaving the room—treated as infected waste.

72.4.5 Ventilation and Exhaust in Patient Rooms and Service Rooms

If high risk for spread of infection, for instance, when removing hepafilters from exhaust hoods in infectious isolates or laboratories, the infectious agent should be

deactivated in advance. Formaldehyde damp evaporating is often used in the disinfection of exhaustion hoods. Note allergy to formalin!

Also hydrogen peroxide dry gas (“mist”) can be used [1, 5–8]. There are also good systems of hydrogen peroxide gas with higher humidity, but this can corrode instruments more than dry gas, if moisture is not removed immediately [9–12]. Proper guidelines including control of effect should be available for such procedures if used. Contact infection control personnel if questions. *See Chap. 59 on disinfection.*

72.4.6 Work with Aggregates and Channels

When working in aggregate rooms and with channels serving isolates and other risk areas, a negative pressure in the room must be established. It will often be necessary to use a mobile exhaust fan with exhaust to the outside. Protective equipment and written procedures must be followed. Use respiratory protection—P3 mask, hood and gloves, gown/boots/shield/tight glasses. Contact infection control personnel in advance and learn procedures for using infection protection equipment, on and off. *See Chaps. 14–21 on isolation.*

72.4.7 Cleaning of Rooms for Technical Work

- Daily cleaning of benches and floors.
- It is important to have good cleaning in rooms where technical equipment is being worked with because of the infection risk.
- The same cleaning principle in the store room for repaired equipment.
- Main cleaning once a year.
- *See Chap. 65 on cleaning.*

72.4.8 Disinfection of Medical Devices Before Returning

After repair and cleaning of internal technical parts, gas disinfection of the equipment is carried out again. Dry hydrogen peroxide gas 5% has been found to have a good disinfectant effect without destroying metals or other fine-scale equipment [5, 7]. Spore test ensures that the disinfection process has been active. Performed by treatment aids centres or equivalent. NB medical devices used in patients with tuberculosis are discarded [5, 7].

See Chap. 59 on disinfection.

72.4.9 Return of Repaired Equipment

Upon return of repaired equipment, the recipient must ensure proper cleaning and—if necessary—disinfection/sterilization of the equipment before reuse of the unit.

72.5 Background Information

Medical equipment/patient equipment often come in direct or indirect contact with organic materials and contaminants. This results in infection risk. Therefore, the equipment must be cleaned and disinfected in a hygienically acceptable manner after use. The operating instructions of the device must contain cleaning procedures adapted to the equipment and the hospital's routines.

Chemical disinfection (chlorine compounds, glutaraldehyde, perasafe, etc.) is used where instruments and equipment cannot be treated with thermal disinfection or sterilization. Chemical disinfectants in combination with heat are used for flexible endoscopes that have been in contact with mucous membranes, etc. Devices like blood gas analyser should have routines for inactivating (killing), infectious blood agents.

In many cases, the disinfection process cannot be carried out for the internal mechanical structures of equipment, for instance, apparatus using air cooling systems or systems associated with water and drainage or ventilation ducts. In such cases, the device/equipment must be treated as contaminated or, if possible, be treated with gas disinfection, while the device is on—air/gas is pulled through the internal machine parts [5, 7].

It may be appropriate to decontaminate equipment with formaldehyde gas or other gaseous forms such as hydrogen peroxide, chlorine gas, etc. before working, such as laboratory extractors and exhaust ducts from infectious isolates. Gas exposure for patients or personnel must be avoided. See Chap. 59 on disinfection.

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Abstract

Patient test samples are taken and examined at outpatient clinics, in bed posts and at polyclinic consultations and treatment units. They are collected and transported to central laboratories or examined by smaller laboratory units, adapted to the patient group. Samples are sent in pipes or transported by defined methods to the laboratory. A large number of samples are also sent to other hospitals, laboratories or diverse private laboratories.

The following chapter is focused on laboratory safety for patients and personnel to avoid spread of infections between patients, personnel and environment.

Keywords

Laboratory tests · Safety · Blood-borne infections · Sampling · Storage · Transport Control · Hygiene

73.1 Purpose

Protect staff, patients, other persons and the environment against infection [1–10].

73.2 Comprise

- All who work with patient testing, sampling, transport and investigation.
- All who work with further examinations of organic test samples from patients.
- Anyone who otherwise handles organic and/or biological material.

73.3 Responsibility

The hospital's management provides written procedures and resources for proper handling of sample materials and other organic material, and that personnel, patients and visitors are not exposed to infection [1, 2].

The department's management provides for hygienic guidelines and training of personnel and to report to the Director in case of laboratory activities that may expose personnel and patients to infection.

Personnel follow guidelines for personal and general infection protection and report accidents or injuries that expose patients or personnel to infection.

73.4 Practical Measures [11, 12]

Patient samples often pass multiple links, from when they are taken to when they are analysed and destroyed. The entire sampling-packaging-transport-analysis-waste system must be ensured so that patients, personnel, others and the environment are not infected [1, 2, 5, 6].

73.4.1 Sampling from the Patients in the Wards

- The patient should be informed and placed at ease, and there should be peace and quiet during the procedure.
- Personal good hygiene, clean work clothes—not jewellery or personal clothing, and carry out good hand hygiene before and after testing/sampling from patients.
- Wear gloves and gown/surgical mask/shield/cap in case of a risk of splash and spill.
- Perform spot disinfection if spill of organic materials; wear gloves when disinfecting.
- Avoid storing of sampling equipment in patient rooms and do not place the “sampling basket” in the patient’s bed.
- Wash or clean stasis hose, etc. with alcohol between each use.
- Fixed routines for cleaning of sample trolley/sample basket—once per week.
- Do not place the sampling equipment in the textile store or room for sterile equipment!
- In case of infection, the hospital’s isolation regimes and procedures are followed.
- If any questions, contact the responsible head of the ward *before* going to the patient.

73.4.2 Laboratory Work: Personal Infection Protection

- Follow the laboratory procedures and regulations.
- Always wear gloves on contact with biological material.

- It is not allowed to eat, drink or smoke in the laboratory! Mouth piping is forbidden!
- Hand hygiene after use of gloves/contact with biological agent.
- Hand hygiene before leaving the laboratory and before food break.
- Change clothes if contaminated with biological material, new outfits every day.
- Do not eat in the same clothes as you work in, eventually use an “eating/pause gown” over laboratory clothes.
- Do not pour biological material from pipes or glasses; use pipette.
- Avoid spills and splashes! Think about what you do and work calmly!
- If spills, splashes and aerosols of biological material are expected/risk:
 - Work in a separate exhaust hood with gloves and gown
 - Or if exhaust hood is not present, work with gloves, surgical mask/cap, eye protection and single-use gown in a separate room with negative pressure.
- Carefully follow the instructions for routine cleaning of equipment.
- Avoid equipment where blood must be wiped away manually between each sample!
- If such equipment is still in use, protect hands with gloves, practise good hygiene and use eventually surgical mask/cap/eye protection (risk of aerosols).
- Provide instructions placed on safety benches, doors of rooms with higher risk of infection, centrifuges, etc.
- All equipment must be disinfected regularly. Make routines for this.
- All equipment must be disinfected before repairs. If this cannot be done, it must follow the guidelines for handling/personal protection during repair.

73.4.3 Workplace Functions in Laboratory

The laboratory should be spacious with proper placement of doors, exhaustion hoods and other major equipment in relation to ventilation requirements and working procedures.

- *Reception for samples* with registration and distribution of samples must be adapted to a level of hygiene that also takes care of unknown infection.
- *Division of samples* into separate tubes/glasses, by opening primary samples, should take place under the exhaustion hood/shield with gloves, gown and optional surgical mask/cap.

Note: Special treatment of rare types of risk samples, special microbes (Biosafety Laboratory 3–4).

Regular laboratory with good control over procedures must meet the following requirements:

- Hand wash and hand disinfection on all sections.
- Note! There should be *hot water* in the wash basin! At tapping, the temperature should reach 75 °C to avoid biofilm formation and growth of legionella and gram-negative environmental microbes.

- Good distance, at least 2 m between each workplace to avoid cross-infection (aerosol).
- Benches shall be easily washable and withstand disinfectants like 5% chloramine.
- Centrifuges should be in separate technical rooms, separate from regular laboratory work to prevent accidents (aerosol). Alternatively, place in exhaustion hood with negative pressure and at a good distance from workplace.
- Washing centrifuges should be treated in the same way.
- All fixtures must be washable and withstand disinfectants such as chloramine, including chairs. Textile-covered chairs are not suitable for laboratories.
- *Wastewater* from laboratory analysers should be treated as infected waste.

Risk laboratories/rooms where the risk of infection is greater than elsewhere (aerosol-forming procedures, known infection, work with specific pathogenic viruses or bacteria, autopsy, etc.).

- Limited access, interlocking doors that open the right way and with clear warning sign on the door.
- Negative air pressure with pressure gauge (25–70 pascal) and controlled airflow against separate extract via hepafilter/UVC/electrostatic filter.
- A separate decontamination system and autoclave for the destruction of contaminated waste and water/liquids, if necessary.
- Sluice function with the possibility of high-level personal protective equipment and a decontamination unit after work in the laboratory.
- Dedicated personnel, trained in and understanding the importance of high-risk mitigation and infection protection.

Service room with disinfection room, autoclave room, waste room, laundry room, clean storage, storage for samples, media, and other equipment; toilet, shower and washbasins, office, rest room, etc. must be carefully planned for each laboratory.

Note! Carefully separate between unclean and clean areas in the laboratories using sluice systems or corridors.

Technical rooms are planned for technical equipment such as robots and centrifuges.

Waste room Human biological material and/or contaminants/microbes must be handled as potentially infectious. It can be disinfected or autoclaved at the laboratory before it is disposed of as ordinary waste. Particularly contaminated waste (e.g. from microbiological laboratory) must be destroyed before it leaves the section/department.

- Handwash in the waste room.
- The waste room must be under negative pressure and there should be floor drain for cleaning.
- Infectious waste should not be compressed if it has not been disinfected beforehand.

73.4.4 Cleaning in Laboratories

- Benches are washed daily with soap and water. Organic material is removed first with spot disinfection.
- Chloramine 5% has a good effect against viruses, fungi, bacteria and spores.
- Floors are washed daily in laboratories that are in daily use, as well as toilets. Waste of organic material is removed immediately by the person who is soiling on the floor; spot disinfection.
- Equipment, etc. should not stand on the floor, preventing cleaning.
- Sampling carts and similar equipment are cleaned daily.
- See chapter on room cleaning.

73.4.5 Spot Disinfection

It is usually only necessary to disinfect the area contaminated with biological material.

1. Spilled blood and other organic materials are removed using gloves and absorbent material. It is packaged and treated as hazardous waste.
2. Suitable disinfectant—like chloramine 5%—is applied on contaminated surfaces/equipment with cloth or sponge.
Acting time:
 - 30 min (dried surface)
 - 60 min (dirty surface)

73.4.6 Transport of Biological/Organic Samples

Transport pipes should not be used in case of high risk of infection. There must be a negative air pressure in the system. Routines for cleaning of transport containers should be implemented; cleaned in a decontaminator once a week or more frequently if contaminated/spill. All paper material should be replaced. The transportation system should be gas disinfected once a year or more often if contaminated.

Manual transport should be performed with packaged sample material in containers that are cleaned in a decontaminator once a week. Samples should stand upright—opening up—during transport.

See Chap. 74 on transport of samples.

73.4.7 Accidents with Samples: Blood or Tissue

Accidents occur most often in connection with centrifugation, tube/glass opening, test tube crushing and sampling and procedures that may cause spills/stab wound/cut.

- Immediate action: see *accidents with blood—or tissue*
- Registration, corporate health service
- Accident registration for the laboratory for measures:
 - New equipment due to less risk
 - New work procedures to reduce risk

73.4.8 Prophylactic Measures for Specialty Laboratories

Local routines and guidelines should be made for each laboratory specialty (microbiology, pathology, clinical chemistry, blood bank, immunology, medical genetic).

73.5 Background Information

All biological material is considered to be potentially infectious and should be treated as such [1, 2, 5, 6].

Laboratory infections are well known.

- A survey of 4079 people infected at work at microbiological laboratories showed that 168 died of infection [13]. Dominant agents were *Brucella* sp., Q fever, hepatitis, typhoid fever, tularemia and tuberculosis [13].
- In an English survey of 24,000 laboratory workers, 45 were infected with *Shigella* sp., 38 with hepatitis, 21 with tuberculosis and 1 with brucellosis [14].
- In 2012, a laboratory outbreak with a fatal course of meningococcal meningitis was reported in San Francisco [15]. This type of infection is rare today. Globally, in the period 1985–2001, 16 laboratories reported infections with *Neisseria meningitidis*, half of which were fatal.
- HIV and hepatitis C are newer microbes that represent a clear risk for laboratory personnel, as well as resistant mycobacteria. The SARS virus has been documented to have infected laboratory personnel, as well as *Sabia virus* and other high-pathogenic viruses despite alleged use of protective equipment. Current agents are also prions—*infectious, resistant protein molecules*.
- By 2015, 309 laboratory infections were published in 47 reports worldwide—reviewed by a group in Belgium [16]. Infections with *Salmonella* dominated; 42%, followed by *Brucella*; 40%, *Neisseria meningitidis* 4%, vaccinia virus 4%, *Francisella tularensis* 2%, Ebola and Marburg virus 2%, *E. coli* (O157: H7) 1%, *Mycobacterium* sp. 1%, *S. aureus* 1%, *Bacillus anthracis* and *Bacillus cereus* 1%, *Burkholderia pseudomallei* and *B. mallei* 1%, *Clostridium difficile* 1%, West Nile virus 1%, *Chlamydia psittaci* <1%, cowpox <1%, dengue virus <1%, leptospirosis <1%, SARS <1% and *Shigella sonnei* <1% [16].
 - The infection routes recorded in this material were 46% inhalation, 28% parenteral inoculation—cut injuries—20% oral infection and only 6% contact infection [16].

- The main reason for infection was lack of compliance 73% (did not follow routines) and indifference/lack of knowledge 2%.
- Bio-accidents were the cause of 24% of cases, hence technical error 8% and human error 93% [16].
- Laboratory infections are usually highly under-reported as they often cause mild symptoms [16].
- The study also showed that the staff perceived that accidents were associated with lack of experience, insufficient training, excessive workload, lack of knowledge about work risk, distraction in work and lack of respect for personal protection [16].

73.5.1 Risk of Infection

The accident hazards in laboratories are many, especially because *aerosols* are easy to generate in laboratory work [16–19]. Drop of bottles, agar plates with microbes, etc. have been investigated and generally show significant formation of aerosols [19]. It is well known that in the case of blood spills, most of it will be invisible aerosols or splashes [18]. This is important because bacteria, viruses and fungi can penetrate the mucous membranes of the upper respiratory tract and conjunctivae.

Risk work depends on the material and what to investigate. By “known” infection status, the personnel are most often carefully following preventive guidelines. If “unknown” infection status, it is easier to break the routines for personal preventive measures if no good general precautions are taken.

Risk situations are procedures that are especially known to cause infection to personnel.

- Sampling
- Opening of tubes/containers
- Distribution of samples
- Analyses of blood samples
- Work with blood cultures
- Resistance determination of microbes
- Aerosol-forming procedures (centrifugation, splash on distribution of samples, resistance studies, splash and stabbing at sampling, etc.) [16–19].

73.5.2 Spread of Infection

- Contact: direct, indirect, and contact with drops that fall onto the surface/equipment/textiles.
- Airborne: “dust”, droplets (particles <10 µm), droplet nuclei and microscopic drops of blood, microbes and tissues. This is probably the most frequent and dangerous infection in the laboratory [16–19].
- Inoculation/puncture/stab: transmission of blood/tissue from one person to another; direct or indirect via contaminated equipment, etc.

73.5.3 Safety/Security Cabinet

In case of known or suspected risk of infection, and in the case of possible aerosol-forming procedures, the laboratory work should be carried out in safety cabinet class I–III. Glass cabinet is often better and easier to keep clean than plastic. The location of the cabinet in the room is important, not too close to the door or to exterior wall.

Class I with hepafilter is a clean cabinet and provides good personal protection if the air extractor works satisfactorily. Hepafilter protects the exhaust duct from contaminants.

Class II with hepafilter and recirculated air in the cabinet provides good personal protection and also protection for the material in the cabinet (cell cultures, etc.).

Class III with hepafilter for intake and exhaustion of air and work through gloves connected to cabinet provides maximum protection. Used only at risk laboratories at particularly hazardous agents to public infections (Ebola, Lassa, Marburgvirus mm.). The cabinet is heavy to work in and requires training/competence.

73.5.4 Infection from High-Risk Laboratories

There have been a number of—probably more than 200 “leaks”—infectious agents from high-risk laboratories both in the United States and in Europe. In the United States, a congressional hearing was done in 2014 after a laboratory accident with anthrax, smallpox and a fatal bird flu virus. During the period 2008–2012, there were more than 1000 laboratory accidents in the United States—Involving bacteria, viruses and toxins that could pose a bioterror threat to the population. In 2012, CDC documented 727 unfortunate laboratory events and 11 laboratory infections, including theft of microbiological agents.

In summer 2014, it was at Tulane Primate Research Center in Louisiana that laboratory studies were made for vaccine production on the highly virulent bacterium *Burkholderia pseudomallei*—first and foremost present in Australia and Asia [20, 21]. During the autumn 2014, it was discovered that four monkeys located outside the complex and far from the laboratory and not involved in the project were infected with this bacterium. At the same time, a man who was to investigate the cause of the spread of infection in the laboratory was infected [20].

In July 2014, CDC closed high-risk laboratories after accidents with bird flu virus and anthrax spores that were not inactivated before shipment to other laboratories [22]. There were more than 100 people exposed to infection, but no one became ill.

73.5.5 Transport and Shipment Risk

There is a very large shipment of human biological material and microbes in most countries in the world. Accidents can happen here as well. A Canada post office car crashed during transport between laboratories with samples containing among others anthrax, *E. coli*, *Salmonella*, tubercle bacteria and influenza virus [23].

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Abstract

In hospitals, there is a busy transport activity between departments of equipment, technical instruments, textiles, food and beverages, patient samples, waste, etc. This activity may spread infectious diseases between wards and departments if not taken care of by good hygienic methods. The following chapter is focused on transport of clean equipment, food and other clean items, contaminated equipment and other goods, and patient samples.

Keywords

Transport in hospitals · Clean and unclean equipment · Goods · Food and beverages · Patient samples

74.1 Purpose

Protect staff, patients, other persons and the environment against infection.

74.2 Comprise

All who work with transport in hospitals of clean or unclean equipment and goods, food and beverages, patient samples, other organic materials and waste.

74.3 Responsibility

The hospital's management provides written procedures and resources for proper handling and transport of clean or unclean equipment and other goods, food and beverages, patient samples and other organic materials and waste, and that personnel, patients and visitors are not exposed to infection.

The department responsible for all internal transport at the hospital provides hygienic guidelines and training and control of personnel and reports to the Director in case of activities that may expose personnel or patients to infection.

Personnel follow guidelines for general infection protection, and report accidents or injuries that may expose patients or personnel to infection.

74.4 Practical Measures [1, 2]

74.4.1 Clean Equipment, Food and Other Clean Goods

- Perform hand hygiene and wear clean clothes.
- Check that the transport equipment is clean before transport.
- Check that clean goods are well covered with clean packaging.
- Do not transport clean and unclean goods together.
- Place clean goods as directed by the recipient but never in unclean rooms as a waste room or disinfection room.

74.4.2 Used, Unclean Equipment

- Used medical equipment, aids, etc.
- Used equipment to be transported must be cleaned/disinfected outside of the department before transport.
- Protection (gloves, etc.) during transport is not necessary if the equipment is cleaned.
- Wash hands well after finishing the transport.

74.4.3 Patient Samples

From the department/ward to different laboratories:

- The patient sample (tube, box, etc.) shall be clean *outside* and marked during transport.
- The sample must be transported in containers that can be cleaned with common disinfectants.
- Use disposable gloves when placing the sample in containers.
- Remove the glove and close the container.
- Carefully transport the sample to the receiver.
- Routines for cleaning and disinfection of transport containers are followed at the laboratory.

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Ambulances, Emergency Medical Service (EMS) and Other Transports of Patients

75

Abstract

Ambulance personnel are often the first healthcare personnel who meet and take care of the patient in different situations outside the hospital. Patients may have unknown or known infections or carrier states like MRSA, other resistant microbes, blood-borne viruses or respiratory infections. Most often the infection status is not known. During epidemics of influenza or noroviruses, for example, the transport in ambulances may be challenging, concerning infection control. Very seldom, there may be questions about special dangerous infectious agents. Acute patient treatment during transport to hospitals, often require use of sterile or disinfected equipment. Good hygienic routines during work in ambulances are very important to prevent transmission of infections between patients and personnel. During the last 10–15 years, a number of guidelines have been provided for emergency medicines and other transports of patients with infection—both on land and in the air. The following chapter is focused on emergency and transport safety for patients and personnel to avoid transmittance of infections between patients, personnel and environment.

Keywords

Emergency medical service · EMS · Ambulances · Safety · Patient transport
Infection control · Hygiene

75.1 Purpose

To avoid transmission of infections between patients and personnel during emergency medical service, transport/treatment and care [1–15].

75.2 Comprise

All personnel involved in emergency medicine/transport system related to the hospital and patients treated in ambulances and other transport systems.

75.3 Responsibility

The hospital's management provides written procedures for hygiene and safety during transportation and emergency medical treatment [15]. Competent personnel and necessary resources for infection protection must be available.

The management of ambulances/emergency medicine/transport follows procedures for infection control, competence and quality, so that personnel, patients or the environment are not exposed unnecessary to infection [15]. The Director of the hospital is immediately informed if patients, personnel or others may be at risk of infection during this activity.

The management of clinical departments/outpatient clinics/nursing homes/healthcare centres, etc. shall provide information to ambulance personnel concerning patients with/suspected infections and infection control procedures and special measures to protect patients with increased susceptibility to infections.

Everyone involved in the emergency medicine/patient transport system follows guidelines and is educated in hygiene and infection control.

75.4 Practical Measures [11, 12, 14]

(“Transport” here is meant emergency medical treatment/ambulances-car-flight-boat/patient transport.)

75.4.1 Ambulance Station, Other Locations and Service

- The ambulance station must have a laundry and decontamination area. Chemical disinfectants in liquid and in gas form should be used, if necessary [16–18].
- There should be separate, clean stores for textiles, sterile equipment, clean equipment and decontamination—and washing facilities for instruments—and access to packing and sterilization of instruments.
- Larger medical-technical equipment (ECG, heart starter, ventilator, etc.) that may extract dust and microbes from the ambulance's coupe is routinely sent to the medical-technical treatment centre for cleaning and disinfection of internal parts.

- Ward office must be clean. All floors and other surfaces in common areas, restrooms and toilet must be washed daily.
- Washing of work clothes and textiles should be carried out professionally as a routine at the hospital's textile department or at the approved laundry. Work clothes are changed after each shift or more frequently if contaminated, and there must be enough work clothes to ensure that this is carried out safely. *See textiles.*

75.4.2 General Infection Control Measures

- Hand hygiene before and after transporting/treating a patient.
- Working clothes should be clean, possibly clean gown outside of other work clothes.
- Transport of patients shall not present a risk to the person who treats the patient in the ambulance.
- All health units/levels should report infection risk when the ambulance is ordered.
- External ambulance transports are ordered via emergency centrals/transport/ambulance, etc., or otherwise in the local system.
- Avoid large storage of clean equipment and textiles in the ambulances, etc., which collect dust and microbes from patients and personnel in the ambulance.
- *Patient with (suspected) respiratory tract infection:* put a surgical mask on the patient and mask/cap on yourself.
- *Biological materials:* always wear single-use gloves when in contact with biological material, including injections, IV treatment and the like.
- *Respiratory system/intubation/suction:* use surgical mask/eye protection/cap/gloves, and change the gown/dress/uniform afterwards.
- *Trauma/acute wound treatment/stop bleeding, etc.:* use surgical mask/eye protection/cap/gloves and change the gown/dress/uniform afterwards.
- *Much spill of biological material during transport:* cover the patient (not head) with clean cloth/blanket, etc., as far as this does not inhibit observation and therapy!

75.4.3 Risk of Infection During Emergency Treatment

- Follow routines for using personal protection equipment and for safe donning and doffing.
- *Risk of infection:* the person who arranges the transport must be informed of any person who is exposed to and suspected for or has symptoms of infection. Follow the hospital's guidelines for transport, according to isolation regimes. See Chap. 47 on early measures to prevent spread of infections.

- Transport of patients with *increased susceptibility to infections* (placement of bed/stretcher, contact with other patients, etc.); follow current guidelines and notify to the ambulance unit. See Chap. 20 on protective isolation.
- Ambulance personnel/emergency medical personnel with severe respiratory tract infection, gastroenteritis or wounds on their hands, or other possible infectious diseases that can easily be transmitted, should not be in close contact with patients and clean goods. See Chap. 8 on personal hygiene and infection control.

75.4.4 Internal Transport Within the Hospital

Transporting the patient in bed and wheelchair, following and supporting a patient for examination or treatment, etc.:

- Hand hygiene before transport begins.
- The uniform must be clean. The work clothes often come into contact with the patient when lifting and other help.
- In case of infection, infection control measures should be informed by the responsible nurse at the patient's department/ward (see below).
- In case of protective isolation, the infection protection regime must be informed from the patient's department/ward.

75.4.5 External Transport Between Hospital Buildings

Transport of the patient in a stretcher, wheelchair or car; follow and support a patient for examinations, transfer to another department, treatment, etc.:

- Thoroughly clean the transport car—at least one time per week—and disinfect after transport of the patient with infection. Clean the wheelchair and stretcher before and after each transport.
- Do not use the patient transport car for transportation of unclean goods. If this is still necessary, wash the car thoroughly with soap and water before patient transport.
- When transporting an infected patient, the requester must provide the infection prevention regime to be used. The car is disinfected and washed inside after the transport of the patient with infection/potential infection according to the infection regime given by the department (see below).
- In case of protective isolation, the infection protection regime must be stated from the patient's department.

75.4.6 Ambulance, External Transport: Outside Hospital

Transport to and from the hospital in an ambulance stretcher, wheelchair or regular seat:

- The car is thoroughly cleaned with soap and water once a week.
- The car is disinfected and cleaned thoroughly after each transport in case of suspected infection.
- Depending on the amount of organic material spilled, such as blood, vomiting, etc., spot disinfection or complete disinfection and cleaning are performed (see below).
- When transporting an infected patient, the requester must provide the infection regime to be used. The car is disinfected inside after transport according to the infection regime specified by the department (see below).
- The infection regime may vary according to patient handling and activity.
- In case of protective isolation, the infection protection regime must be stated from the patient's department.

75.4.7 Ordinary Cleaning Routines of the Ambulance

75.4.7.1 Between Each Patient Transported on Stretcher

- The bed sheets, pillowcases and duvet covers are changed, and the stretcher cover/mattress is washed with soap and water.
- Carpet without cover is sent to wash after each use. Store in a clean room/bag before reuse.
- Pillows/duvets that are soiled by blood and tissue secretion and excretion are sent to the laundry. Keep it clean in the storage afterwards.
- The chair that the patient or staff has used is washed with soap and water (damp cloth) between each use.
- All medical equipment, laryngoscopes, etc., which have been used are sent for disinfection and/or sterilization. Clean equipment is placed in a clean suitcase/unit.
- Disinfect stethoscopes, blood pressure equipment and other items that have been used for the patient.
- Used equipment is placed in a separate unit—do not return in the medicine box together with clean equipment.
- Medical equipment that extracts air from the ambulance unit must be wiped over external parts and transmitted to disinfection of internal parts upon infection. *See Chap. 59 on disinfection of instruments and clean equipment.*
- The equipment/touch points of the patient during transport are washed with soap and water (damp cloth) on the surface, possibly disinfected.
- Disinfectant containers are disinfected outside if used several times (or single-use devices discarded afterwards are recommended).
- Waste containers are disposed as contaminated after each use.
- If work clothes are contaminated, change this before the next transport.
- Spill of small amounts of biological materials may be spot disinfected.

75.4.7.2 Routine Every Day

- Floors and fixtures in the ambulance are washed daily.
- Check the medication box for cleanliness, wipe over with a damp cloth and refill.
- Clean equipment is filled up.

75.4.7.3 Weekly

- Wash the entire ambulance outside and inside with soap and water.
- Medicine container and other containers for equipment are washed inside and outside, and equipment is being controlled.
- All wall-mounted equipment is washed with soap and water.
- Check that infection control equipment is available in the ambulance.
- Set up a wash and disinfection list with date.

75.4.7.4 Monthly

- All cabinets and drawers are cleaned and washed in addition to weekly wash.

75.4.8 Disinfection of the Ambulance

After transport of a patient with possible or defined infection:

- Wash hands thoroughly.
- Remove personal protective equipment (PPE) (surgical mask/cap/eye protection/gown and gloves) according to the defined isolation routine used.
- Learn to undress PPE without contaminating yourself or the environment.
- Change to clean uniform (clean gown/dress) and wash your hands again.

Follow isolation regimes. Depending on the degree of infection (spill, splash) and type of infection (contact, airborne, etc.), the car is thoroughly disinfected and cleaned.

- Contact transmission: spot disinfection or complete disinfection (spray, aerosols).
- Blood-borne pathogens: spot disinfections or complete disinfection (spray, aerosols).
- Airborne transmission: wash with soap and water and wipe over with 70% (+) alcohol.
- Strict isolation (high risk): complete disinfection and wash afterwards with soap and water. Contact infection control personnel for information.

75.4.8.1 Disinfection of the Car's Transport Compartment

Responsibility: the head of the department decides the level and extent of disinfection and the means to be used. *See also isolation regimes Chaps. 14–21.*

Procedure: the person who performs the disinfection procedure takes on:

- Surgical mask/eye protection/cap
- Shoe covers/special shoes/boots
- Gown/waterproof/coveralls
- Gloves with long cuff

1. In case of massive contamination, most of the stain is removed with absorbent material, packaged and treated as hazardous waste in yellow solid waste bag. A suitable disinfectant—chloramine 5%—is applied on contaminated surfaces/equipment with a cloth or sponge. Work time 60 min. Close the door. PeraSafe can also be used, working time 30 min.
2. Equipment used, cloths, etc. are packaged and treated as infectious.
3. Buckets, etc. are emptied and disinfected in the decontaminator in the disinfection room.
4. Stretcher is disinfected with the same agent.
5. Protective clothing is removed and packaged/treated as infectious.
6. At the end of the disinfection period, the contaminant is removed, and regular cleaning can be done.
7. The door is open for ventilation.

75.4.8.2 Spot Disinfection

- Limited blood spills and stains of biological material on the car's floor and other surfaces without known infectious hazard.
 - Personnel who transport the patient carry out the spot disinfection immediately/as soon as possible in connection with the accident. It is only necessary to disinfect the area contaminated with biological material.
1. Spilled blood and other organic materials are removed with gloves and absorbent material, packaged and treated as hazardous waste.
 2. A suitable disinfectant—chloramine 5%—is applied on contaminated surfaces/equipment with a cloth or sponge.
 3. Acting—30 min (dried surface) or 60 min (dirty surface).

75.4.8.3 Gas-Mist Disinfection

Chemical gas disinfection of the ambulance before ordinary cleaning is a good disinfection method after transport of patient with a suspected or defined airborne infection, but not used with suspected tuberculosis or other mycobacteria [10, 16–18]. The use of a dry gas/mist of hydrogen peroxide 5% is effective and may be tolerated by corrosion-sensitive equipment [10, 16–18]. The process is defined in cycles, and spore test is used for control of effect on microbes. During the disinfection period, medical-technical instruments may be run to draw the gas through and

disinfect the inner parts of the instruments [16–18]. All openings may be closed, and the disinfection may be done in a separate room. Concentration of the gas is recorded. Personnel is not entering the room before the concentration is 1 ppm or lower [16–18].

75.5 Background Information

Ambulance personnel are often the first healthcare personnel who meet and take care of the patient in different situations outside the hospital. Patient may have unknown or known infections or carrier states like MRSA, other resistant microbes, blood-borne viruses or respiratory infections. Most often the infection status is unknown [1–3]. Epidemics of influenza or noroviruses, for example, may be challenging concerning infection control during transport in ambulances. Very seldom, there may be questions about very dangerous infectious agents [4–9].

Organic material and microbes may easily be spread during transport/treatment in the small compartments of the ambulances, especially during a rapid and turbulent transport. Acute treatment during ambulance transport in high speed is a demanding work that may expose personnel and patients to infection if no infection protection is carried out [1–9]. Increasing incidence of dangerous microbes means that knowledge, expertise and resources must be on top [19–24]. Staff must be able to efficiently and easily carry out personal protection with appropriate equipment and ensure that ambulances, instruments and medical devices are cleaned in a proper and regular manner [2–12].

Transport of patient with possible infection

Type of infection (regime)	Infectious agents/disease	Personnel attire
Contact	All gastroenteritis (diarrhoea /vomiting)	H FM
	Hepatitis A (contagious jaundice)	HF
	Skin and wound infections, moderate secretion	HK FK
	Gram-negative rod bacteria with abundant secretion from respiratory tract or wound	HK FK
	Untreated scab and lice	HF
	Other diseases that are spread by contact (e.g. tuberculosis in the intestines, urinary tract or fistula)	HF
Blood	HIV/AIDS uncomplicated	HK
	Hepatitis	HK FK
	<i>Malaria falciparum</i> , <i>Brucella</i> , yellow fever	HK FK

Type of infection (regime)	Infectious agents/disease	Personnel attire
Air borne	Pneumonia caused by <i>Staphylococcus aureus</i>	M
	Influenza, respiratory infection	M
	Systemic infection with meningococci, <i>Haemophilus influenzae</i> , pneumococci first 24 h after treatment starts (meningitis or septicaemia)	HFM
	MRSA (recently or during the past year)	HFM
	Import patient (from healthcare outside country)	HFM
	Other multidrug-resistant bacteria	HFM
	Widespread wounds, a lot of blood spills	HFM
	Widespread wound, skin infections—uncontrolled secretion	HFM
	<i>Suspected</i> infectious pulmonary tuberculosis	HFÅLS
	<i>Known infection</i> – Multidrug-resistant tuberculosis bacteria or—highly infectious tuberculosis with open cavity and expectoration (first 14 days after initiation of treatment, by resistance—longer time). Note: In case of suspicion, contact infection medicine/hospital hygiene/microbiologist <i>before</i> the transport	H FXÅLS
Strict isolation	Rare diseases (diphtheria, rabies, pest, anthrax, viral haemorrhagic fever, Ebola) Note: In case of suspicion <i>before</i> transport, contact infection medicine/hospital hygiene/microbiologist	Infection protection bag

H gloves, *HK* gloves on contact with the patient

F gown/coverall with hood, *FK* gown/coverall on contact with the patient

M surgical mask, *L* cap, *S* boot cover/special cover

FX bacterial/viral—impermeable/tight gown or coverall with hood

Å respiratory protection P3 (tight mask with hepafilter), or portable respirator (see also “Respiratory protection” Chap. 13, and “Isolation” Chaps. 14–21)

Infection protection bag (for two or more persons): respiratory protection P3 and bacterial/viral impermeable gown, tight goggles, shoe cover and gloves. Instructions for doffing after use are enclosed. This bag should be in preparedness, only used after consultation with departments of infectious disease/infection control/microbiologist. See strict isolation Chap. 19

Patient transport *internally* in hospitals—to and from—and *between* hospitals and other institutions increases and can pose a risk of spread of infections [19]. Ambulances may be infected with microbiological agents such as MRSA in *endemic* areas with high levels of MRSA, as shown in England [20]. Among the 21 ambulances tested for MRSA in June 2006, 10 were MRSA positive. In one ambulance, the steering wheel was MRSA positive, and the rest of the positive MRSA samples were found in the patient compartment around handles, etc. [20] A number of other microbes can also live long in the ambulance environment [22–24].

The ambulance coupé is small and narrow and poorly ventilated. The patient comes in close contact with the equipment and personnel when lifting and handling the stretcher or bed.

When arriving at the hospital, the placement of patients in the waiting area must be well planned for both suspected infected patients and patients especially susceptible to infection. Personnel transporting patients should obtain information about current measures.

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Part XIII

Hospitals: Areal and Function



Hospital Buildings—Construction Projects

76

Abstract

The development of more advanced medicine and breaking new borders in treatment of serious illnesses may involve poorer and more helpless patients in the hospitals. They will need more personal help with everything and are more bed-ridden and exposed to infections. Those who are in a better shape will probably be day-treatment patients at the hospital, staying at patient hotels, nursing homes, other homes or at home. The future probably also leads to more resistant and contagious microbes and less effect of antimicrobial agents. Therefore, the hospital buildings, construction, outfit, design and maintenance, are very central elements in the management of modern hospitals with increasing risk of transmitting nosocomial infections. New hospitals, buildings, rebuilding, changed functions and logistic solutions may be well planned and considered thoroughly. Special focus may be placed on effective infection control measures like enough patient beds, single patient rooms and service rooms, design and quality of furniture and the implementation of effective, safe and good hygiene.

Keywords

Hospital buildings · New and rebuilding · Function · Construction · Design Capacity · Logistics · Maintenance · Nosocomial infections · Infection control Hygiene

76.1 Purpose

Prevent hospital infections by ensuring key infection-preventive principles when building new hospitals, upgrading hospital buildings/areas and rebuilding hospital units for other medical use.

76.2 Comprise

- Infection control competence and local user representations should be included in all plans and implementation of new buildings and changes in use at hospitals.
 - This includes current plan solutions, logistics and building quality, aiming at a satisfactory user-friendliness and fulfilments of hygiene requirements and of protection for employees and patients.
 - This includes conditions around patients, family and staff located in patient hotels associated with and used by hospitals.
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76.3 Responsibility

The granting authority and hospital management provide resources for construction and maintenance that is expected in modern hospital activity. Included are safe conditions for patients, personnel and visitors and a safe working environment. Physical conditions and logistics may not expose patients, employees or visitors to infection [1].

Construction manager/project manager, etc. are responsible for ensuring that all important professional groups are consulted and that long-term, good and flexible solutions are in front of short-term ad hoc solutions.

Architect, user groups, entrepreneurs, etc. shall ensure solutions tailored to the department's needs, requirements for quality of work and materials, requirement of a complete construction budget and plan for annual maintenance costs.

Infection control personnel should attend from the beginning, during the planning phase, the project phase and the implementation phase, to ensure that new buildings, rebuilding and change of use satisfy the requirements for infection protection for patients, visitors and personnel at the hospital [1].

76.4 Practical Measures [2]

- *Hand hygiene.* Access to good hand hygiene in all patient areas. Hand hygiene should be offered to everyone at the entrance of the patient room, at the main entrance, in the elevator, etc. It reduces the spread of infectious microbes. Electronic handwashing is not recommended due to the risk of growth of gram-negative, resistant bacteria and *Legionella* [3].
- *Telephone/computer systems* should not constitute a common source of infection in the environment—between patients, personnel and visitors.
- *Toilet/shower/bathroom* attached to each patient room significantly reduces cross-transmission of microbes. It avoids repeated outbreaks of norovirus, *Clostridium difficile* and other agents. The bathroom should be handicap-designed with plenty of space for a healthcare worker who can help the patient without the risk of being contaminated. The room should not be used by other

patients or visitors. Establishing a throughput decontaminator from the bathroom to the sluice/anteroom may be evaluated.

- *Patient rooms.* Free area around the patient's bed with work access from both sides and at the bed end. There should be at least 2 m clearance on both sides of the bed and at the foot (5×4 m) and in addition 2 m clearance from the sink. This is necessary for the use of walking chairs and wheelchairs and effective care of heavy, severely ill patients. The bed should be taken in and out of the room without damaging walls and doors and without contaminating the surroundings.
 - *Good space* simplifies and improves the working environment, increases patient well-being and air volume and reduces patient-to-person transmission of infection. Each patient needs an area of at least 20 m² and a separate toilet/shower with entrance from the patient's room.
 - Curtains, rails in the ceiling, etc. must be removed; it collects dust.
- *Single rooms* should replace all double- and multibed rooms in all new buildings. Studies show that single rooms have so many benefits in terms of patient satisfaction, patient safety, privacy, visitor friendliness, silence, efficiency and infection protection and that establishment of such rooms is considered to be cost-effective for hospital operations.
- *Anterooms or sluices* associated with a regular single room are an advantage for visitors to hang out outerwear and wash hands before and after visits and for use with contact or protective isolation.
- *Automatic, silent door opener* for patient rooms will streamline work and prevent cross-contamination.
- *Large, practical and separate service room* in the ward (15–20 beds) for clean textiles (16 m²), sterile equipment (16 m²), clean equipment (16 m²), disinfection room (18–20 m²), medicine room (14–16 m²), large equipment (wheelchairs, crutches, etc.) (10–12 m²) and waste room (10 m²).
 - Service rooms are arranged in such a way that those who work there do not come too close to the walls and equipment in the room. In a good work area, cross-contamination in the service room is reduced.
 - *Service room properly placed* in relation to patient's rooms and personnel. Adjusted smaller service rooms with little walking distance for the personnel can be most effective. Also smaller service rooms should have ample area for those working there. For a regular ward of 15–20 beds, each such room should have an area of approx. 16 m².
- *Treatment rooms and examination rooms:* minimum of 16 m².
- *Conference room for 2–3 persons:* approx. 12 m².
- *Paper office without patient:* 6–9 m².
- *Toilet for personnel:* 3 m, minimum of 1 per 7–14 employees present.
- *Kitchen and disinfection room/cleaning room*—see separate chapters.
- *Stock for sterile equipment*—see separate chapter.
- *Meeting rooms and ward office* adapted to the fixed number of staff during the daytime. Today's ward office is often small, crowded and tidy with many open shelves that collect dust and dirt. There is a great need for access to data and for daily cleaning and more often disinfection of computer keyboard. It should be

facilitated for more good work places and for proper storage of records, other paper and equipment. There should be plenty of room for hand washing and preferably automatic disinfection of hands at the entrance. Do not eat and drink while dealing with patient data due to the risk of cross-contamination (keyboard, journal, etc.).

- *Furniture for patient and visitor* should not be of textile and should be washable, cleaned daily and disinfected regularly.
- *Floors, walls, ceilings and fixtures* should be of good quality, easily washable and robust against daily cleaning and frequent use of disinfectants. The surfaces should be whole and shiny and do not form the basis for microbes. There should not be tiled floors, and floors should be cleaned easily without loosening of the covering. It is recommended to use the floor coverings a little up on the wall to avoid loose mouldings and facilitate cleaning.
- *The ceiling* should be completely robust and slippery and easy to clean without loosening of ceiling panels and without openings for repairs and the like.
- *Light fixture* collects dust and microbes and for that reason should lie evenly with the ceiling, covered with glass.
- *Corridors, wet rooms (toilet, shower, disinfection room, etc.) and patient rooms* are especially exposed to contamination of larger amounts of organic materials (excretes, leftovers, etc.) with growth of microbes. This causes bad odour and reduces well-being for both employees and patients and is a contagion in the environment. These areas should have daily cleaning, preferably twice daily, dependent on activity and situation, and must withstand frequent use of disinfectants.
- *Water systems must satisfy monthly* quality controls with regard to germ numbers and particularly unfortunate water bacteria such as *Legionella* and *Pseudomonas*.
- *Ventilation systems* should be checked annually and protected from growth of microbes in water and condense microbes, such as *Legionella*, gram-negative bacteria and fungi.
- *Cooling and heating of rooms* should not be done by local room systems that are quickly filled with dust and condensation and thus constitute a risk of airborne infection in the room.
- *Ventilation of patient rooms* and other rooms should ensure at least 6–12 fresh air exchanges every hour. This reduces the amount of air contamination in the room by dilution and increases personal well-being.
- *Negative air pressure should be present in waste rooms, disinfection rooms, unclean rooms (toilets etc.) and all isolates* for infections so that microbial agents are not spread by air to other rooms. Doors must turn right ways so that the negative pressure is not impaired.
- *Isolation units for infectious patients* should be available in all patient departments and must have negative air pressure and separate ventilation with hepafiltered air exhaust. Contact isolation should preferably be at minus 5–10 pascal negative pressure, while isolates for airborne infections should be at least 25–45 pascal negative pressure. It is an advantage that all isolates get direct access from outside via sluice. See Chaps. 14–21 on isolation regimes.
- *Operation rooms*—see the operation department.

- *Intensive care and postoperative*—see the intensive care unit.
 - *Patient logistics* should be facilitated so that the patient is not moved between departments.
 - *Flexible solutions*. New building and rebuilding must be carried out in such a way that later change in usage (different specialities) is reasonable and easy to implement.
 - *Redecorating* floors, walls and fixtures every 5–7 years should be included in a maintenance plan for the department.
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76.5 Background Information

The development of more advanced medicine and breaking new borders in treatment of serious illnesses may involve poorer and more helpless patients in the hospitals. They will need more personal help with everything and are more bedridden and exposed to infections. Those who are in a better shape will probably be day-treatment patients at the hospital, staying at patient hotels, nursing homes, other homes or at home. The future probably also leads to more resistant and contagious microbes and less effect of antimicrobial agents. Therefore, the hospital buildings, construction, outfit, design and maintenance, are very central elements in the management of modern hospitals with increasing risk of transmitting nosocomial infections. New hospitals, buildings, rebuilding, changed functions and logistic solutions may be well planned and considered thoroughly. Special focus may be placed on effective infection control measures like enough patient beds, single patient rooms and service rooms, design and quality of furniture and the implementation of effective, safe and good hygiene [4–14].

76.5.1 Single Room and Area for Patients and Visitors

Modern hospital research has shown an increasing need of area for patients in hospitals. An international study from 2007 of 18 hospitals demonstrated higher activity and shorter hospital stay—from 7 days in 1990 to 3.5 days in 2003 [15]. At the same time, the area per patient has increased in patient wards (not intensive) from 25 to 35 m² per bed from 1990, and the entire hospital department area has increased from 60 to over 90 m² per bed in 2003, i.e. a total increase of the area of 25% [15].

However, many hospitals having the same total area as 50 years ago still are putting more and more patients in the same room, using more and more rooms for offices and administration and producing overbooked and understaffed hospitals with even higher risk of infection and other patient accidents, than before.

The following advantages are documented for *single room* compared to *two-bed rooms* (and dormitory) [5–23]:

- Reduction of hospital infections.
- Less risk of transmitting infections to roommate [5–14].

- Reduced fall injuries.
- Fewer transfers and medical errors.
- Less cost of transfer.
- Less noise.
- Better sleep quality.
- Better communication with personnel.
- Greater patient discretion, privacy and security for the patient.
- Greater patient satisfaction (very big difference).
- Less costs with regard to daily operations—better utilized room.
- Greater flexibility and ability to fill capacity—especially in medical departments.
- More satisfaction for personnel, nurses and doctors.
- Better conditions around student education.
- Efficiency of personnel.
- Flexibility in hospital planning and change of function.
- Reduced operating costs in the long term due to reduced number of hospital infections. The rooms are easier to clean; there is a shorter patient stay; there is a better compliance with health and safety, etc.; and there is a more flexible use of single rooms—even compared to a four-bed patient room.
- Greater initial construction costs on the other side.

76.5.2 Infections

Twenty to thirty percent of hospital patients have infections, hospital-onset or non-hospital-onset infections, and are given antibiotics while they are hospitalized [24, 25]. Today an increase of resistant bacteria is observed like MRSA and resistant gram-negative bacteria (ESBL, CRE and others) and VRE. *Clostridium difficile* (CD) has changed to become a more serious, dangerous, resistant bacterium, developing chronic diarrhoea with kidney injury, especially in patients with increased susceptibility to infections and on antibiotics. CD spores live for years in the environment if not removed. Outbreaks of gastrointestinal infections are increasing where many or all departments must close for the intake of new patients (see gastrointestinal infections). Norovirus and other gastrointestinal viruses like sapovirus and rotavirus are highly contagious and return year after year and inactivate a significant part of health-related work at hospitals. Influenza and respiratory syncytial virus (RSV) is an annual phenomenon and an increasing global challenge. Common influenza is easily spread in institutions and vaccines do not prevent infection. Modern water and ventilation systems may spread *Legionella* and other waterborne bacteria in health institutions, unless preventive measures are included in building plans.

Emergency preparedness for serious epidemics or accidents with dangerous materials should be developed at all hospitals, not least at the functional level. How a serious lethal epidemic will spread can be demonstrated by the large and inactivating norovirus epidemics that are spread “like fire in dry grass” at older, nonfunctional hospitals.

The hospitalized patient should not be exposed to infection. Also personnel and visitors should be protected against infections in hospitals. The ethical standard around the patient's stay in hospitals is central, concerning hospital infections.

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Abstract

In the hospital kitchens, food and drink are stored especially for providing food between meal times, for patients under examination/treatment when regular food service is in progress and for patients with poor appetite/special food, etc. Food and beverages are well-known vehicles for the spread of infectious diseases in hospitals. The following chapter is focused on areal and outfitts of hospital kitchens to avoid transmittance of infections between patients, personnel and environment.

Keywords

Hospital kitchen · Food and beverage · Building and outfit · Infection control
Hygiene

77.1 Purpose

Protect patients, staff, visitors and the environment from infections by establishing a hygienic and well-outfitted kitchen for patients [1–6].

77.2 Comprise

Personnel who works in the kitchen or supplies goods, food, etc. to and from the kitchen and includes all types of serving, dishwashing, cleaning and cooking.

77.3 Responsibility

The hospital management shall provide hygienic guidelines regarding the serving of food and drink to the patients and for all food services to be carried out in accordance with the country's Food Safety Authority's guidelines (like in Norway) [1–6].

The department's management is responsible for the training and controlling of good kitchen hygiene.

Staff working with foodstuffs should follow guidelines regarding personal and general hygiene.

77.4 Practical Measures [7, 8]

Hand hygiene is a prerequisite before and after handling food and beverages. The post kitchen must have a good sink.

Clean equipment and clean storage for equipment. The post kitchen should be spacious with clear distinction between clean and unclean (used) equipment.

Dishwasher that at least reaches 85 °C in the goods during the washing process. No open washing process in the kitchen area that creates splashes and aerosols and spreads contaminants.

Clean plates, cups, glasses and cutlery should be stored in a clean cupboard with a door, not near a dishwasher or unclean equipment.

Standard for post kitchen (on a ward) with serving food on a tray to each patient

Methods for serving heated food vary and must be set according to local conditions and needs.

77.4.1 Kitchen Area

A minimum of 16 m² areal is necessary for a post kitchen to serve a regular bed post (ward) with 15–20 patients.

77.4.2 Function of the Kitchen

- The food is brought on separate trays or in bulks from the central kitchen.
- Storage of beverages and dry foods such as biscuits, soups, tea, coffee, etc., for patients who need food and drink. The storage needs plenty of space in cupboard with clear glass doors in the kitchen.
- Storing a limited amount of cutlery and crockery and various kitchen utensils. Equipment needed for extra serving may be cleaned at the kitchen in a closed dishwasher.
- All used dinnerware, plates, etc. are sent back to the central kitchen in separate transport trolleys or other local solutions.

77.4.3 Furnishings

- *The bench space* should be shared in *clean and unclean zones*—plenty of space.
- *Unclean zone* should have a *dishwasher* (min. 85 °C for 5–10 min).
- *Sink unit* with long touchless arm.
- *Washbasin* with falling height on the water not exceeding 30 cm. Hot water should be at least 75 °C, after a few minutes. Check with thermometer a few times a year.
- Do not use electronic wash at fixed temperature; there is a risk of increased growth of gram-negative bacteria like *Pseudomonas aeruginosa* and *Legionella* due to low temperature [9–13].
- Hand disinfectants, preferably automatic dispenser.
- Separate washbasin with large washroom—optionally two, depending on the need for use, 50 × 40 cm, and a depth of 15 cm. The hot water should be at least 75 °C, after a few minutes [9–13].
- Waste rack with pedal lock.
- Lockable cabinet for storage of detergents.
- Space for transport trolleys that may return to the central kitchen. Local solutions.
- Clean zone with stove and bench space on both sides. Cabinets/drawers are easy to keep clean.
- Adequate refrigerator, preferably two, to relieve temperature changes; minimum 4 L per person per day, with freezing facilities.
- Good space for microwave.
- Ice machine should be on the clean side, easily accessible for cleaning of the inner and outer parts, and a good distance of 50 cm for other equipment on both sides.
- Space for storage of clean transport trolley for food.
- Room for refrigerator for employees.

77.4.4 Surfaces

- *Unclean side*: Continuous stainless steel worktop and edge to the wall.
- *Clean side*: Worktop of durable, water resistant, smooth surface (laminate) that can withstand satisfactory cleaning and which is not made of wood material.
- Cabinets and drawers should have a smooth surface, laminated or painted with min. gloss 20.
- Floors should have a durable surface (high quality) and be waterproof and easy to clean, for example, vinyl with vinyl hole lists, 75 mm on the wall, glued with contact adhesive.
- Walls should be smooth, water repellent and easy to keep clean. Painted surfaces must have minimum gloss 20 (acryl proof 20). If “reinforcement” is required due to the nature of the wall, glass fibre cloth must be used. Over the benches there should be suitable tiles on the wall, good standard 15 × 15 cm with smooth epoxy

joints. Use of moving joints should be used with polyurethane with good adhesion and which contain fungicides. Optional vinyl coating over kitchen bench.

- Roofs should be constructed with a minimum of potential for dust and impurities accumulation. Painted ceiling must have a minimum of shine 20 (acrylic).

77.4.5 Traffic

- The kitchen should not be used as a thoroughfare room. Wide door, if possible, turns out into the corridor.
- The post kitchen is placed as centrally as possible in relation to the bed rooms. Daylight if possible and a good working light.
- Patients, relatives and others have no access to the kitchen.
- See also the health institution's food procedures.

77.5 Background Information

At the kitchen, food and drink are stored especially for patients under examination/treatment when regular food service is in progress and for patients with poor appetite/special food, etc. Ice cubes from a contaminated ice machine can be a source of infection in the environment.

Dishwashers at post kitchen shall meet the requirements for hot water, >85 °C, and hot water from sink must have a temperature of 75 °C or higher. This is to avoid heat-resistant microbes, biofilm formation and growth of legionella and gram-negative environmental bacteria such as *Pseudomonas aeruginosa* [9–13] (see also Chap. 70).

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Disinfection Room: Cleaning Room

78

Abstract

The disinfection room is central to all operations and is a multifunctional room. Here, all contaminants and organic materials are taken care of and removed. Contaminated textiles are sorted and ordinary waste from infectious waste. Used syringes and other stabbing/cutting waste, glass, etc. are collected as hazardous waste. Used wheelchairs and other major patient aids are usually washed here. The bedpan, urine bottles, etc. are disinfected in the decontaminator. The room has a large load of dirt and microbial agents where the personnel may perform many space-demanding tasks. A large and efficient area with good separation between clean and unclean work tasks, good ventilation and negative pressure ventilation and good methods for cleaning and disinfection are necessary. The following chapter is focused on areal and outfit of the disinfection room to avoid transmittance of infections between patients, personal and environment.

Keywords

Disinfection room · Waste room · Used equipment · Decontaminator · Instrument washing-machine · Bedpans · Urine bottles

78.1 Purpose

To protect patients, personnel and the environment against infection [1–4].

78.2 Comprise

All staff who use the disinfection room. All equipment, textiles, waste, etc., which are treated/stored/collected and sorted in the disinfection room.

78.3 Responsibility

The hospital's management ensures that disinfection rooms are adapted to the function and patient beds of the individual department. The disinfection unit may, according to area, outfit, structure and routines, protect personnel, patients and environment against infections [1]. Written procedures for work and control in disinfection rooms shall be available.

The department's management complies with hygienic guidelines, ensures that staff are educated and reports to the director if the disinfection system may present a risk to patients and personnel.

The personnel follow guidelines for personal and general hygiene and procedures for the disinfection room.

78.4 Practical Measures [5, 6]

78.4.1 Location, Size and Design of the Disinfection Room

- The disinfection room must be easily accessible, centrally located in the department/ward and with direct access from the corridor. Do not throughput to the corridor because of the fire department's rules.
- The disinfection room must have a negative air pressure so that airborne contaminants are kept mostly within the room. Keep the door closed. Keep all throughput openings closed. The ventilation should be good, at least 8 fresh air exchanges/hour.
- Separate extracts/hoods may be established if using special chemical disinfectants.
- Large enough area for the department/patient beds activities; at least 3 m between clean and unclean sides (due to splash and aerosol formation). The area required is usually 18–20 m [2]. The work must be carried out efficiently and risk-free even if the doors to the decontaminator are opened.
- Floors and walls must withstand strong disinfectants and frequent cleaning.
- Drain in the floor may be correct.
- There should be a large enough area for cleaning of wheelchairs, aids, etc., if the hospital does not have a separate cleaning facility or system for large equipment between patients.
- The disinfection unit may have its own clean storage room for cleaned and ready-to-use bedpans, urine bottles, flower glasses, cleaned walking chairs and other noncritical aids. This store room should **not** be used for clean textiles, sterile equipment, etc.!

78.4.2 Equipment and Fixtures

- Sink with single-grip battery and with long touchless arm.
- There should be plenty of space for one to two machines (decontaminator, instrument washing machine) with the position of the soap system well above the floor.

The area requirement for machines may be approximately 4–6 m [2]. It should be easy to carry out cleaning around/under the machines.

- Hand washbasin with soap and hand disinfectant at the door with plenty of space for washing and tiled wall down to the floor. Fall height of the water should not exceed 30 cm (avoid splash).
- The hot water should be at least 75 °C, after a few minutes. Check with thermometer a few times a year. Discuss the use of electronic wash at fixed temperature because of risk of increased growth of gram-negative bacteria such as *Pseudomonas aeruginosa* and *legionella* due to low temperature [7–11].
- Hand disinfectants, preferably automatic dispenser.
- Collecting racks for laundry, waste, special waste, etc. (unclean side)—area requirement approximately 6 m [2]. Racks with pedal lock.
- Benches for unloading equipment for clean and unclean side.
- Separate washbasin with large rinsing basin—possibly two, depending on usage needs and other benches for storage.
- Throughput closet for optional drying after wash in a drying cabinet. Note that the doors in the drying cabinet must not stand open! In such cases, the negative air pressure may disappear, and possibly infectious agents may spread to other rooms via the air.
- Lockable closet for disinfectants.
- Cabinet for storage of clean equipment for waste management.
- All important procedures must be in writing in protected, washable plastic.

78.4.3 Control Functions

- Daily check that machines are working properly. Check daily that there is soap on the container of the decontaminator. Report to medical-technical department if leakage, suspicion of low temperature or if the equipment is unclean after washing.
- Daily check that all waste, including infectious, cans with cutting/stinging contaminants and the laundry, is properly handled and removed by appointment and before it gets overcrowded.
- Unauthorized personnel are not allowed to stay in the room. No access for relatives or patients.
- Daily check of cleaning of floors and benches. Daily washing of floors, surfaces and around wash all day of the week; see Chap. 65 on cleaning of rooms.
- Equipment not belonging to the disinfection room system shall not be placed on the disinfection room.
- Temperature control of decontaminator and instrument washing machine every 14 days. Register in the list.

78.5 Background Information

To the disinfection room, a number of potentially infectious agents are brought daily, which—if not properly treated—exposes personnel and patients to infection.

Microbiological agents brought into the disinfection room can cause serious infections via:

- *Blood-borne infection*: hepatitis A, B, C, D, E, HIV, HTLV, etc.
- *Contact-transmitted infection*: *Staphylococcus aureus*, streptococci, *Salmonella*, *Shigella*, *Clostridium difficile*, hepatitis A, norovirus, rotavirus, etc.
- *Airborne infection (including contact)*: tuberculosis, MRSA and other resistant bacteria, influenza, respiratory syncytial virus—RSV, norovirus, sapovirus, bocavirus, coronavirus, etc.

78.5.1 Good Hygiene Prevents Infection Risk

In the disinfection room, both *clean and unclean* material is treated, often at the same time during a busy day in the ward. It is important to distinguish between clean and unclean sides of the room and carry out good hand hygiene between work tasks. Risk processes that cause splash/contamination of biological material must be avoided. Everything must be treated with care. No contamination or misunderstanding may occur that exposes personnel or patients to infection risk.

See also Chap. 66 on disinfection.

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Internal Infection Control: Checklist

79

Abstract

Internal control is an important and time-saving way of reviewing the department's standard with regard to hygiene and infection control. Internal control is carried out by the department's own employees and is an internal matter. Results of the check often result in a note/report that is then used as a document for improvement measures. The following chapter is focused on hygienic control and check routines that may protect against the spread of infections between patients, personal and environment.

Keywords

Internal control · Hygienic checklist · Patient ward · Infection control

79.1 Purpose

- To ensure good hygienic routines for the department.
- To detect defects, unfortunate routines, procedures and measures that may be of major importance for infection control and hygiene at the department.

79.2 Comprise

- Patients, visitors and healthcare personnel at the department.

79.3 Responsibility

The hospital's management should provide a written infection control programme including a procedure for internal control.

Department management should implement internal controls with regard to hygiene and infection control, twice per year, and with written report to the Director and to the infection control personnel.

Hygiene contact is responsible for participating in internal control work.

The safety deputy is responsible for protection issues that must be submitted to the safety overseer.

The cleaning manager is responsible for the feedback to the workplace and the head of the service department regarding deviations according to hygiene and infection protection.

All personnel are responsible for ensuring that current procedures and guidelines are implemented and followed up.

79.4 Practical Measures

Internal controls regarding hygiene and infection protection are carried out at all departments at least twice a year. The control should be performed by the department's management (manager), hygiene contact, safety representative and cleaning manager. Department nurses attend at their wards; the kitchen manager participates in the ward kitchen. Technical department is contacted concerning technical internal control, i.e. control of technical equipment.

The department's responsible physician should, if possible, participate in internal control, especially during periods of problems with hospital infections.

Prevalence and incidence of all infections and hospital infections at the department should be included as documentation.

Inspection reports from the hospital hygiene/infection protection personnel are used as the basis for internal control.

79.4.1 The Department Management Is Responsible for

- Hand hygiene training for all department employees (including extra duty, night duty, etc.)
- Adequate washbasins with liquid soap and disinfectant dispensers, paper towels and waste bin with bag and placement of this.
- Good personal hygiene among the staff, patient hygiene and use of the hospital's work uniform.
- The quality and cleaning of patient beds, mattresses, bed linen, toilet chairs, wheelchairs, other chairs, textiles and other equipment.
- Proper cleaning of patient room, toilet room, washroom, laundry room, storage for clean/sterile equipment, other storage room, dining room, corridor and living room.
- Good hygienic conditions for newly operated patients.
- Proper wound care and treatment of wound infections.
- Measures for epidemics or outbreaks of communicable diseases, according to hospital routines.

- Responsibility for proper use of isolation regimes.
- Knowledge of guidelines concerning resistant microbes.
- Good hygienic conditions in nutrition, fluid treatment and care.
- Distribution, storage and handling of drugs.
- Training in correct treatment and separation of clean versus unclean items: patient clothes, waste, equipment, etc.
- Distribution, storage, inspection and expiry date of disinfectants.
- In case of purchasing new equipment, disposable equipment, etc., contact infection control personnel/medical technical units for advice and approval.
- Errors and deviations are reported to the hospital's management, quality selection and infection control nurse.

79.4.2 Responsibilities in the Ward Kitchen (Kitchen Chef)

- Proper cleaning, preventing microbes from spreading in the environment and causing infections in patients and personnel. This applies to daily cleaning and main cleaning.
- To comply with procedures and regulations of the Ministry of Social Affairs—the country's Food Safety Authority to ensure that staff have good practices for personal hygiene and hand hygiene.
- To arrange washbasins with liquid soap, paper and hand disinfection container.
- Make sure the kitchen has trash cans with pedal lock.
- To ensure proper storage of clean equipment.
- That all sorts of foods are kept in a hygienically satisfactory manner.
- That the dishwasher has a satisfactory temperature and that the machine has a proper flush/cleaning and disinfecting effect.
- Checking the temperature of the dishwasher according to plan.
- To distinguish clear between clean and unclean equipment.
- To clean equipment in a satisfactory way.
- Daily cleaning and order in the kitchen.
- Cleaning of food trays, trolleys and containers.
- Main cleaning of kitchen and storage rooms once a year—or more often if needed.
- Equipment replacement and maintenance (of the equipment).
- Errors and deviations are reported to the department's management; the kitchen chef reports to the hospital's management.
- Conditions of importance for hygiene and infection control are reported to the hospital's management, quality committee and infection control unit.

79.4.3 Responsibilities for Cleaners (Cleaning Management)

- Hand hygiene training (including temporary staff).
- Personal hygiene and uniform.
- Current procedures for cleaning are followed.

- Proper cleaning of patient room, toilet room, washroom, laundry room, storage for clean/sterile equipment, other storage rooms, dining room, corridor and living room.
- Proper cleaning of patient beds, mattresses, toilet chairs, wheelchairs, other chairs, etc.
- Proper methods and soaps are used, according to plan. This applies to daily cleaning of the department and main cleaning once a year or more often.
- Storage, checking and shelf life of disinfectants.
- Training in current infection control procedures and practical review of disinfection and cleaning of contaminated rooms and furniture.
- Errors and deviations are reported to the department's management and hospital management via the hospital's reporting system for deviations.
- Conditions of importance for hygiene and infection control are reported to the hospital's management, quality committee and infection control unit.

79.4.4 The Safety Deputy Is Responsible for Controlling

- That the staff are not exposed to infection.
- That technical equipment and aids work appropriately, to avoid strain injuries.
- Disinfectants/chemicals are stored and used in accordance with the regulations.
- Error and deviations are reported to the safety overseer, the department's management, the hospital's management, the quality committee and the infection protection unit.

79.4.5 Technical Department Is Responsible for Controlling

- Maintenance of windows, ceilings, walls and floors, as well as all technical installations.
- That the ventilation filter is checked and replaced by agreement with the supplier of the hospital ventilation system and that there is no leakage between the filter and the ventilation duct.
- That in some departments, filter change is advised twice a year.
- Cleaning of valves for air intake and extraction.
- That hot water from the crane has at least 75 °C.
- Temperatures of dishwashers (at least 85 °C) and decontaminators (at least 85 °C).
- That logbook is kept to document temperatures in decontaminators, washing machines, dishwashers and filters.
- Error and deviations are reported to the department's management and to the hospital's management, quality selection and infection control unit.

79.4.6 Responsible for the Textile Department Must Check

- Hand hygiene training (including temporary staff).
- Textile personnel's personal hygiene and working suit.

- Training of personnel in washing procedures and proper treatment and separation between clean and unclean textiles.
- Adequate washbasins with liquid soap dispensers, paper towels, hand disinfectants and waste bin with bag and placement of this.
- Purchasing, transportation and use of all fabrics at the institution.
- Internal control in the laundry.
- Washer/dryer and other laundry equipment.
- Storage of clean textiles.
- Laundry of different textile fabrics.
- Laundry of regular hospital textiles.
- Laundry of infected textiles.
- Storage and sorting of used textiles.
- Storage and sorting of infectious textiles.
- Cleaning of laundry trolleys.
- Cleaning of laundry containers.
- Daily cleaning in the laundry unit and dust removal.
- Main cleaning of the laundry unit at least once a year.
- Errors and deviations are reported to the hospital's management, quality selection and infection control unit.

79.4.7 Checklist for Internal Control: A Regular Patient Ward

This is a checklist for a regular patient ward. It is recommended that special departments (laboratory medicine, radiology departments, internal service, surgery and intensive care unit) should make their own checklists, even contact the infection control unit.

79.4.7.1 Patient Rooms

- Beds/mattresses/bedding, storage, placement and cover of clean beds.
- Washbasins, liquid soap, paper towels, hand disinfectants.
- Waste bin with bag.
- Cleaning of fixtures and rooms.
- Cleaning of call button, telephone, light switches, door handles.
- Cleaning of wardrobe, curtain and display board.
- Light.
- No storage of clean clothes, bandages, ointments, etc. in the patient room.
- Check the number of patients/ m^2 area in the patient room (at least 16 m^2 per patient); furthermore the distance between beds (at least 130 cm) and between beds and washbasin (at least 130 cm) and between bedside and wall (at least 130 cm).
- Check that beds do not stand against the wall with long sides.
- Check cleaning/disinfection of medical devices used by patients.
- Everything up from the floor.
- Hygienically safe toilet/shower.

79.4.7.2 Isolation Unit (Patient Room, Sluice, Toilet/Shower/Decontamination)

- Check routines for isolating patients with infection.
- Check that the department's cleaner can provide decontamination and isolation routines.
- Check negative air pressure in airborne isolation unit and check logbook for measurements of pressure.
- See also patient rooms.

79.4.7.3 Toilet-Bathroom Conditions

- Handwash, hand disinfection.
- Liquid soap, paper towels, waste bin with bag.
- Hanging for toilet paper.
- No storage space for equipment.
- Cleaning twice a day.
- Control of toilet, lid, cleaning.
- Check the silicone at the floor around the toilet.
- Cleaning of toilet seats, seat higher (also below).
- Check that the correct cleaning routine is followed (how to clean the toilet).

79.4.7.4 Shower

- Daily cleaning of the sink and shower room.
- Cleaning in showers between each patient.
- If a shower cabinet is used by several patients, an infected patient will shower as the last person. Disinfect the shower afterwards.
- Check the wall and floor coverings.
- Disposable bag for textile rack.

79.4.7.5 Bathroom

- Check cleaning procedures of bath/handwash, hand disinfection.
- Cleaning and disinfection procedures for patients with and without infection.
- Bubble bath should preferably not be used.
- Waste bin with bag.
- Cleaning of shelves.
- Stand for unclean laundry/towels.
- No storage space for clean textiles, bandages, ointments, etc.

79.4.7.6 Textile Storage

- Order.
- Cleaning.
- Everything up from the floor.
- No unauthorized effects.

79.4.7.7 Disinfection Room

- Handwash.
- Liquid soap/paper towels/hand disinfectants.
- Disinfectants and strong detergents in locked cabinets.
- Own stand for waste and laundry.
- Cleaning of shelves and cabinets.
- Cleaning of all surfaces, floors daily.
- Strong distinction between clean/unclean.
- Temperature control and function control of the decontaminator and instrument washing machine.
- Container with tight fitting lid for disinfectant, if used.
- Collection of waste.
- Collection of laundry.
- Do not wash or dry laundry in the disinfection room.
- Order.
- Everything up from the floor.
- Negative air pressure compared to other rooms and corridor.

79.4.7.8 Clean Storage

- Order.
- Hand hygiene.
- Check daily cleaning and cleaning of cabinets.
- Everything up from the floor.
- Only clean equipment on clean storage.
- No unauthorized effects.
- No office space.

79.4.7.9 Post (Ward) Kitchen

- Handwash.
- Liquid soap, paper towels, hand disinfection.
- Sink, sufficient washbasins.
- Cleaning of cabinets and drawers weekly.
- Cleaning of floors daily.
- Replacement of worn-out equipment.
- Waste container with pedal lock for food residue.
- Waste bin with a waste bag.
- Check that the Foodstuffs Act with regulations is followed.
- Cleaning of cookers, etc., daily.
- Weekly cleaning of ice machine.
- Cleaning of refrigerator once a week.
- Freezer compartment/cupboard twice a year.
- Main cleaning twice a year.

- Temperature control on the fridge every day.
- Temperature control on dishwasher (measured in the basket) every 14 days.
- Temperature control of hot food.
- Check storage of food.
- Daily cleaning of the food trolley.

79.4.7.10 Ward Office

- Check training in hand hygiene.
- Are written routines for infection control and hygiene easily accessible?
- Is the staff familiar with the routines?
- Washbasin with soap dispenser/paper towels/hand disinfectant/lotion and waste bin with bag.
- Daily cleaning of all surfaces/phone/floor/data and keyboard.
- Weekly cleaning of chairs and fixtures.
- Make sure that there is no food or drink when working with patient journals, patient samples or medicines.
- No equipment or wires on the floor.

79.4.7.11 Medicine Room/Medicine Cabinet/Unit

- Daily cleaning of all surfaces.
- Weekly cleaning of all shelves/drawers/cabinets and carts.
- Main cleaning of the room twice a year.
- Check the hood.
- Check opened vials/ampoules/medicines for durability and storage.
- Check the handling of medications.
- Check cleaning of medicine boards, trays, trolleys, etc.

79.4.7.12 Storage Room of Washing Equipment

- Sink.
- Liquid soap, paper towels, hand disinfection.
- Sufficient shelf space.
- Peg for hanging equipment, etc.
- Daily wash of the sink/bucket rack.
- Daily disinfection of the buckets.
- Cleanliness and order.
- Floor space free of equipment and supplies.
- No private laundry.
- Waste bin with bag.

79.4.7.13 Dining Room and Living Room

- Washing tables after each meal.
- Cleaning of floors daily, possibly twice a day and when needed.
- Washing of seats, window frames, lists and fixtures weekly.

79.4.7.14 Corridors on Wards

- Cleaning once a day.
- Cleaning of railings twice a week.
- Wash the door handles daily.
- All furniture is vacuum cleaned and cleaned weekly.
- Dirty/broken furniture is sent for cleaning/repair.

79.4.7.15 Elevator

- Daily cleaning of floors, railing and pushbuttons.
- Check cleaning.
- Light conditions.

79.4.7.16 Waste Disposal

- Proper treatment of waste.
- All surfaces easily washable.
- Drain to water in the floor.
- Check routines for removal and transport of waste.
- Cleaning once a week.
- Negative air pressure relative to the corridor.
- Check any shafts for dropping.

79.4.7.17 Physiotherapy

- Handwash, soap dispenser, paper towels, hand disinfection.
- Waste bin with bag.
- Adequate closet space for all equipment.
- Cleaning procedures for equipment are followed.
- Daily cleaning of all tables/benches/floors.
- Hygiene rules for physiotherapists are followed.
- Check cleaning.

79.4.7.18 Ergo-therapy Room

- Handwash, soap dispenser, paper towels, hand disinfection.
- Waste bin with bag.
- Daily cleaning of all tables/benches/floors.
- Regular cleaning and order in the cabinets.
- Check cleaning.

79.4.7.19 Ventilation Valves

- Cleaning/cleaning of all valves every 3 months.
- Note! Fungi are growing in valves, especially in bathroom/shower room/kitchen/ laundry and waste room.

79.4.7.20 Ventilation Filter

- Regular check of filter, eventually shift.

79.4.7.21 Wardrobe for Employees

- Handwash, soap dispenser, paper towels, hand disinfection.
- Waste bin with bag.
- Clean storage room for clean uniforms/clothes.
- Proper storage of used clothes and good emptying routines.
- No equipment, shoes, clothes on the floor.
- Check cleaning of available wardrobes.
- Check cleaning under and on top of the wardrobe.

79.4.7.22 Shower

- Daily cleaning of washbasin, shower room and toilet.
- Check walls and floor coverings.
- Disposable bag for used clothes and rack.

79.4.7.23 Toilet

- Handwash.
- Liquid soap, paper towels, waste bin with bag.
- Hanging for toilet paper.
- No storage space for equipment.
- Cleaning daily.
- Control of toilet, lid, cleaning.
- Check the silicone at the floor around the toilet bowls.
- Check that the correct cleaning routine is followed (how to clean the toilet).

79.5 Background Information

Internal control: to ensure compliance with requirements stipulated in or in compliance with the law or regulation.

79.5.1 Law/Regulation/Guidelines: Example from Norway

- Regulations on internal control. Determined by kgl res. 22 March 1991 pursuant to Act 4 February 1977 No. 4 Section 16a on Workers protection and Work Environment, etc.
- Regulations on infection protection in healthcare institutions—hospital infections. Established by the Ministry of Social Affairs and Health on 5 July 1996 pursuant to Sections 4–7 and 7–11 of Act No. 5 of 5 August 1994 on protection against communicable diseases.
- Infection control programme for each hospital, updated locally.
- Hygiene Regulations for production and marketing, etc., of foodstuffs, determined by kgl, 8 July 1983, No. 1253, changed by kgl. of 29 April 1988 No. 312, pursuant to paragraphs 1 and 3 of the Act of 19 May 1933 No. 3 on supervision of foodstuffs, etc. with later changes.

- Internal control in foodstuffs—businesses IK—Food at NMT, INFO G 3 7 October 1997.
- Working Environment Act published by the Directorate for Labour Inspection.

Internal control is an important and relatively little time-consuming way of reviewing the department's standard with regard to hygiene and infection control. Internal control is carried out by the department's own employees and is an internal matter. Results of the check often result in a note/report that is then used as a document for improvement measures.

Part XIV

High-Risk Microbes



Dangerous Microbes

80

Abstract

The most dangerous microbes for humans are those that are easily transmitted, virulent and invasive to central organs like the blood and lung, robust survivors in the environment, have a low infection dose and are without any specific treatment or vaccine. Most of them are zoonoses transmitted from animals and often with insects as vectors. The most dangerous microbes cause a very high mortality, are identified as high-risk agents or “biohazard-level 4” agents and are treated at the highest level of infection protection with strict isolation measures. Dangerous microbes occur as a problem mostly in countries with low hygiene standards/high population density and in tropical-subtropical areas. Infection control must always be based on hygienic measures and strict infection protection.

This chapter is a short information about the most virulent and pathogenic agents, geographic area and severity of disease.

Keywords

Microbes · Dangerous microbes · Geographic area of virulent agents · Dangerous virus and bacteria · Zoonosis · VHF · Anthrax · Plague · Biosafety level 4 · Infection control · Survivors · High-risk microbes · Severity of disease

80.1 Dangerous Microbes

New, emerging or re-emerging infectious diseases and agents still appear. More than 15 new potential human pathogenic microbe types may be registered every year. New infectious diseases and emerging virulence properties still appear, for

Current agents are described in more detail in: Andersen BM. Part 1. Microbiology and infection protection. Fagbokforlaget 2014.

example, avian influenza viruses (H5N1 and others), HTLV and other retroviruses, HPV, Sindbis virus, Parvovirus, Bocavirus, Coronavirus, or bacteria like *Legionella*, *Borrelia*, group A streptococci and meningococci [1–5].

Virus not vaccine preventable or without specific treatment option, low infection dose and high capacity to survive in the environment will be a major problem if associated with incurable disease, disability or death. Virulent and dangerous microbes occur as a problem mostly in countries with low hygiene standards/high population density and in tropical-subtropical areas. Infection control must be based on hygienic measures and proper infection protection [2–7].

The most dangerous microbes for humans are those that are easily transmitted, virulent and invasive to the central organs like the blood and lung, robust survivors in the environment, have a low infection dose and are without any specific treatment or vaccine [2–5]. Most of them are zoonosis transmitted from animals and often with insects as vectors [8–12]. Dangerous microbes have also been used as biological weapons like anthrax, plague, botulism, *Coxiella*, *Brucella*, viral haemorrhagic fever (VHF) viruses, poxviruses and a number of other unusual agents [4, 13–25]. In the United States, there was an anthrax bioterrorism attack in 2001 [18, 19].

If the infectious agent and transmission ways are unknown and the situation is uncontrollable, it is important to follow pre-planned practical measures like strict isolation in negative air pressure isolation, registering of all contacts and the use of personal protective equipment (PPE) for air- and contact-borne infection [4, 8–13, 17, 20, 24, 26–29].

80.1.1 Dangerous Virus

During the last 20 years, there have been several large outbreaks of new and re-emerging viruses. Examples are systemic acute respiratory syndrome (SARS) (2002–2003), avian influenza viruses (H5N1, 2005), pandemic influenza (2009), Middle East respiratory syndrome (MERS) (2012) and Ebola (2014 and 2016) [1, 4, 5, 8, 11, 12].

VHF virus and a number of other special viruses are considered to cause the world's most dangerous infections with very high mortality, lack of therapeutic possibilities and often absence of effective vaccines. Such viruses are identified as high-risk agents or “biohazard-level 4” agents and are treated at the highest level of infection protection with strict isolation measures [4, 11, 12, 26–28].

- Virus families, with members especially dangerous to humans, are *Arenaviridae*, *Filoviridae*, *Flaviviridae*, *Bunyaviridae*, *Togaviridae* and *Paramyxoviridae* (Nipah encephalitis virus, etc.) and several others. They are mostly vector borne by insects and animals (zoonosis), dependent on a tropical-subtropical climate and temperature. Therefore, the colder zones in Europe, America, Asia and Australia are nearly free from more such serious infectious agents (see the table below) [1, 2, 4, 11, 12].

- Some very virulent viruses may be spread on all continents: TBE, RSSE, CCHF, rabies virus (*Rhabdoviridae*), avian influenza virus (AH5N1) and other high-pathogenic influenza viruses (*Orthomyxoviridae*). SARS and MERS (*Coronaviridae*) may be spread globally as nosocomial infections. MERS is a newly discovered coronavirus-zoonosis (dromedaries, bats, etc.) and acts as SARS, also with a tendency for nosocomial spread in hospitals, still going on in the Middle East. [30] These and other viruses are adapted to the climate and spread by direct transmission person-to-person, by increased mobility in the population and/or spread via new vectors, like animals, birds and insects [1, 4].
- A few of these dangerous viruses are vaccine preventable, and specific antiviral therapy is lacking in most cases.

80.1.1.1 Other New Virulent Viruses

- *Zika virus*—newly discovered flavivirus in South America, with mild to serious symptoms and teratogenic effect [11].
- *Polio-like illnesses*, especially among children, discovered in August 2014 in the United States. Probably caused by enterovirus D68 [31].
- *HIV aggressive variants* (CRF19) have been detected in Cuba in 2015 and earlier in Africa, with a faster course from infection to AIDS development [32].

80.1.2 Dangerous Bacteria

Bacteria resistant to antibacterial drugs have developed rapidly among staphylococci (MRSA), enterococci (VRE), tuberculosis bacilli (multidrug-resistant mycobacteria) and gram-negative rods (ESBL) in the last 30–50 years. From 2009 to 2010 onwards, super-resistant gram-negative rods (CRE, CPE) have increased rapidly with transmission of genes with total drug resistance (NDM-1) [1–5]. Bacteria sensitive to common antibacterial agents will probably not be a major problem in the future, unless changed antibacterial sensitivity.

- Anthrax is still endemic or hyperendemic on all continents in the world, mainly as a zoonosis among unvaccinated cattle [1–6, 13, 33]. It has been known for more than 4000 years and was earlier called “Black bane”. Natural anthrax in human is associated with contact with sick animals and animal products. The bacterium *Bacillus anthracis* is producing lethal toxins and spores that can survive in the environments for 100 years or more. Minimum infectious dose is 1–3 spores, and toxin-producing anthrax may cause skin, lung or intestinal anthrax, dependent on the transmission via contact, air or food. The non-skin anthrax has a very high lethality. Today, about 2000 people are infected each year, from eating or handling infected meat. During peace time, there are few incidents of threats using bioterror weapons like anthrax. However, autumn 2001 anthrax was spread in the United States by “powder letters” [18, 19].
- Plague, caused by *Yersinia pestis* (*Enterobacteriaceae*), is a zoonotic disease, vector-transmitted from infected rodents to humans via infected insects (fleas and lice)

[1–5, 8]. It is one of the great historical diseases. In the last 1500 years, plague has killed more than 200 million people during large epidemics (Black Death), especially from the year 1347. Still, plague causes bubonic-glandular pest, lung pest and/or septicaemia in 2000–3000 cases each year, and more than 10 outbreaks (Africa, Asia, Australia, Madagascar) have occurred since the year 2000 [8, 34].

- Cholera caused by *Vibrio cholera* is one of the great quarantine diseases, called “mother of all epidemics”, still very active in Asia and Africa. Cholera is associated with contaminated water, war and nature catastrophes, like in Haiti 2010, with 670,000 cholera cases (profuse diarrhoea) [1–5, 35].
- *Brucella* species (*Brucellaceae*) are one of the most important zoonotic diseases both for animals and humans all over the world. They easily spread via contact and air from animals and food, survive in the environment for months especially during colder seasons, are very easily transmitted and may cause nosocomial infections, chronic febris undulans, septicaemia and lung diseases. Vaccination of animals may eradicate the zoonotic disease [15]. *Brucella* are particularly related to laboratory outbreaks but are easily transferable outside the laboratory and are considered highly infectious [36].
- *Francisella tularensis* (zoonosis) is defined as a category A bioterrorism agent, highly infectious and increasing in the society, has low infection dose (one to ten bacteria) and can be inhaled or infected via food and water [1–5, 8]. Occasionally, such patients are detected in hospitals, even in the operating department [37]. Tularemia is a zoonotic disease or colonization among wild animals as rodents and hares and may survive at colder seasons for long periods in water, amoebas, birds and insects like ticks. The infection (skin, lung, intestine) is transmitted via contact with infected animals, inhalation of airborne bacteria, contaminated water and ticks.
- *Botulism* is caused by a bacterial-produced toxin (*Clostridium botulinum*) that causes paresis and is common in soil as spores [1–5]. The disease can be associated with toxin formation in contaminated and poorly canned foods, shrimp fish, bacon, etc. under anaerobic conditions and randomly affects both healthy people and vulnerable groups, such as infants who have had honey infected with the bacterium, which has happened repeatedly [38]. The toxin is the most dangerous we know and is on the list of bioterrorism.
- Family *Rickettsiaceae* is associated with many different types of small, intracellular microbes that are zoonotic and survive for a long time in the nature and in infected animals, birds, insects, water and amoeba [2, 3, 10]. *Coxiella burnetii* is a global zoonosis among animals like sheep and goats and may be airborne for several kilometres, causing frequent outbreaks of Q-fever in Europe in more than 4000 cases in the Netherlands during 2007–2010 [10]. *Rickettsia* species are more than 25 types, and many of them, especially the typhus group, are causing severe diseases. Humans are mostly infected by insects, including ticks from infected wild animals and rodents usually found in tropical or subtropical areas, but climatic changes, lack of good hygiene, war and natural catastrophes may spread these infections. During the period 1881–1920, 30 million people got epidemic typhus, and three million died in East Europe and Russia [2, 3, 10].

80.1.3 Other Bacteria That Are Causing Concern

- *Borrelia (Spirochetaceae)* has an increasing number of species that may infect human cases all over the world. The disease may cause chronic infections in the skin, muscles, heart, nerve tissue and brain. Borreliosis is a typical emerging zoonosis, spread via different ticks from animals and birds over large geographic areas and with large climatic variations [9].
- *Syphilis (Spirochetaceae)* and *Treponema pallidum* are old, historical diseases, transmitted via sex, from mother to child during pregnancy and via blood products. Now re-emerging and increasing worldwide [9].
- Other spirochetes or the like may cause zoonosis, like *Borrelia recurrentis* and *Leptospirosis* [9].
- *Burkholderia pseudomallei* is causing melioidosis, pneumonia, septicaemia, disseminated infection and shock. Incubation period may be up to 20–40 years. It is a long survivor in the environment (2–10 years), robust at tropical-subtropical temperatures >25 °C and is very dangerous. Endemic in Southeast Asia and may be spread by increasing globalization [1–5].

80.1.4 Other Infective/Dangerous Agents

- *Fungi and mould*—different types are especially related to floods, water damage, etc. and to contamination of medical products and equipment [39, 40]. Especially, the newly defined *Candida auris* may be very virulent.
- *Prion disease-new Shy-Drager syndrome* is rediscovered in 2015; Multiple-system atrophy (MSA) [5, 41].
- *Ricin* is a plant-derived toxin that is still used for bioterrorism in letters to, among others, President Obama [42].

Serious and unusual microbial infections

Microbes	Geographic area	Disease
<i>Virus</i>		
<i>Arena virus</i>		
Lassa	West Africa	Severe, often fatal
Guanarito	Venezuela	Severe
Junin (Argentine haemorrhagic fever-HF)	Argentina	Severe
Machupo (Bolivian haemorrhagic fever)	Bolivia	Severe
Sabia	Brazil	Severe
LCM	Global	Mild to severe
<i>Filovirus</i>		
Marburg	Africa	23–100 % fatal
Ebola	Africa	20–100 % fatal

Microbes	Geographic area	Disease
<i>Bunyaviridae (over 60 viral types from asymptomatic to fatal)</i>		
Rift Valley fever	Africa	1 % develops HF
California enceph	United States, Europe	2 % fatal
Crimean-Congo haemorrhagic fever (CCHF)	Africa, Asia, Europe	Severe
Hantaan group	North and South America, Europe, Asia	Moderate to severe
<i>Arbovirus (Togaviridae and Flaviviridae)</i>		
Tick-borne (TBE) encephalitis virus complex	All continents	Moderate to fatal
Russian spring and summer encephalitis (RSSE)		
Omsk haemorrhagic fever		
Central European encephalitis viruses		
Venezuelan equine encephalitis virus		Moderate to severe
Yellow fever virus	Africa, America	Moderate to severe
Semliki Forest virus	Africa, epidemic	Mild to fatal
Dengue virus	All tropical-subtropical areas	Mild to fatal
Japanese B encephalitis	Asia; Korea, Japan, Philippines	Often fatal
<i>Rabies</i>	In all parts of the world	100% fatal without tr.
<i>Monkey pox (B)</i>	Animal experiments	Severe, often fatal
<i>Smallpox Virus</i>	Eradicate, but kept	Severe, often fatal in unvaccinated
<i>Avian influenza A H5N1</i>	Asia, Africa, Europe	80% fatal without treat
<i>Nipah encephalitis virus (paramyxovirus)</i>	Asia, Malaysia, India, Bangladesh	75% fatal
<i>Corona Virus</i>		
Systemic acute respiratory syndrome (SARS)	Asia, Canada, proliferation	Severe, 10% fatal
Middle East respiratory syndrome (MERS)	Middle East, emerging	Severe, 30–40% fatal
Bacteria		
<i>Rickettsiaceae</i>		
<i>Rickettsia</i>	All continents	Many types, severe
<i>Orientia</i>	Asia, Australia	Moderate to severe
<i>Bartonellaceae</i>	All continents	Moderate to severe
<i>Coxiella burnetii</i>	All continents	Moderate to severe
<i>Bacillus anthracis</i>	All continents	Moderate to severe
<i>Brucella</i>	All continents	Mild to severe
<i>Burkholderia pseudomallei</i>	Asia	Mild to severe
<i>Francisella tularensis</i>	All continents	Mild to severe
<i>Vibrio cholera</i>	Asia, Africa and South America	Mild to severe
<i>Bacillus anthracis</i>	All continents	Moderate to severe
<i>Yersinia pestis</i>	Africa and Asia	Moderate to severe

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Abstract

Outbreaks of infectious diseases during peacetime or in disaster/war-related conditions, may most often need an effective crisis management in the hospital. The emergency preparedness in hospitals may vary within, and between countries, dependent on endemic and epidemic conditions, capacity, knowledge and economy. Lack of preparedness may result in a high risk of disease burden and death and cause a high economic impact on the health care.

Keywords

High-risk microbes · Lassa/Ebola/SARS/MERS/Nipah/avian influenza and other viruses · Anthrax/pest/cholera/diphtheria and other bacteria · Emergency Preparedness · Crisis management · Infection control · Isolation · Disinfection

81.1 Purpose

- Protect the healthcare institution and the society in general:
 - Against spread of infection during outbreak of unusually infectious and universal very dangerous disease
 - Unusually high number in the society of transmitted contagious disease in peacetime, in disasters, and when the country is in war or when war threatens
- Have an emergency plan for how to act in situations of such outbreaks.

81.2 Comprise

- All persons responsible for the emergency plan and for implementation of the plan
- Determined by epidemic situation and the type of infectious agent

81.3 Responsibility

The hospital's management/crisis management in cooperation with the emergency response team for infection control supervises the work at the hospital in cooperation with national health authorities and county governor [1–7].

The Directorate for Social Security and Preparedness is responsible for the national risk image and for follow-up. (DSB, Norway 2014)

Law on Health and Social Preparedness for Infectious Diseases may be present and implemented in some countries, like in Norway [1].

Emergency Plans, Guidelines and Reports are made for outbreaks of infections like anthrax, SARS, avian influenza, pandemic influenza, MERS, Ebola, etc, see Table 80.1 [1–64], Chap. 80.

- **National**—example Norway [1–15]
 - **Local**—example Ullevål University Hospital, Oslo [16–34, 52, 53]
 - **International**—WHO, ECDC, CDC, UK, etc. [35–51]
-

81.4 Practical Measures [23]

Epidemiological conditions—concerning infectious diseases:

81.4.1 “Normal” Conditions

Globally, there are endemic and epidemic conditions that may vary by time, localisation and use of antibiotics and still be perceived as “normal” for this actual country [65–77]. Special infections, like resistant microbes, are increasing in most countries in the world, and WHO made in 2017 a priority list of 12 families of bacteria (“nightmare” bacteria) that agency experts say “pose the greatest threat to human health and kill millions of people every year” (WHO 27 Feb 2017) [67]. In 2017 CDC identified more than 220 samples of these “nightmare” bacteria containing unusual resistance genes in the United States and more than 1400 isolates from clinical samples of 32 states during the first 9 months of 2017 [66–70]. The endemic and epidemic conditions of these resistant bacteria vary between countries and are associated with risk of deaths, a high disease burden and death and an overall economic impact, reducing the gross domestic product (GDP) up to 1.6% [70].

Resistant microbes usually follow patients and personnel with “import status” (from other countries or areas with endemic conditions) and are caught early in the process by good routines and preliminary investigations [52, 53, 73–77]. Import routines (testing for MRSA, ESBL, CRE, CP, VRE, TBC, etc.) work usually well at the hospital, both for patients and for personnel (MRSA and TBC) [52, 53, 71–75]. Resistant microbes create even larger problems in primary care.

Healthcare professionals are generally exposed to infection if relevant precautions are not used. About 5–10% of MRSA-exposed healthcare persons may be infected or carriers with MRSA, and 10–20% of infected may need treatment, long-term sick leave, etc. [74–76] Screening of healthcare contacts of patients infected with carbapenemase-producing, very resistant bacteria with super-resistant genes in the United States found that one in ten was colonized with these bacteria [66].

Annual norovirus epidemics occupy the isolation capacity and lead to high sickness absence among infected healthcare professionals. Winter epidemics of RS virus and rotavirus in infants and flu outbreaks in all age groups occur each year. These are normal epidemiological conditions.

See also pre-examinations of patients, Chap. 47 and different isolation procedures, Chaps. 14–19.

81.4.2 Sporadic Outbreak of Serious Infectious Disease: Import Disease

Preparedness measures depend on the agent, extent and rate of development. As a rule, such infections are far from most countries in Europe, such as SARS, bird flu and Ebola, and are usually taken care of where they occur. It may rarely lead to import, for example, Ebola-infected healthcare personnel transported to actual homeland for treatment, in 2014.

81.4.3 Disasters: Natural or Inflicted—and Bioterrorism

The hospital emergency preparedness plan/disaster plan must be available and followed after adaptation to the current situation.

A number of natural disasters lead to increased risk of outbreaks of serious epidemics in society such as earthquakes; floods; tsunami in holiday paradises; earth, stone or clay landslides; snow avalanches; extreme heat; radiation damage; hurricane/tornado; fire over large areas; volcanic eruptions; explosions; etc. The disasters may cause a heavy load on the healthcare system in general [54]. This may happen in own country or harm own citizens abroad [1, 3, 4, 12].

War-related or disaster-related measures at terrorist attacks against the population often cause major damage and spread of infections due to a paralysed infrastructure. Bioterrorism, for example, by anthrax can cause uncontrolled epidemic outbreaks in the population; *see separate chapter*.

The result could be a massive destruction or paralysis of infrastructure such as water and sewage, energy supply, transport system, access to food and water, healthcare systems, broken hospitals and communications networks, etc.

In such statements it is important to have both disaster plans and infection control plans in place, like the examples published from CDC [54–64, 78–82].

Proposal for a mandate for the emergency response group for infection control/crises team [23]:

- The director at the hospital has overall responsibility and determining authority and leads the emergency group.
- The emergency group shall advise on unusually large outbreaks, particularly dangerous microbes, in an uncontrollable epidemic and in disasters/state of war/ suspected biological sabotage.
- The emergency group shall be adviser before, during and after the situation described above and shall propose preventive measures and guidelines in the current situation.
- Infection control leader coordinate the infection protection according to what is determined, in the same way as under normal conditions.
- Under normal circumstances, the emergency group meets once a year with ongoing updating of the action plan. The director summon for the meeting.
- In case of epidemic outbreak, particularly dangerous microbe or uncontrollable situation, the director summons the hospital's disaster leader in cooperation with the infection control leader for emergency group meetings. The group meets so often it is necessary to come up with updated recommendations and measures.

81.4.4 Suggestions to Members of the Emergency Response Group

81.4.4.1 Permanent Members

- The director (manager)
- Assistant hospital director
- Head of disaster committee or equivalent (deputy head)
- Emergency chief
- Information officer
- Head of Infection Control Department (coordinator for disease prevention) [82]
- Head of the Department of Infectious Diseases
- Head of the Department of Medical Microbiology
- Head of the Department for Internal Service, prehospital service (ambulances), etc.
- Hospital medical officer

81.4.4.2 Situational Members

Head of the department(s) with the problem(s), external participants from the state and municipal health authorities, safety overseer, HR representative.

81.4.5 Work Tasks at Situation of Increased Preparedness

The emergency preparedness group assesses the situation on a continuous basis and checks that:

- Competent infection control personnel (hygiene nurses, infection control doctor, epidemiologist, etc.) are available and can provide advice and guidance as well as carry out preparatory control measures regarding:

- Isolation regime and routines for the actual patient group
- Written infection control procedures for patients, personnel and visitors
- Personnel access to and use of personal protection equipment (PPE)
- Control of isolates (air pressure and function)
- Triage—practical plan
- Patient logistics, to avoid spreading to other patients
- General infection control at the hospital, including cleaning and disinfection
- Other prophylactic measures such as vaccines and drugs
- Special measures for infection-exposed persons and especially susceptible persons (patients, personnel and visitors)
- *Infection isolates*: A written updated overview must be available for all types of isolates and single rooms at the hospital. The required number and quality must be calculated. The isolates must be routinely checked for ventilation and negative pressure—by the technically responsible at the hospital.
- *Cohort treatment and mobilization*: There should be a feasible plan for cohort treatment of patients that have the same diagnostic type of infection, mobilization and relocation of other patients and an escalation plan for more beds in cooperation with other hospitals, health institutions, etc.
- *Competent hospital staff* (doctors, nurses, cleaners, porters, ambulance staff, service units, etc.) must be available for the appropriate infection control work, in addition to treatment staff. Resources must be considered.
- *Infection control equipment* should be available and sufficient (respirators, tight-fitting goggles, double gloves, infection gown, cap/hood, coverings of the head/neck, room-bound shoes/shoe coverings, decontamination equipment/machines and chemical disinfectants, including hand disinfectants) and in accordance with the actual infectious agent (see isolation procedures).
- *Vaccines* that are currently preventive should be made available from defined stocks within a certain time limit (flu, rabies, anthrax, plague, smallpox, diphtheria, tetanus, polio, BCG, haemorrhagic viruses, etc.).
- *Drugs and specific immunoglobulins* should be made available from defined stocks as needed.
- *The escalation plan* must be available for further treatment and isolation of patients and exposed personnel, including healthcare professionals.

81.4.6 Intentional Infection: Bioterror and High-Risk Science Laboratories [79–83]

The Norwegian biotechnology community has warned about inadequate preparedness—easy to spread disease and hazardous agents in drinking water, air or food [83]. This is a well-known phenomenon for many other countries. Biosafety level 4 is the strictest level of safety where dangerous infection is identified and worked on. Nonetheless, infection occurs, and biologically dangerous and living agents have—by misunderstanding—been sent from such laboratories [84]. Work in high-risk laboratories is complicated and not everyone is equally well-trained [85].

There is a great variety in Europe in terms of quality of how high risk-infected patients become isolated [86, 87]. Checklists for infection control at high-level isolation have been designed and tested for five special units in Europe: in France, Germany, Italy, England (London) and Sweden (Linköping) [88]. The isolation unit was checked for separate entry for healthcare personnel and infected patient, safety control and security personnel, constant power and throughput autoclaves. The isolation room was checked for internal communication system, negative air pressure indicators, self-closing doors and separate/private bathroom/toilet. It is also checked for medical technical devices for intensive treatment and diagnostics and infection control procedures such as the use of PPE, hand hygiene, disinfection and waste management, external and internal transport, training in infection control and post-mortem treatment [88].

Guidance for outbreak response and incident management is recently made for acute care hospitals in the United States [89].

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Scenarios: Serious, Infectious Diseases

82

Abstract

Scenarios for serious, infectious diseases are important procedures used to understand the special microbe's behaviour (clinical illness, spread of infection, etc.) and how to act most rational during special dangerous outbreaks. Furthermore, scenarios describe how to handle patients, personnel and others possibly exposed to infections,- outside and inside the hospital- to stop spread of the infection as soon as possible. Today, it is not acceptable to place a patient with a known high-risk, serious infection in the same hospital room as other patients with not the same disease (WHO). In this chapter, some seldom but realistic scenario is described to better understand how to react and treat patients to stop spread of microbes during the primary phase of dangerous transmittable diseases.

Keywords

High-risk microbes · Scenarios · Transmittable dangerous agents · Lassa/Ebola/ SARS/MERS/Nipah/avian influenza and other viruses · Anthrax/pest/cholera/ diphtheria and other specific dangerous bacteria · Emergency · Preparedness Crisis management · Infection control · Isolation · Disinfection

82.1 Purpose

- Describe some rare but not unthinkable scenarios in the primary phase of dangerous transferable diseases.
- Describe certain important scenarios and practical measures to avoid spread of life-threatening disease among roommates, other patients or personnel, equipment or environment [1–3].

Current agents are described in more detail in: Andersen BM. Part 1. Microbiology and infection protection. Fagbokforlaget 2014.

82.2 Comprise

- All personnel who are the first in contact with the infected/exposed person, relatives, other contacts and environment.
 - *It is not acceptable to place a patient (with not defined same disease) in the same room with a patient with known high-risk infectious disease (WHO).*
-

82.3 Responsibility

The hospital's management provides written plans for how to react in situations where personnel and others may be exposed to known/unknown serious communicable disease and a practical arrangement for how to handle the situation.

The *infection control officer* at the level of where the problem occurs, and at the departments/ward where the infection may spread, is responsible for following local emergency plans.

Personnel who unprotected have come in a seriously contagious situation and may have been exposed to infectious agents are responsible for contacting the nearest responsible/infectious unit for advice and of following written guideline and practical advice.

82.4 Practical Measures [4]

- *The patient* (infected/suspected infected) is usually relatively easy to deal with since there are guidelines for preventing spread of infection and treating the patient for the current disease; see *isolation routines*.
- *Contacts exposed to infection* are often worse to handle since it may be larger numbers of people (travel company, etc.) and because fear of being infected itself creates uncertainty. Therefore, some imaginable scenarios are made that deal with infected contacts.
- *Transport by ambulance*. All transport of infectious patients from the place of arrival to the hospital should take place in ambulances using the same infection control regime as for the individual infectious disease (contact infection, air-borne infection, strict isolation); see *isolation regimes*; Chaps. 14–19 and chapter on *transport of patients*; 75. *The infection regime should be in accordance with information/suspected findings and contact infection control personnel to ensure that this is the correct isolation level.*
- Always use respiratory protection and PPE in case of suspected pulmonary tuberculosis and other highly infectious, severe diseases, and use a surgical face mask or respiratory protective device (P2-P3 mask without valve) on all patients with respiratory symptoms.

82.5 Scenarios

82.5.1 Suspected Viral Haemorrhagic Fever (VHF) or Similar High-Risk Infection [4–6]

(Lassa, Ebola, Marburg, Machupo, Guanarito, Junin, Sabia, Nipah, Congo-Crimean, etc.)

82.5.1.1 Patient: Strict Isolation Airborne Infection in Isolate with Negative Air Pressure

Example: person from Liberia visiting relatives in Oslo in spring 2014. Sick 10 days after arrival in Oslo. He attended a number of family gatherings. At the onset of disease (*fever, respiratory symptoms and skin bleeding*), he lived with a family of eight people in Oslo. Medical contact was taken after 3 days of illness. In all, there had been 20 contacts with the patient after he became ill, and before Ebola virus, infection was suspected. He was admitted directly to the isolate for airborne infections with direct access from outside. Ambulance staff was pre-equipped (PPE) for transport of patients suspected of VHF. The municipality's infection control doctor is notified and takes responsibility for the message, measures and follow-up outside the hospital together with the emergency preparedness group for the municipality.

- *Unlikely in countries like Norway.* However a verified Ebola patient was imported autumn 2014. The patient came to the country as a high-risk infection patient and treated as such at Ullevål University Hospital, Oslo.
- *Quarantine disease.* Usually no more than one to two cases that (unexpectedly) get symptoms in Norway or while travelling to Norway. It is most likely that the symptoms come after arriving to Norway (2–21 days of incubation).
- *Registration.* Close contacts (name, address, telephone number and contact level with the patient). If sick on plane/boat/train, etc. to Norway, fellow passengers (same cabin/room/flight) must be registered.
- *Ambulance* personnel and other personnel use—*in suspicion*—infection control routines for VHF on contact and transport of the patient (see serious viral disease and personal infection prevention). Use respiratory equipment (P3 mask) and personal protective equipment (PPE), and put on a surgical mask on the patient.
- *Remember! Once too much is better than once too little!*
- *Risk of spread of VHF.* There is no significant risk of infection in Norway if the proper use of protective equipment is used when handling such patients. The Ebola outbreak in 3 African countries in 2014 showed that almost 30,000 were registered ill, more than 11,000 died, 800 health professionals became ill and more than half of them died. Lack of use of PPE and proper infection control led to escalation of the epidemic. The staff used only 1 m distance from the patient

as a zone of infection, as recommended by the WHO and CDC, and lacked protection for the head, hair and neck when within the 1 m zone and used only ordinary masks [7–10]. This occurred despite the fact that Ebola is defined as a high-risk, biosafety level 4 infection in which airborne infection could be relevant [11–14]. The epidemic declined from 14 September 2014, following the introduction of more proper use of personal protection equipment and infection control routines [11, 12, 15].

Contacts are differentiated after infection risk:

1. *High-risk contact*: physical contact with VHF, or with blood secretion or excretion. Healthcare staff, ambulance staff, laboratory staff, family or others who have treated the patient before admission.
2. *Low-risk contact*: been in the same room with the patient after the onset of the disease, but not in direct contact with the patient, equipment or others in the room. Examine the contacts; measure temperature two times for 3 weeks.
3. *Transmission from healthy contacts is considered unlikely*. However, everyone who has been in the same place at the same time with a VHF sick patient should be informed and followed up.

82.5.1.2 Monitor Contacts at Home

If probable or verified VHF, inform the contacts—low chance of infection:

- The contacts keep calm at home and measure the temperature daily two times for 3 weeks after the last contact with the index patient. No crowding with many people and no use of collective traffic.
- If temperature 38 °C or more, or rash/flu symptoms/sickness, contact the infection medical department.
- If this cannot be achieved at home, the contact may come to defined outpatient clinic for temperature measurement by appointment or is admitted to hospital.
- Served with food, etc. brought out from store to door, possibly, while isolated at home.

82.5.2 Multidrug-Resistant Bacteria: Outbreak of Infection

MRSA (methicillin-resistant *Staphylococcus aureus*), vancomycin-resistant MRSA, penicillin-resistant pneumococci, super-resistant gram-negative bacteria (ESBL, CRE,CP, NDM-1 bacteria), multidrug-resistant tubercle bacteria (tuberculosis), vancomycin-resistant enterococci (VRE), etc. evaluated in collaboration with microbiological laboratory. This was especially observed during the major tsunami disaster in 2004 [16]. Serious problems can occur in areas with melioidosis and other highly virulent bacteria.

82.5.2.1 Patient: Isolated in Accordance with Bacterial Type and Routines (Contact and/or Air Isolated)

In hospital, not usually many at the same time, but dependent on endemic situation. The patient can be contact or air isolated, depending on the infectious agent.

- *Registering* of direct contacts—depending on the infectious agent (name, address), and include where the patient have been earlier (information).
- *Ambulance* personnel and other personnel use routines for the relevant infection type according to *isolation procedures* and in accordance with emergency department's report. In case of doubt, contact infection control personnel.
- Use respiratory protection, P3 mask, if suspecting pulmonary tuberculosis, and put a surgical mask or P2/P3 mask without a valve on the patient in case of suspected pulmonary tuberculosis or respiratory tract infection.

Contacts/carriers—differentiated follow-up—low chance of getting sick:

1. Treated/controlled by the municipal infection control team in collaboration with infection protection personnel according to the type of infection.
2. Carriers live at home with eventually contact infection restrictions as defined and followed up by the Municipal Infection Surveillance Authority.
3. During stays at nursing homes, other hospitals, and in home nursing, these are followed up by the municipal infection physician/institution's physician in collaboration with infection control personnel.
4. In case of pulmonary tuberculosis, follow the defined guidelines for the control and follow-up of unprotected contacts according to defined routines (tuberculin test, screen check, clinical examination; *see separate chapter*).

82.5.3 Notification of Air Passengers with “Cholera” at Oslo Airport

82.5.3.1 Patient Is Contact Isolated

Example: Three people in a Norwegian travel company get voluminous, watery, painless diarrhoea on return from Bangladesh, just before landing at Oslo Airport, Gardermoen. Due to a loss of fluid, they were transported with an ambulance equipped for “import infection” and admitted directly into contact isolation. Municipal infection control doctor is notified and is responsible for reporting, measures and follow-up outside the hospital together with the municipal emergency response group.

This is one of the old, major quarantine diseases. Only a few get sick (top of the iceberg), i.e. 1–4 patients out of 1000 infected. There is a low mortality by proper treatment (<5%). The transmission risk is relatively low due to good hygiene and good sanitation in today's Norway and other developed countries. Most patients are shedding bacteria in large amounts and are also carriers without symptoms. Patients are isolated with contact isolation regimens.

The infection can reach unmanageable heights in disaster areas, by hunger, contaminated water supply and destroyed infrastructure. Following the natural disaster in Haiti, cholera was introduced with infected helper crew from Asia (carriers), and an epidemic started in 2010, which in 2013 had increased to 670,000 cholera patients, 370,000 hospitalized and 8200 deaths [17].

- *Registering* of contacts and remaining passengers in the airplane and from same travel company (name, address, telephone number).
- *Ambulance staff* and other personnel use the contact regime. If risk of spills, etc., use also surgical mask, visor and cap in addition to gloves and gown/overall.

Contacts/carriers of infection—low chance of getting sick:

1. Sampling (feces sample) from close contacts—those that may have the same source of infection as the index case (same travel company).
2. Enhance hand hygiene and personal hygiene for all.
3. Contact outpatient clinic for infections directly by gastrointestinal symptoms—contact by phone in advance.

82.5.4 Diphtheria After a Bus Trip to Moscow

82.5.4.1 Patient: Strict Isolation—Airborne Disease Isolation with Negative Air Pressure

Example: An elderly woman who recently attended a bus trip to Moscow became sick 2 days after returning to Oslo. She had sore throat, fever, cough and eventually a white, firm-sitting “plaque” in the throat. She was hospitalized after 3 days because of suspected diphtheria. Contact persons and other close contacts were contacted for follow-up and treatment with erythromycin (according to resistance pattern).

Municipal infection control doctor is notified and is responsible for reporting, measures and follow-up outside the hospital together with the municipal emergency response group.

Diphtheria may still be periodic problems in Eastern Europe and many places in the world. Vaccination status is good in children in most countries but more uncertain in elderly, especially in women. This is a contact and airborne infection, relatively highly infectious. There are probably few cases in an outbreak due to herd immunity. Patients are isolated with air and contact isolation regime until free from bacteria (negative culture). A historically serious infectious disease also in Norway, with high mortality rates until the middle of the last century [18]. Ullevål Hospital, Oslo, introduced treatment with the diphtheria serum in 1914 and achieved an impressive response—from 20–35% mortality to 3–5% [19].

- *Registering:* All exposed persons (name, address, telephone number) and follow-up; see below.

- *Ambulance staff* and other personnel use the contact and airborne infection regime when picking up and transporting a patient. Use respiratory protection, visor and cap in addition to gloves and gown/overall, and put a surgical mask on the patient.

Contacts/carriers of diphtheria are differentiated—vaccination protects against disease:

1. Sampling (nasopharynx samples) of *all* exposed persons (even if vaccinated and are not sick, you may be a carrier).
2. Prophylactic/therapeutic treatment with erythromycin may be initiated rapidly.
3. If living at home, others should not be exposed to infection/carrier state.
4. Short-time airborne isolation may be relevant for carrier or exposed to infection until the infection state is clarified/effect of antibacterial therapy.
5. Booster vaccine against diphtheria is considered for all contacts.

82.5.5 Lung Pest Plague After Stay in Madagascar, Sick on the Plane Home

82.5.5.1 Patient: Strict Isolation—Negative Air Pressure Isolation

Example: A person of a family of five who has stayed in Madagascar for a month got sick on his way home to Norway. He coughs, has fever and develops skin rashes that resemble big boils, especially in the groin. He was admitted directly to strict isolation in hospital and suspected of serious import infection.

The municipal infection control doctor is notified and is responsible for reporting, measures and follow-up outside the hospital together with the municipal emergency response group.

- *Quarantine disease:* Periodic problem in the East Asia, especially India, and ongoing outbreaks in Africa, Namibia and Madagascar. Pest may be a war-related disease (biological warfare). Untreated dies more than 50% of the cases while, with streptomycin treatment, less than 5%. This is a typical airborne disease, relatively highly infectious when respiratory tract symptoms. There is usually small outbreak with few cases (1–2). Air and contact infection regime until free for bacteria. In November 2014, new pest outbreaks were reported in Madagascar. About 120 patients got sick, of whom 40 died of bubonic plague [20]. The infection spread rapidly between humans and “killed quickly” [20]. Multidrug-resistant *Yersinia pestis* is described in this country [20].
- *Registering:* All infected persons (same travel company, all in the same flight home) are registered (name, address, telephone number) and followed up.
- *Ambulance staff* and other personnel use the contact and airborne isolation regime when picking up and transporting a patient. Use respiratory protection (P3 mask), visor and cap in addition to gloves and gown/overall, and put a surgical mask on the patient.

All close contacts/carriers are isolated to infection state is clarified—little chance of getting sick:

1. Sampling from all exposed persons
2. Prophylactic/therapeutic treatment, eventually vaccine
3. Short-time airborne isolation of exposed cases until the infection state is clarified/effect of antibacterial therapy

82.5.6 Anthrax After Staying in Turkey, Sick on the Plane Home

82.5.6.1 Patient: Strict Isolation—Air Pressure Isolate with Pressure [21, 22]

Example: Two out of six people who have been on family visits in Turkey for a week, on farms with goats and skin production, are acutely ill on the plane home with cough, shortness of breath and fever. Upon arrival, the emergency outpatient clinic was contacted by the patients who were immediately transferred to intensive care unit for airway symptoms and suspected import infection. At the hospital, anthrax is suspected, and patients are strictly isolated in air isolate and treated.

Municipal infection control doctor is notified and is responsible for reporting, measures and follow-up outside the hospital together with the municipal emergency response group.

- *Endemic problem* in several places (Asia, Africa, Middle East, North and South America), war-related (biological warfare). Varying number of cases of anthrax at outbreaks during peacetime, depending on how many people have eaten, for example, infected food, etc.
- *Symptoms:* 95% are cutaneous, 5% are respiratory, and a few cases are gastrointestinal anthrax. The latter two are two-phasic and almost always fatal.
- *The bacterium Bacillus anthracis* is a spore-forming, resistant, gram-positive rod that survives nearly infinity in the environment if not removed. The bacteria are usually penicillin-sensitive.
- *Infection:* Person-to-person infection is unlikely, but hospital infection is described. Air and contact regime is conducted around such patients in hospitals until free of bacteria (ca 24 h treatment); however spores may survive for a long time.
- *Registering:* All directly exposed persons are registered (name, address, telephone number) and followed up.
- *Ambulance* personnel use contact and airborne regime for patient pickup and transport. Use respiratory protection (P3 mask), visor and cap in addition to gloves and gown/overall, and put a surgical mask on the patient.

Contacts/carriers—low risk of getting sick:

1. Sampling and antibacterial treatment are offered to all contacts that may have a common source of infection with the index patients (travel company, co-passenger). Person-to-person transmission is unlikely.

2. Vaccine may, in addition to antibacterial treatment, be applicable to people with a common source of infection with the index patients—when risk of large outbreaks (note that vaccination should be discussed due to some serious adverse reactions).
3. While waiting for result of the sampling, close contacts live at home with contact isolation restrictions.
4. In case of detected anthrax in contact (incubation phase for disease 3–7 days), the person is isolated and treated, and vaccination may be assessed for close contacts.

82.5.7 Rabies

82.5.7.1 Patient Is Isolated

This is an endemic problem among wild animals in most countries. Person-to-person transmission is unlikely. It is almost never reported more than one case at a time, infected by animal bites or licking but occasionally without known exposure. Close contacts/exposed persons are registered.

- *Registering:* All exposed persons are registered (name, address, telephone number) and followed up.
- *Ambulance staff* and other personnel use the contact and airborne regime when picking up and transporting a patient. Use respiratory protection and PPR; put a surgical mask on the patient.

Contacts/exposed—low chance of getting sick:

1. Close contacts/exposed persons are assessed for vaccine and rabies immunoglobulin.
2. Followed up at the infection outpatient clinic.

82.5.8 SARS and MERS: See Separate Chapter

Patients and contacts are treated just like at VHF.

82.5.9 Avian: Pandemic Flu (API) (See Separate Chapter)

Patients and contacts are treated mainly like VHF.

82.5.10 New Contagious Severe Disease: Unknown Agent and Pathway

See also SARS and bird flu.

New infectious diseases and agents still appear, for example, SARS, avian viruses (H5N1), HTLV and other retroviruses, HPV, sindbis virus, parvovirus, bocavirus, coronavirus, etc., or bacteria like *Legionella* and *Borrelia*, or agents with virulence changes, like group A streptococci, meningococci, etc.

- *Biological terrorism* made anthrax, plague, botulism, *Coxiella*, *Brucella*, VHF, poxviruses and a number of other unusual agents more appropriate as biological weapons [21–41].
- *Bacteria* sensitive to common antibacterial agents will probably not be a major problem.
- *Viruses* with no vaccine or treatment against low infection dose and high capacity to survive will be a major problem if associated with incurable disease, disability or death.
- It is probable that this will be a problem first in countries with low hygiene standards/high population density.

If the infectious agent is unknown, transmission ways are unknown and the situation is uncertain or uncontrollable, this practical measure may be followed:

Patient and contacts: strict isolation—negative air pressure isolation

1. Serious illness: isolation of index case and all contacts
2. Less severe disease: isolation of index case and close contacts
 - *Registering*: All exposed persons are registered (name, address, telephone number) and followed up.
 - *Ambulance* personnel use contact and airborne regime for patient pickup and transport. Use respiratory protection (P3 mask), visor and cap in addition to gloves and gown/overall/shoe covers/dedicated shoes, and put a surgical mask on the patient.

82.5.11 Other Dangerous Agents/Infections

- *Botulism* is caused by a bacteria-produced toxin (*Clostridium botulinum*) that causes paresis and is common in soil as spores. The disease can be associated with toxin formation in contaminated and poorly canned foods, shrimp fish, bacon, etc. under anaerobic conditions and randomly affects both healthy people and vulnerable groups, such as infants who have had honey infected with the bacterium, which has happened repeatedly [42]. The toxin is the most dangerous we know and is on the list of bioterrorism.
- *Brucella* bacteria (zoonosis) are particularly related to laboratory outbreaks but are easily transferable outside the laboratory and are considered highly infectious. [43]
- *Francisella tularensis* (zoonosis) is defined as a category A bioterrorism agent, highly infectious and increasing in the society, has low infection dose (10–25

- bacteria) and can be inhaled or infected via food and water. Occasionally, such patients are detected in hospitals, even in the operating department [44].
- *MERS—Middle East respiratory syndrome*—newly discovered coronavirus zoonosis (dromedaries, bats, etc.) and acts as SARS, also with a tendency for nosocomial spread in hospitals. In 2015 there were 1100 cases, of which 40% died [45].
 - *Polio-like illnesses*, especially among children, were discovered in August 2014 in different states in the United States. Probably caused by enterovirus D68 [46].
 - *HIV—aggressive variants* (CRF19) have been detected in Cuba in 2015 and earlier in Africa, with a faster course from infection to AIDS development [47].
 - *Prion disease—new Shy-Drager syndrome* is rediscovered in 2015; multiple-system atrophy (MSA) [48].
 - *Ricin* is a plant-derived toxin that is still used for bioterrorism in letters to, among others, President Obama [49].
 - *Fungi and mould*: different types that are especially related to floods, water damage, etc. and to pollution of medical products [50–53]. In Norway, a recent overview of candida in blood cultures showed a stable state for the past 22 years [54].
 - *Zika virus*: newly discovered flavivirus with mild to serious symptoms and teratogenic effect [5].

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Abstract

All persons staying in hospitals should be protected against exposure to infectious agents, and especially to high-risk, dangerous agents - that pose a risk to health and life. It is not acceptable to place a patient with a known high-risk, serious infection in the same hospital room as other patients (WHO). In this chapter, the preparedness of isolation capacity and escalation of hospital beds for patients with dangerous infections are described.

Keywords

Isolation capacity · Cohort isolation · Contact isolation · Airborne isolation
Escalating increased need of beds

83.1 Purpose

- Describe the need for preparedness concerning isolation capacity in case of serious outbreaks and escalating need for isolation beds.
- Evaluate in cooperation with other hospitals (regional, national) the acute need for isolation capacity.
- Evaluate measures to handle outbreaks during normal epidemiological situation, smaller outbreaks and large outbreaks [1–3].

83.2 Comprise

- The hospital' management, infection control personnel and all persons responsible for the emergency plan and for implementation of the plan.

83.3 Responsibility

The hospital's management, emergency group and infection control personnel provides updated written information concerning isolation capacity and types in the hospital and the actual region.

The decision of increased need of isolates, more special trained personnel and equipment is made in cooperation with emergency team and with regional and national infection control coordinators.

Department management has the overall responsibility for ensuring that isolates are functioning as they should and that routines are followed.

83.4 Practical Measures [4]

83.4.1 Patients with Infections: Need for Isolation Units in Hospitals

Normal situation—concerning infectious diseases caused by bacteria—is dependent on endemic situation, use of antibiotics and development of resistance.

- In Scandinavian countries like Norway, at least 20% of hospitalized patients may have infections—community or institutional associated—and 20–30% receive antibacterial agents, prophylactically or therapeutic [4–8]. Approximately 20% of all admitted patients need at minimum a single room due to risk of transmission of infections. At least 10% of nosocomial infections are transmitted via droplets—airborne [4–8].
- At least 5% of invasive *Escherichia coli* in Scandinavia were resistant to third-generation cephalosporins in 2016, while up to 50% were resistant in countries in the south of Europe [9]. The EARS-Net surveillance data for 2016 showed a pattern of more resistant, invasive bacteria in the south than north of Europe, for *Klebsiella pneumonia*, *Acinetobacter* sp., MRSA and *Enterococcus faecium* [10].
- The consumption of antibiotics in the community was up to 20 DDD per 1000 inhabitants per day in Scandinavia, while up to 36 DDD per day in the south of Europe in 2016 [10].
- The consumption of antibiotics for systemic use in the hospital sector was 1.4–2.1 DDD per 1000 inhabitants per day, in Norway, Sweden and Denmark and higher, up to 2.9 DDD, in Finland that included remote primary healthcare centres and nursing homes [10]. The population-weighted mean consumption of antibiotics for systemic use in the hospital sector in Europe/EEA was 2.0 DDD per 1000 inhabitants per day [10].

Local outbreaks of, for example, norovirus, rotavirus, influenza virus, metapneumovirus, respiratory syncytial virus (RSV) or resistant bacteria from home and abroad double the need for isolates or single rooms in hospitals in periods.

Influenza pandemics it has previously been estimated that in larger outbreaks, 0.3% of the population will need hospitalization, and approximately 13% need outpatient treatment. Capacity and readiness for escalating—if needed—should be calculated and included in emergency preparedness plans in and outside hospitals. In such cases it may be appropriate to request *predefined*, newer hotels or healthcare institutions.

For example, the need in the Oslo region with about 800,000 inhabitants would be 2400 additional hospitalizations of isolation-needing patients over a short period of 1–2 months. If the average stay would be 10 days and the patients were equally distributed over this period (which is not the situation), the need at any time would be approximately 400 extra isolate beds.

83.4.2 Pandemic Flu AH1N1 2009: Experience from Norway

The pandemic flu AH1N1 came quickly and disappeared relatively rapidly—from spring to autumn of 2009—in Norway [5, 6, 11–17]. There was a tendency for a two-phase epidemic development, with a slight top during weeks 28–32 [11]. Microbiological detection of virus (AH1N1) was quickly established but never exceeded 2800 positive findings on a weekly basis in a population of ca. five million inhabitants; see Fig. 83.1 [11].

On a national basis, the number of hospitalized patients per day in the peak period was approximately 90 patients, and 20–30 patients were in intensive care units (Fig. 83.2).

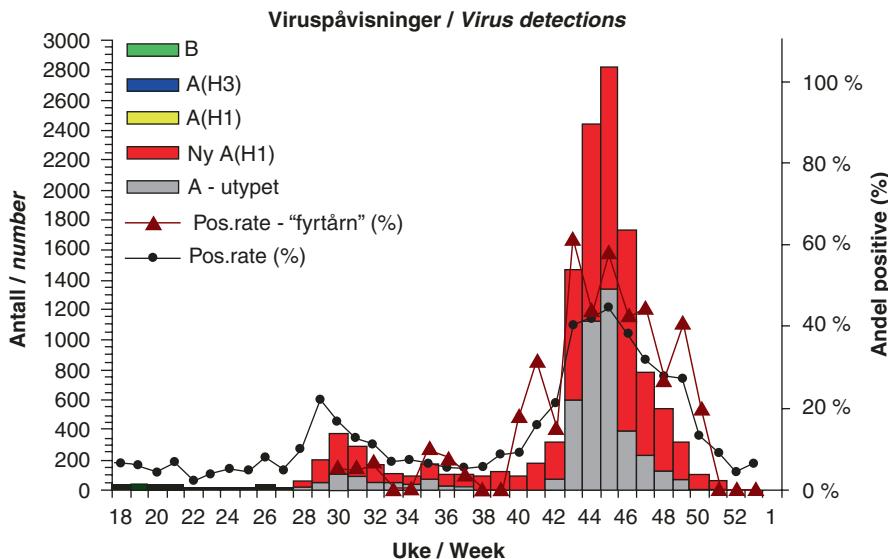


Fig. 83.1 Pandemic influenza had a two-phase development from spring to autumn 2009. Source: National Public Health Norway [11]

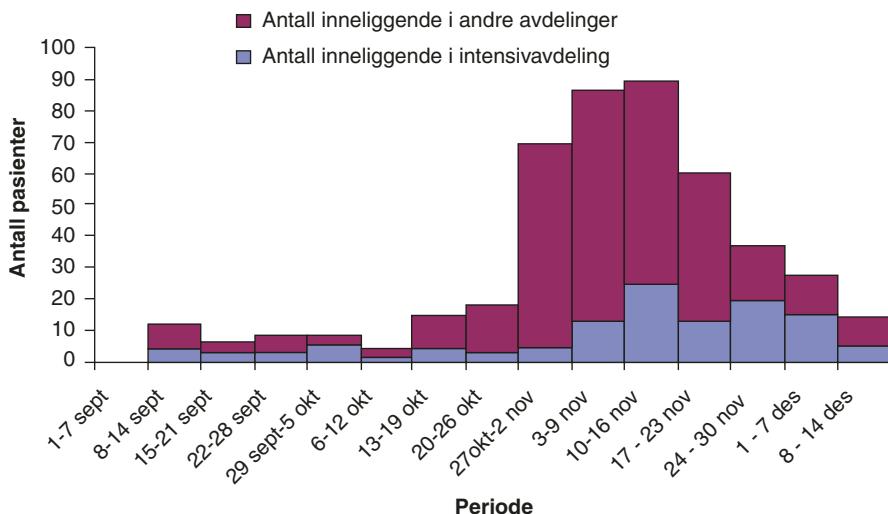


Fig. 83.2 Number of hospitalized patients with laboratory-detected pandemic influenza A H1N1 from 1 September 2009. Patients: blue admitted to ICUs and red to other departments. Source: National Public Health Norway [11]

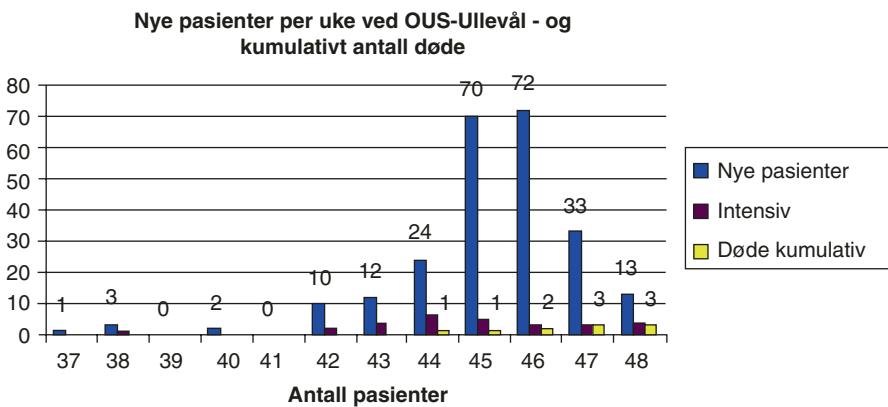


Fig. 83.3 Number of new patients with influenza AH1N1 (blue), admitted to OUS—Ullevål University Hospital per week; number of patients in intensive units (red)—and cumulatively number of deaths (yellow). Source: BM Andersen, OUS—Ullevål University Hospital 2009 [5, 6]

OUS—Ullevål University Hospital, Oslo, is the main hospital for about 800,000 inhabitants in the southeast of Norway. There were a maximum of 72 patients admitted to the hospital per week (46), because of influenza AH1N1, including ca. 10 patients at the intensive care units per week (Fig. 83.3) [5, 6]. There was no capacity shortage due to a ready distribution system for patients, as well as a plan for cohort isolation at a separate hospital building [5, 6]. Three patients were registered dead because of the pandemic at Ullevål; one of them was dead on arrival [5, 6].

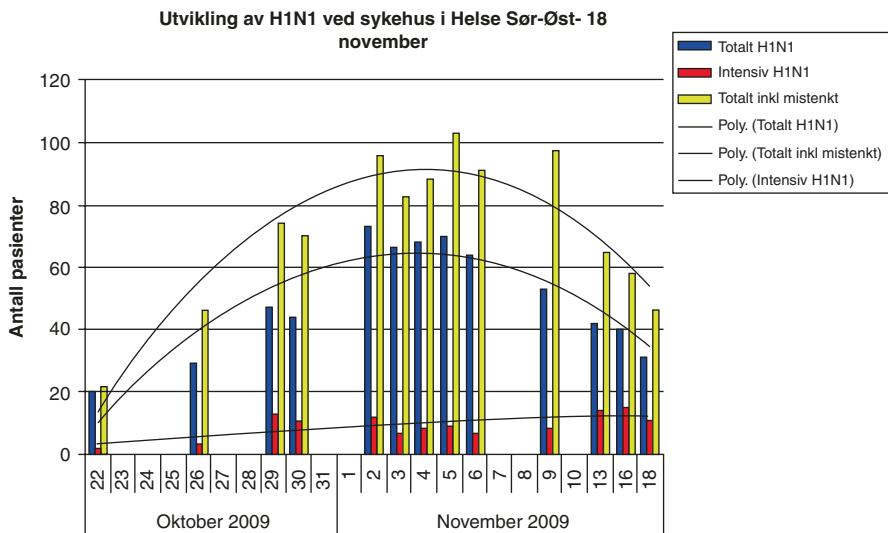


Fig. 83.4 Number of patients with influenza AH1N1 (blue), admitted to hospitals in the health region southeast of Norway (ca 2.5 million inhabitants) per week; number of patients in intensive units (red)—and total number, included suspect cases (yellow) from October to November 2009. Source: BM Andersen, OUS—Ullevål University Hospital 2009 [5, 6]

Including all hospitals in the health region southeast of Norway (2.5 million inhabitants), there were around 100 hospitalized influenza patients daily during the period 2–9 November and then a rapid decline (Fig. 83.4) [4, 5]. Between 10 and 18 intensive patients were treated for pandemic flu each day during this period.

Experiences from this pandemic showed that the calculated scenarios did not agree with the facts, either regarding the number of infected (probably), hospital admissions, intensive care or death rate.

83.4.3 Isolates: Capacity

83.4.3.1 Number and Status [5, 6, 11–17]

It is important to have an overview of the number and types of isolates for infectious diseases in a radius of at least 100 km around densely populated areas. The isolates should be checked at least once a year that they function according to the mode of use. Isolates for airborne infectious agents should have a negative air pressure, sluice and separate bathroom disinfection room with decontaminator, and contact isolates should also have a separate bathroom disinfection room with decontaminator and through-put and should have some degree of negative air pressure in relation to corridor, etc.

Single room with toilet/shower. It is essential to have a list available on the number of well-equipped rooms that can be used for contact isolation.

A large hospital like Ullevål University Hospital with approx. 800 somatic beds have 41 (5.1%) isolation units for airborne infections (of which 20 for children), 25 contact isolates (3.1%) and 74 single beds (9.3%).

Isolation requirement in case of minor outbreaks under normal epidemiologically situations:

- *Patients:* Under normal circumstances, the number of satisfactory isolates should cover the usual needs of the population, if also included the use of other hospitals in the area, flexible. Most outbreaks of serious epidemics are related to a few patients, 1–5.
- *Close contact/exposed/carriers:* Short-term isolation may be applicable to persons exposed to infection by diphtheria (adults, elderly), plague and possibly anthrax. In some cases, isolation is applicable to infected persons or carriers who cannot take care of themselves/do not follow preventive measures or other conditions that require isolation (e.g., exposure/cARRIER status of cholera and other intestinal pathogenic microbes, multidrug-resistant bacteria, VHF).

Isolates needed for major outbreaks—serious epidemic in the population—exceeds capacity:

- *Escalating situation.* An escalation plan must be available, with an overview of hospitals, other health institutions, hotels, etc. that can be predefined and staffed by appointment. Fixed, annual technical control must be carried out. It should not be far away from core areas but sheltered.
- If *cohort treatment* of patients with the same microbiological diagnosis—put patients in the same room; it will facilitate the care situation and save personal protection equipment (PPE). In case of major outbreaks, the entire departments or hospitals can be dedicated to patients with laboratory-diagnosed infection (see SARS outbreaks in China and Singapore 2003 where they had their own SARS hospitals).
- *Avoid long transportation of infection patients.* Isolate units should not be far from hospitals that take care of the epidemic (where most cases are occurring). Long transport takes large resources and time and can cause fear in the population.

How to increase the capacity if the outbreak escalates:

Depending on the *number of* people involved in an outbreak of infection, it should be planned as follows:

- Patients with identical microbiological agent and increased need of hospital treatment—escalate:
 - Infection disease wards or intensive units with isolates
 - Other suitable departments (area shielded/the building is closed for other patients)
 - Other suitable hospitals in the region.
 - If necessary—a complete hospital, entire nursing home or pre-arranged/ requested hotel

- Carriers/exposed/close contacts
 - Isolation at home, if possible.
 - Isolation at designated buildings, at hospital or at predesignated hotel.
 - Note! Nursing homes and similar buildings with common ventilation are not suitable for airborne isolation of exposed, close contacts or infectious carriers because of risk of transmission via air.
 - It is assumed that the general minimum requirements for emergency response/mass isolation are met (see below).

Isolate need for major epidemics/disasters:

In case of war with for instance biological weapons or an unusual epidemic extent/condition, the need for isolates will be large. Here it will probably be relevant for cooperation between states and countries. In such cases it may be appropriate to request *predefined*, newer hotels, cf. the Norwegian Health and Social Preparedness Act, §3-1 Requisition [12–17]. A report of 22 February 1984 to the Director General of Health, under review, “Proposal for Planning of Epidemiological Preparedness” by a reference group set up by the Directorate of Health on 30 March 1982. The report states that after the “nature and extent of the disaster,” different measures may be needed for the isolation, treatment and care of patients with infectious diseases. “In all these cases, one must assume that the best suited for these purposes are our many and good *hotels*.” It is emphasized that in all parts of the country, *preferentially, new hotels* should be *predesignated* for this purpose. Most hotels have a high quality of the building and hygienic standard. They have single and double rooms, most of them with separate bathrooms and toilets, which is of the utmost importance as it facilitates isolation and care. They also have laundry facilities and kitchens, and most have wings that can be shut down. These are qualities that are approaching the requirements of an isolation department. The ventilation should be considered turned off. Ventilation can be done via windows if not large passage of people directly outside (WHO).

General requirements for emergency response/mass isolation—area:

- Fast, mobilizable and flexible.
- Preferably direct access from outside or via closed corridor.
- Preferably one bedroom with a high hygienic standard; sink, bath/shower.
- Access to kitchen or other cooking facilities.
- Can be closed to other parts of the building.
- Preferably not in densely populated areas.
- If situated outside the main hospital, it should be so close that it can be operated from the hospital departments (infectious medicine, intensive, lung, X-ray, sampling, cleaning, textile, purchasing, kitchen, transportation and a number of other service functions).

Need for personnel, equipment, service, transport, etc.:

- An estimate of needed qualified personnel in an escalation plan must be available.

- Requirements for specific equipment such as respirator, other ventilation equipment, etc.—escalation plan must be available.
 - Service plan of service (food, water, laundry, consumables, etc.).
 - Plan for cleaning, disinfection and disposal.
 - Transport plan (patients, equipment, vehicles, etc.) must be available.
-

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Personal Protective Equipment (PPE)

84

Abstract

It is not acceptable to work with patients with dangerous infections without using, knowing and implementing adequate personal protective equipment—PPE. Personnel, patients and visitors should not be exposed to infectious agents by patients, others, equipment or the environment—which may be serious to health or life (ECDC). It is not acceptable to place a patient with undefined infectious disease in the same room as a patient with known high-risk disease (WHO). In this chapter the need and use of PPE are described, to stop spread of infections in the hospital during outbreaks.

Keywords

Personal protective equipment · PPE · Infection control · Hygiene · Disinfection

84.1 Purpose

- To describe necessary capacity and types of PPE - personal protective equipment -needed for protection of health care personnel during epidemics.
- Describe the need for PPE in case of serious, dangerous outbreaks in hospitals [1–3].

84.2 Comprise

- Personnel in contact with infected/exposed patients and/or equipment used on such patients.
- Special trained personnel in work with high-risk, infectious patients.
- Emergency groups and infection control personnel.

84.3 Responsibility

The hospital's management is responsible for written procedures for the use of PPE in the actual situation, provide plans for necessary supply of PPE, storage and use.

Infection control doctor and emergency team are responsible for practical advice and training in taking on and off PPE and infection risk around these procedures.

Personnel follows written routines and contacts nearest responsible for advice if unprotected exposed to dangerous agents.

84.4 Practical Measures [4–7]

84.4.1 Need for Personal Protection Equipment in Case of Serious, Dangerous Infection Outbreaks

A survey was conducted in Australia with regard to the need for disposable sets of personal protective equipment recommended by the WHO (disposable gown, respiratory protection, gloves and eye protection—PPE kit), if a patient with suspected avian influenza was hospitalized [4–7]. Healthcare staff went through training in advance. At an unknown time, a patient—an actor—was admitted with “clinical symptoms” as if he had bird flu [7]. The symptoms were clear for suspicion of bird flu (avian pandemic influenza—API): *3-day high fever; cough, shortness of breath, severely impaired general condition and recent return from countries in Southeast Asia and had handled diseased poultry in an area of bird avian influenza.* The course was recorded by observers who followed what happened around the patient for the first 6 h after admission to the emergency department [7].

Each incoming API patient led to a consumption of 20–25 sets of PPEs—already *the first 6 h after the admission* [7]. However, more than 40% of healthcare professionals would need post-exposure treatment with antivirals in this situation due to lack of or incorrect use of PPE! In the absence of access to PPE, the need for anti-viral treatment would increase with 12–13 treatment schedules per API patient. A real event would expose many more people over a longer period of time with a high need for additional PPE resources per API patient.

The emergency preparedness exercise in Australia is an important alert to show the need for more thoughtful preparations for personal protection for healthcare professionals and others who are going to take care of patients with severe pandemic influenza. During the SARS epidemic, it was after a short time—impossible to get PPE from a number of key and major manufacturers. The same must be considered if a serious pandemic should occur.

84.4.2 Under Norwegian Conditions, the Australian Experiment would give the Following Results

Estimated need for personal protection equipment (PPE) in case of severe pandemic outbreak [4–7]

	Norway Need of PPE set	Oslo region Need of PPE set
<i>Hospitals</i> (0.3% of the population) ^a		
1. First 6 h in hospital (20 PPE/patient)	2,700,000	50,000
2. Addition for average 10 days in hospitals; 10 PPE/day/ patient	1,350,000	250,000
<i>Primary health services</i> (13% of the population) ^b		
1. Polyclinic/primary health service— <i>first contact</i> ; 3PPE/ <i>contact</i>	1,560,000	312,000
2. Supplement for others ^c ; about 10 PPE set/patient	5,200,000	1,040,000
Total estimated PPE sets needed	8,380,000	1,652,000

^aca. 13,500 admissions on a national basis, 2500 in Oslo

^bca.520,000 additional contacts on a national basis, 104,000 in the Oslo region

^cFamily/contacts, transport, service, home care, nursing homes, public services, etc., ca. 10 PPE sets/patients

This scenario demonstrates that the earlier a strict, comprehensive and proper intervention is done to stop a serious epidemic, the faster it may stop and the less need for PPE.

84.5 Emergency Preparedness Stocks

Emergency preparedness stocks for PPE and disinfectants in hospitals and primary care must be reassessed. Continuous consumption and rotation must be ensured in today's infection control work so that the equipment does not become outdated, at the same time as the personnel are training in the use of PPE. Stocks should be controlled by infection control personnel responsible for training and protection against improper or wrong use of PPE.

PPE is particularly important in cases where there is delayed or lack of access to an effective vaccine and in the absence of antiviral/antimicrobial agents such as SARS, MERS and Ebola. PPE is of particular importance for healthcare professionals and other service providers to feel safe and to work effectively during serious epidemics/pandemics.

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Abstract

Information and communication are central measures during serious outbreaks of infections, especially concerning high-risk, dangerous microbes. A thorough and clear information about how to act in the society to protect against infection may calm and reduce the panic among people. It is important to have enough people to answer all who is asking about the outbreak and to react rapidly to information of disease-suspected cases.

Keywords

High-risk infections · Communication · Information · Infection control · Hygiene · Disinfection

85.1 Purpose

- To inform leaders in the hospital, municipal health service, (eventually regional and national) when detecting suspect dangerous infection in the hospital or in the community [1–3].
- To inform the population, media etc. concerning how to act during outbreaks.
- To inform each person/patient/family that asks for advice about a possible dangerous outbreak.

85.2 Comprise

- All personnel who are the first in contact with the infected/exposed person, relatives, other contacts and environment.
- All who are predefined to do the information work during serious outbreaks.

85.3 Responsibility

The hospital's management provides written plans for how to react in situations where personnel and others may be exposed to known/unknown serious communicable disease and a practical arrangement for how to handle the situation.

The *infection control officer* at the level of where the problem occurs, and at the departments/ward where the infection may spread, is responsible for following local emergency plans.

Personnel who unprotected have come in a seriously contagious situation and may have been exposed to infectious agents are responsible for contacting the nearest responsible/infectious unit for advice and of following written guideline and practical advice.

85.4 Practical Measures [4–6]

85.4.1 Hospital

Telephone/Internet centre with registration of all hospitalized patients. Information telephone for advice and measures, staffed with healthcare personnel and in close cooperation with emergency services, ambulances and municipal health services.

85.4.2 The Municipal Health Service

Telephone/Internet centre with registration of patients in homes, nursing homes, home nursing, etc. Information telephone for advice and measures, staffed with healthcare professionals and in close cooperation with hospital, emergency room, ambulances.

Important general information in case of major epidemic outbreaks and high risk of infection:

- Most homes, apartments, etc. with own shower and toilet are really very good isolates.
- Avoid gatherings, meetings, etc.
- In case of major outbreaks, children should be home from school/nursery—there will be a large spread of infection if someone is infected.
- Stay home if exposed to severe infectious disease (been in the same room, cared for a patient). Measure temperature $\times 2$ every day—usually for 10-14-21 days—depending on the infectious agent.
- Good hand hygiene with alcoholic wipes, hand washing.
- In case of respiratory symptoms, cough/sneeze in disposable wipers that are disposed of in waste bag. Hand hygiene afterwards. Do not use your clothes like “handkerchief”!

- If you think you are ill, call your doctor/hospital/hospital's telephone for advice.
- If you are to be examined by a doctor/admitted to hospital, you will be notified of where to come or if you are being picked up in an ambulance. Use surgical mask and wash hands.
- Avoid public transport if you are ill—and avoid other people. You can drive your own car.
- Listen to the radio regarding reasonable measures.
- If contaminated via water or food, boil the water and cook current food (possibly throw the food away).
- Do you have a dog/cat that needs to be aired—keep the animal in a strap and wipe off the paws with an alcoholic wipe afterwards.
- Food, etc. can be ordered from the store and brought to your home, possibly other solutions in cooperation with the civil defence.
- Handle waste trash in a safe manner so that collector workers and others are not unnecessarily exposed to infection.
- Listen to the radio, TV, etc. for advice and messages.

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Triage: Serious Infections

86

Abstract

Triage is a system used to avoid spread of serious infections between infected and noninfected persons seeking help and advice at hospitals or other healthcare institutions. It is usually one way in (all) to a place for examination and two ways out (suspected infected or not infected). It is especially important to protect non-infected persons during the way into the triage, using surgical mask, hand hygiene and no contact between people.

Keywords

High-risk infections · Triage · Information · Infection control · Hygiene Disinfection

86.1 Purpose

- Triage is a system to select sick or exposed patients from healthy people or patients with other disease.
- The purpose is to protect and isolate infected patients or exposed persons from others and to stop spread of infection between infected and non-infected persons [1–3].
- Triage is also used for vaccination, giving prophylactic medicaments, use of PPE and other protection advice.

86.2 Comprise

- All persons with or without symptoms on actual illness.
- All who may have been exposed to the actual infection and all who are worried of being infected.

- The triage separates between not infected, maybe infected, and infected - and gives advice, vaccination, medicaments, use of PPE and other protection.

86.3 Responsibility

The hospital's management and emergency group provides written plans for using the triage system at the hospital, when it is to be used, technical supply, vaccines, prophylactic medicaments, enough trained personnel, etc.

Departments management is following routines for triage treatment in the hospital.

Predefined trained personnel are working in the triage situation.

86.4 Practical Measures [4, 5]

86.4.1 Definition

A three-parted system:

- One input and two outputs (home or further diagnostics/treatment/vaccination, etc.).
- A good triage system in primary and specialist health services is an important factor in stopping epidemic development.
- Triage must be used in such a way that it does not constitute an epidemic spreading factor.
- Triage can be used for diagnostics, categorization of persons with symptoms, vaccinations, drug delivery, infection protection equipment, information, etc.

86.4.2 Triage for Personnel at the Hospital

- Vaccination/medication—as needed and available—is provided by the corporate health service in cooperation with health authorities.
- Respiratory equipment—as required and available—is provided by the infection control staff.
- Use of PPE—training and control—is provided by infection control staff.

86.4.3 Triage for Patients at the Hospital

- Diagnostics, categorization of patients and information at the hospital are planned in advance.
- Preliminary examination to determine admittance or provide information (separate house, etc.).

- Avoid queue (increase spread of infection). Delivery of surgical mask and information to all who are waiting.

86.4.4 Triage for the Municipal Health Service Personnel

- Vaccination/medication—as needed and available
- Respiratory equipment—as needed and quantity available
- Use of PPE—training and control

86.4.5 Triage for Patients in the Municipality

- Diagnostics and preliminary examination—to determine admittance to hospital or provide information
- Avoid queue (increase spread of infection).
- Delivery of surgical mask and information to all who are waiting.
- Vaccination and/or delivery of drugs.

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Abstract

During outbreak of very dangerous and/or easily transmittable infections, the handling of infected patients in the hospital is both difficult and important when the hospital at the same time has to take care of other acute patients - like road accidents or heart infarct etc. Dangerous infections may cause paralysis of all hospital activity if the infection is out of control. A written consensus plan for how to act when high-risk patients are admitted to hospitals is therefore important.

Keywords

High-risk infections · Patient-logistic · Information · Infection control · Hygiene Disinfection

87.1 Purpose

- To handle seriously infected patients in such a way in the hospital that transmission of infection to others is avoided.
- To take care of other emergency activities at the same time in the hospital by using logistic and infection control.

87.2 Comprise

- All patients with suspected high-risk, dangerous /easily transmitted infectious disease admitted to hospitals [1–5].
- *All health care personnel handling infectious high-risk patients.*

87.3 Responsibility

The hospital's management provides written plans for how to react in situations where personnel and others may be exposed to known/unknown serious communicable disease and a practical arrangement for how to handle the situation.

The *infection control officer* at the level of where the problem occurs, and at the departments/ward where the infection may spread, is responsible for following local emergency plans.

Personnel who unprotected have come in a seriously contagious situation and may have been exposed to infectious agents are responsible for contacting the nearest responsible/infectious unit for advice and of following written guideline and practical advice.

87.4 Practical Measures [4, 5]

87.4.1 Patients: Admission to Hospital

1. Admission priority in relation to outbreak and epidemic situation:
 - Calculated by the extent of the outbreak, symptoms and need for treatment and how quickly the epidemic develops; see SARS.
 - *First phase—minor outbreak:* Only sick, treatment-needing patients are admitted. Patients with laboratory-confirmed diagnosis may be cohort treated (in the same room).
 - *Second Phase—large outbreak:* Only patients who need intensive or other life-saving treatment are admitted to the hospital. Patients with laboratory-confirmed diagnosis or a reliable clinical diagnosis can be cohort treated; however, a laboratory-confirmed diagnosis is needed for children and adolescents.
2. Release of isolation space for high-risk infections:
 - *Isolates are emptied and clarified.* Local isolates are prepared for the intake of high-risk patients. Other (previous) isolation patients are transferred to other departments or hospitals—preferably with infection-medical expertise.
 - *Normal bed wards are emptied as needed.* Patients that were admitted are sent home or transferred to other hospitals/nursing homes, freeing of beds and staff.
 - *Elective treatment is reduced or stopped,* freeing of patient beds, postoperative treatment, intensive beds and staff.
 - *Intensive personnel are displaced* to relevant isolates as needed.
 - *Emergencies and loops for other patients* (caesarean surgery, traffic accident surgery, myocardial infarction, etc.) are established in a separate unit or at another hospital with the possibility of isolation of the infected patient with another emergency disease (like pregnant with high-risk infection).
 - *Transfer of treatment—needing* patients with epidemic disease to a dedicated, separate hospital/unit with adequate competence and capacity.

- All transport of infectious patients between hospitals and from the place of arrival to the hospital must be based on the infection control routines determined for the individual infectious disease (contact, airborne, high-risk isolation); see *isolation regimes*.
- Disinfection of the ambulance used for high-risk infection patients is carried out partially after each transport and once a day or more often if possible—a complete disinfection (dependent on outbreak and severity). The ambulance is not used for noninfected patients.
- See Chap. 75 on ambulance and transport.

87.4.2 Infectious Carriers, Close Contacts and Persons in Incubation Phase of High-Risk Disease

Carriers of high-risk agent. Healthy carriers can mostly be taken care of outside hospitals. This should be done in cooperation with and under the supervision of the municipal infectious healthcare provider. In case of doubt, infection control persons should be contacted. Carriers of intestinal bacteria, MRSA, VRE, and other multi-drug-resistant microbes—MDRO, etc.—are usually not defined as high-risk carriers.

In a possible incubation phase of illness, most people may be at home. Serious infectious diseases are most commonly contagious *after* disease outbreaks (but not all). The case should be followed up in cooperation with and under the supervision of the municipality's infection control. In case of doubt, contact infection control personnel.

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Viral Haemorrhagic Fever (VHF) and Other Serious Viral Infections

88

First contact - how to act and protect

Abstract

Viral haemorrhagic fever—VHF—virus and a number of other special viruses are considered to cause the world's most dangerous infections with very high mortality, lack of therapeutic possibilities and often absence of effective vaccines. Such viruses are identified as “biohazard-level 4” agents and are treated at the highest level of infection protection with strict isolation measures. At least 14 patients with Ebola disease were transported to Europe and the United States (11 patients) for hospital treatment during the African epidemic in 2014. There were no secondary spread of VHF import cases in Europe and the United States from 1999 until the Ebola outbreak in 2014. Then there were three cases of nosocomial spread to personnel in hospitals, two in the United States and one in Spain, despite alleged use of strict containment routines. This indicates a high risk of spread of infection through intensive treatment and handling of very sick persons with VHF like Ebola. In most cases vaccines are not available or specific antiviral drugs. Therefore, infection control must be based on a proper infection protection. This chapter is focused on practical means to handle and treat patients with suspect VHF or other dangerous agents to avoid spread to personnel and environment

Keywords

Viral haemorrhagic fever · VHF · Ebola · Lassa · Other VHFs · SARS · MERS Nipah · Biohazard-level 4 agents · High-risk infections · Information · Infection control · Hygiene · Disinfection · PPE · Emergency · Transport · Admittance

88.1 Purpose

- Protect healthcare professionals and close contacts against infection from blood and other body fluids in suspected or documented high-risk, dangerous infectious disease [1–18].
 - Prevent spread of infection by means of infection control barriers.
 - Patients or personnel should not be exposed to dangerous infections which may be serious to health or life [19, 20]. It is not acceptable to place a patient with not defined disease in the same room as a patient with known high-risk disease (WHO).
-

88.2 Comprise

1. *Patient* without signs of infectious disease, but recently in the last 3 weeks from known epidemic area abroad where there is an outbreak of severe, highly infectious epidemic **and**
 - (a) Exposed to SARS or other severe acute respiratory tract infection and been in close contact with sick people with severe acute respiratory tract infection, **or**
 - (b) Exposed to VHF (Lassa, Ebola, etc.) and been in close contact with sick people with bleeding in the skin and high fever, **or**
 - (c) Exposed to bird flu and been in contact with sick birds—suspected of having bird flu
 2. *Patient* with signs of infectious disease, recently arrived in the last 3 weeks from a known epidemic area abroad **and**
 - (a) Have symptoms of severe infection with high fever **and rash/bleeding** (VHF), **or**
 - (b) Have severe respiratory tract infection and been in close contact with patients with severe respiratory tract infection (e.g. SARS or MERS), **or**
 - (c) Have severe respiratory tract infection and been in direct contact with sick birds—suspected of having avian influenza
 3. *Personnel and others* who have treated such patients—unprotected.
 4. *Environment and equipment, etc.* which have been in contact with such patients—unprotected.
-

88.3 Responsibility

The hospital's management provides written plans for handling such cases and of that necessary resources are available.

The department management at the ambulance/emergency department, infectious medicine and anaesthetic and intensive care units must have procedures for the treatment of such patients and other key personnel who have undergone special training and necessary exercises.

The department management admitting and handling such patients are responsible for personal protective equipment—PPE—which is:

- Easily accessible,
- Properly packaged and checked
- That personnel are trained in use and undergo courses in donning (take on) and doffing (takeoff) PPE
- That personnel receive general training in isolation regimes (*see Chap. 19 on Isolation*)

Personnel must use the PPE in the correct situation and properly according to routines. Possibly contact an infection control personnel for advice.

Each user of the equipment must be responsible for a proper and safe use.

88.4 Practical Measures [16–18]

Patients (persons) with no symptoms of infection are usually at low risk of transmitting infection to others, but are still treated with the use of PPE because of some contagiousness which may occur during incubation phases.

Patients with infection symptoms (see above) must be considered as high-risk infectors.

88.4.1 Emergency Action—Transport of High-Risk Patient—“Ebola” Example

Emergency/ambulance personnel are often the first who meet and take care of a patient outside hospital. The patient may have known or unknown infections. Emergency personnel should be especially aware of and handle this situation.

88.4.1.1 Before You Are in Contact with the Patient: At Home, Hotel Room and Patient Room

1. Contact the doctor in charge and ask for advice (contact infection control personnel).
2. Close access to the room/ambulance; mark the door *strict isolation*, and notify others present.
3. Take on the following PPE: cap, respirator (P3 mask), goggles, phantom hood that covers the head and neck, shoe covers, waterproof gown with long sleeves or overall with a hood and double gloves. Learn the order of clothing, and control each other.
4. In agreement with the doctor in charge, enter the patient room (with barrier guidance).
5. Put a regular surgical mask or P2 mask without breathing valve on the patient—preferably let the patient do this himself.
6. If possible, the patient places himself on the transport stretcher.

7. Cover the patient's skin, sore and the entire body as much as possible during transport (e.g. bed sheet, gown, heat coat).
8. Contact the advisor in charge by phone, and ask for further assistance to which reception.
9. Avoid transport through corridors where there are other people.
10. Rooms, fixtures and everything that have been in contact with the patient are treated as infectious. The patient's equipment is left and the room is sealed until a complete disinfection is done.

88.4.1.2 If You Are Already in Direct Contact with the Patient (in the Same Room at Home, Hotel Room, Patient Room) and Detect Suspected Infection "Ebola" (Unprotected) Without PPE

PPE should be taken on before further work with the patient.

1. Do not leave the room, but walk away from the patient, and be calm and explain.
2. Hand disinfection (alcohols 70–85%) inactivates most dangerous viruses.
3. Move right outside the patient's room and do not go elsewhere.
4. New hand disinfection. Contact the doctor in charge by phone and ask for assistance.
5. Notify others present about the need for PPE and other assistance. PPE equipment should always be ready in the ambulance—minimum for two persons.
6. Put on PPE: Gown—waterproof/overall; shoe covers; cap; phantom hood; respirator, P3 mask; goggles/visor; and two pairs of gloves (disinfect hands before wearing gloves).
7. Go back to the patient.
8. Put surgical mask or P2 mask without breathing valve on the patient, or ask the patient to put a mask on themselves. Perform calm with gentle movements so that no particles are swirled up.
9. If the patient is able to it, he will put himself on the stretcher.
10. Cover the patient's skin, sore and the entire body as much as possible during transport (e.g. bed sheet, gown, etc.).
11. Contact the doctor in charge by phone and ask for further assistance to which reception.
12. Avoid transport through corridors where there are other people.
13. Rooms, fixtures and everything that have been in contact with the patient are treated as infectious. The patient's equipment is left and the room is sealed until complete disinfection is done.

88.4.1.3 PPE-Doffing (Removal of PPE) After Contact with High-Risk Patient: In Sluice or in Rooms Separate from the Patient

1. Doffing must be checked by another person wearing PPE.
2. Wash the gloves outside with chloramine 5%, chlorine bath 5%, 60 s; or hand disinfectant.

3. Remove the shoe cover—carefully put it in the waste bag—and move to “clean place”.
4. Remove both gloves carefully, put directly into the waste bag, and do not touch the skin.
5. Wash your hands in new chlorine bath for 60 s or hand disinfectant for 60 s.
6. Put on new gloves before further doffing.
7. Remove carefully PPE in this order: gown, goggles/visor, phantom hood (if used), respiratory protection (P3 mask) and cap, and touch the areas that have been at least infected (usually backside of the body). Disinfect your hands with gloves between each procedure, and follow the written instructions, or see specifically under the infection protection regime—*strict isolation*. Check that used equipment does not contaminate the skin or the clothes under PPE during the doffing. Everything is placed in the waste bag (eventually separate bags for textiles, goggles etc.).
8. Finally remove the gloves and perform hand hygiene.
9. The waste bag is carefully closed and placed in a new clean waste bag that is disinfected outside with chloramine 5%.
10. Wash your hands thoroughly, possibly in a new chlorine bath afterwards.
11. Change clothing that has been used under PPE. Used textiles are treated as infectious in separate textile bag marked infectious.
12. Shower with Hibiscrub (chlorhexidine soap)—body and hair—before new clothes are taken on.
13. After the transport, exposed personnel (contact with the patient without the use of PPE) should be discontinued and followed up 21 days after exposure (VHF).

88.4.1.4 Transport Equipment (Ambulance, Stretcher, Wheelchair, etc.)

1. After use in high risk situations, disinfect the equipment with chloramine 5%, and optionally gas disinfect with hydrogen peroxide dry gas.
2. Use PPE during this procedure; dressing and undressing as outlined above.

88.4.1.5 Blood and Other Spills of Biological Material

1. Disinfect as usual with chloramine 5% or household chlorine.
2. Use PPE during this procedure, dressing and undressing as outlined above.

88.4.1.6 Note! Prevent Spread of Infection from the Patient

- Surgical mask or P2 mask without breathing valve is placed on the patient.
- Skin, sore, etc. are covered as much as possible during transport (e.g. put on bed sheet or plastic cover loose over the patient, but do not cover the head).
- Everything that has been in contact with the patient is treated as infectious. The same precautions as outlined above.
- It is possible to transport the patient in a separate plastic container (stretcher surrounded by plastic).

88.4.1.7 PPE: Equipment, Pre-packed, Expiration Date!

PPE infection box: PPE—equipment for 2–8 persons; listed on outside of the box. Complete PPE sets are in the box.

- Virus impermeable gown with long arms and tight wrists. Complete overall can be used.
- Gloves with long cuff, solid, double, pulled over wrists (Note! Make sure the gloves are ok). Record expiration date.
- Hood/cap that holds the hair in place.
- Tightly sealed mask with hepafilter (P3). Record expiration date.
- “Phantom hood” with long neck covering the head and neck.
- Protective goggles that are tight to the skin and so large that you can use your own glasses inside.
- Boots or shoe covers.
- Two waste bags that can be closed.

PPE infection box or equivalent with pre-packaged PPE sets can be stored at:

- Ambulances, external
- Intensive department’s isolate
- Clinical chemical department
- Infection department
- Microbiological department
- Emergency reception
- Children’s section
- Emergency room

Main storage for PPE in the hospital: Should be available on a 24-h basis, but under control and rotation/replacement of infection control personnel in cooperation with Central warehouse or other local solutions.

88.4.2 Notifications

- Outbreak of serious high-risk infectious disease—import patient.
- Outbreak of severe, uncontrollable epidemic disease.

88.4.3 Department’s Notification Tasks

88.4.3.1 Who Should Notify?

- Responsible physician, doctor in charge, nurse, supervisor and ambulance service
- Microbiological department (in case of specific agent/resistance/clinical data)
- Corporate health service (suspected of serious infection transferred to staff)

- Primary health services if detected outbreaks of severe high-risk infection disease that require admission and high-risk isolation treatment at the hospital
- The Director of the National Institute of Public Health, the County Governor/County Council and the National Public Health Authority (special infections, according to the Infection Control Act, etc.)

88.4.3.2 To Whom Should It Be Notified?

- Medical officer (isolation and treatment)
- Infection control unit
- Department management
- Hospital management (in case of death, resource-intensive measures, serious contagious epidemic situation)
- Hospital emergency preparedness group (severe contagious disease, unusual disease and major epidemic outbreak)
- The company doctor (on infection transferred to staff)
- Primary health services if detected outbreaks of serious high-risk infectious disease that can lead to infection in the population
- National Institute of Public Health, the County Governor/County Council and the National Public Health Authority (special infections, according to the Infection Control Act, etc.)

88.4.4 Notification Method/Urgency

By telephone, e-mail, fax and writing immediately. The message is assessed primarily by professional responsible personnel at the relevant department by extent/severity.

88.4.5 Meeting Place for the Emergency Preparedness Group

The Director of the hospital leads the Emergency Group and decides when it is necessary to call the group to the Director's office. See Chap. 81 on the Preparedness Group.

88.4.6 Actions and Responsibilities

88.4.6.1 Increased Preparedness

The emergency preparedness group assesses the situation on a continuous basis and checks that:

- Infection isolates are available in the required amount and quality (regular air pressure control).
- A feasible plan for cohort treatment of defined infectious patients, mobilization and relocation of other patients.

- Competent personnel available for the relevant infection control work.
- Available and adequate containment equipment (respiratory protection, gown, gloves, etc.).
- Overview of defined stocks with PPE and disinfectants.
- Actual preventive vaccines are set (flu, rabies, anthrax, BCG, diphtheria, tetanus, polio, plague, etc.).
- A plan for further treatment of infected patients and exposed personnel.
- Notify relevant laboratories and X-ray departments and other departments/contacts of the patient so that they prepare measures.
- A plan for trapping up capacity.

88.4.6.2 Alarm

The Emergency Group activates current personnel to participate in the mission.

88.4.6.3 Priorities

1. High-risk isolates are staffed by infection professionals using PPE.
2. Fastest possible diagnosis/identification of microbe (clinical examination and laboratory studies, including microbiological diagnostics).
3. Quick message to exposed persons and responsible health personnel about measures necessary around exposed cases (name, address, number of persons exposed, measures).

See Chap. 82 on scenarios

88.4.7 Information Duty

The Director is responsible for external information to the Director of the National Institute of Public Health, the County Governor/County Council, the National Public Health Authority (according to Infection Control Act) and the National Health Directorate and the Ministry of Health and Care.

Note! Plan your work, and do not walk outside the area of infection with PPE on! Avoid unnecessary transport! Avoid many participants!

88.5 Background Information

VHF virus and a number of other viruses are considered to be the world's most dangerous infection agents, with very high mortality, lack of therapeutic possibilities and often absence of effective vaccines [1–16]. These viruses are identified as “biohazard-level 4” agents and are treated at the highest level of infection protection with strict isolation measures [2–8, 11, 16–18].

There is a large travel activity to epidemic and endemic areas in the world. Many travellers are becoming sick when going abroad, and some get symptoms after

arrival to homeland, mostly harmless infections. A few persons may return very sick or be in incubation period of more dangerous infections, when returning home. This situation may need plans for patient treatment procedures to ensure early isolation of the most serious infectious diseases, such as VHF [1–14]. Viral diseases can have a relatively long incubation times (2–21 days). Many tropical-subtropical viral diseases are transmitted through insects and animals in certain geographical areas, with small ability to spread in most European countries. However, some serious infections may be spread regardless and are especially occurring as a nosocomial problem, like the SARS, MERS and Ebola.

At least 14 patients with Ebola disease were transported to Europe and the United States (11 patients) for hospital treatment in 2014. There was no secondary spread from VHF import cases in Europe and the United States from 1999 until the Ebola outbreak in 2014. Then there were three cases of nosocomial spread to personnel in hospitals, two in the United States and one in Spain, despite alleged use of strict containment routines. This indicates that it may be a high risk of spread of infection through intensive treatment and handling of ill persons. In most outbreaks vaccines or specific antiviral drugs are not available. Therefore, infection control must be based on knowledge, proper use of PPE and disinfectants, effective infection control plan and isolation preparedness [21].

88.5.1 Lassa Fever

Arenavirus group, known since 1969 (in Nigeria, West Africa), mortality is 27–44%. As a rule, it is small outbreaks [7]. Outbreak of Lassa fever is going on in West-Africa, Nigeria in 2018; with until now: 562 confirmed cases, 144 deaths and a case fatality of 25.6% (promed-mail 18 Nov 2018).

88.5.2 Other Haemorrhagic Viruses [16]

Bolivian haemorrhagic fever (Machupo virus); mortality 5–30%. Sabia virus is little known, but the CDC's laboratory infection experience with this virus is described. [8] Congo-Crimean haemorrhagic fever (CCHF) has been known since 1944 and was detected in Kosovo and Pakistan in 2001. Pakistan is an endemic area for CCHF, and especially butchers, farm workers and persons handling animals are prone to infection via blood [22].

88.5.3 Marburg

Filovirus, registered since 1967 (Marburg, Republic of Congo) with mortality rate 17–20%, seldom cause of disease.

88.5.4 Ebola Virus

Ebola is a long filovirus, registered 1972 with mortality rate 42–89% [1, 9, 11, 12, 16, 23–25].

Ebola virus has subtypes: Zaire, Sudan, Ivory Coast and Reston with small genomic differences and variation in mortality. Catchers may be infected by contact with sick monkeys (gorilla), bats and several other animals and “bushmeat”. The antibody level is often relatively high in this population. Vaccines have been under development for over 10 years (DNA vaccine in plasmid/adenovirus modified vaccine with Ebola antigen was worked with before 2008) but again tested and some are used now. Latest outbreaks were in Uganda (2000, 2007), Gabon (2001, 2002) and Sierra Leone, Guinea and Liberia from 2014. In 2017, Ebola virus disease caused epidemic situation in the Democratic Republic of Congo (DRC) -with until now; 356 confirmed cases, 231 deaths, 39 health care workers infected, and 34 800 vaccinated. The epidemic is still going on with more than 20 new cases per 48 hours. (Promed-mail Nov 24 2018).

- *The Uganda epidemic in 2000* with Ebola virus led to 428 cases and 173 deaths—40%.
- *Sierra Leone, Guinea, the Liberia epidemic in 2014* with Ebola virus resulted in 28,429 cases, of which 11,297 died (per 9.10.2015) [26]. CDC calculated an underreporting of cases by a factor of 2.5.

A total of 876 health professionals were registered with Ebola, of which 509 died, as of July 17, 2015 (WHO). Outbreaks were caused by lack of knowledge, routines and the idea of WHO, CDC, and other organizations that the risk of transmitting infection is contact and within metre from the patient [21, 23–32].

This was also shown by the example from Norway [21, 27, 28, 32].

- In October 2014, an Ebola-infected, Norwegian physician was transferred to Norway from the Bo Ebola Clinic treatment centre in Sierra Leone, run by the Norwegian Medicines sans borders (MSB).
 - The Bo Ebola Clinic opened 19 September 2014.
 - Two weeks later, 2–4 October, four healthcare personnel at the Bo Clinic got Ebola; two died.
 - The Norwegian Ebola case was transferred to a high-level isolate in Norway and survived.
 - All four had worked together in the Bo triage area: 25–26 September.
 - Standard equipment in the Bo triage area was gloves and surgical mask, because the healthcare personnel working there should hold 1–2 m distance to the patients, according to WHO and to the Norwegian Public Health Institute.
 - “Then they could not be infected by droplets”, said the Norwegian administrator of the centre.
 - “Triage was an area to talk with the patients—little PPE’s was used in order to create confidence in the local population”!

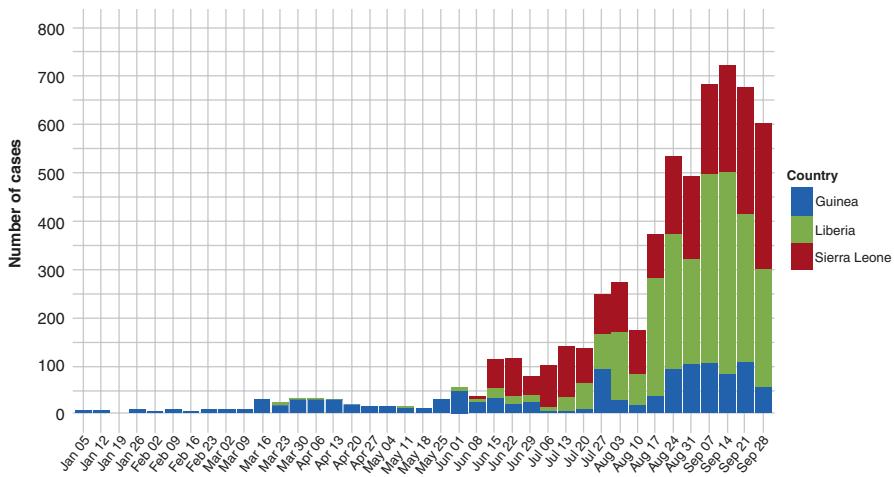


Fig. 88.1 Confirmed and probable cases of Ebola virus disease in Guinea, Liberia, Sierra Leone. Data are based on official information reported by Ministries of Health. These numbers are subject to change due to ongoing reclassification, retrospective investigation and availability of laboratory results. **Source:** WHO 2014

- In all, 21 health workers in the Medicines sans borders were Ebola-infected in October 2014, and 10 of them died. [27]
- Still, the Norwegian Institute of Public Health continued to follow the WHO’s “1-m distance rule” for infection risk.

The epidemic had, in the beginning, a slow escalation that could have been controlled by the right means. From summer 2014, there was a rapid escalation with spreading to towns and cities (Fig. 88.1) [21, 28, 32]. Not before 8 August 2014, the WHO declared that the Ebola outbreak was a “public health emergency of international concern” (PHEIC) [28, 32]. The epidemic reached its peak 14 September 2014.

88.6 Lack of Infection Control Routines [21, 28, 32]

WHO, CDC and the United Kingdom established springtime 2014 guidelines for contact and droplets in a radius of 1 m from the Ebola patient [21, 28–32]. Outside the 1-m zone, personal protective equipment—PPE—was usually unnecessary, see Table 88.1. The spread of Ebola disease and death among many patients, including many healthcare professionals, was observed despite following WHO and CDC’s guidelines [26, 28]. In 20 October 2014, CDC changed its routines for the use of PPE, focused more on training in donning and doffing PPE in sluices, use of head and neck coverings, use of P3 mask and observation of and check by a dedicated person that this work properly [33]. Healthcare staff underwent proper training in

Table 88.1 Recommended use of infection protection equipment; PPE (personal protective equipment) in Ebola virus guidelines from the World Health Organization (WHO), United Kingdom (UK) and Centres for Disease Control and Prevention (CDC), USA (source: Andersen BM *Hospital Health Care* 2015; March [28, 32])

Comparison of recommended PPE equipment for Ebola infection in WHO, UK and CDC guidelines [21, 28–34]

	WHO 2014 ^a September	UK 2014 ^b September	CDC 2014 ^c August	CDC 2014 ^d October 20
Spread of Ebola infection				
Direct contact	Yes	Yes	Yes	Yes
Indirect contact	?	Yes	Yes	Yes
Airborne?	No	No	No	No
Use of PPE at				
Suspected cases of Ebola				
Eye protection	Yes	Yes	Yes	
Gown	Yes	Plastic apron	Yes	
Gloves	Yes	Yes	Yes	
Mask/surgical mask	Yes	Yes	Yes	
Respiratory protection/N95/P3 mask etc.	No	No	No	
Hair/head protection	No	No	No	
Specific shoes/shoe covers	Yes	No	No	
Confirmed cases of Ebola				
Eye protection	Yes	Yes	Yes	Yes
Gown	Yes	Yes	Yes	Yes
Gloves	Yes	Yes	Yes	Yes
Mask/surgical mask	Yes	No	Yes	No
Respiratory protection/N95/P3 mask etc.	No	Yes	No	Yes
Hair/head protection	No	No	No	Yes
Specific shoes/shoe covers	Yes	No	No	Yes
Aerosol-producing procedures				
Respiratory protection/N95/P3 mask etc.	Yes	Yes	Yes	Yes
Hair/head protection	No	No	No	Yes
Specific shoes/shoe covers	Yes	No	Yes	Yes

^aWHO. Interim infection prevention and control guidance for care of patients with suspected or confirmed filovirus haemorrhagic fever in health-care settings, with focus on Ebola. September 2014

^bUK, Department of Health. Management of hazard group 4 viral haemorrhagic fevers and similar human infectious diseases of high consequences. September 2014

^cCDC. Infection prevention and control recommendations for hospitalized patients with known or suspected Ebola haemorrhagic fever in US hospitals. August 2014

^dCDC. Guidance on personal protective equipment to be used by healthcare workers during management of patients with Ebola virus disease in US hospitals, including procedures for putting on (donning) and removal. October 20, 2014

Fig. 88.2 PPE use for Ebola virus infection.
Source: <http://imag.cdn2.vietnamnet.vn>



the use of PPE and other infection control measures before being sent out in the field. From January 2015, WHO also changed its schedule, but still with regular mask, with the exception of aerosol-generating procedures and still “within a meter of the patient” [34].

It is discussed whether Ebola infects via air or not; important for infection control measures [21, 28, 32]. Earlier studies have warned that air transmission cannot be excluded, as shown in animal experiments [9, 11, 16, 23–25, 35]. Based on high risk of fatal progression, preventive measures are better than belated wisdom. However, in April 2015, CDC and WHO still postulated that “Ebola is not spread through air, water or food”. Since the Ebola virus may occur in large quantities in saliva and tears and mucous membranes during disease, studies generally show that drops from cough and sneezing may spread up to 9 m away [36].

Ebola virus survives a long time in biological materials such as blood and other body fluids/secretions (urine, semen, saliva), 9 weeks or more after onset of the disease and also post mortem [37]. Very long-lasting carrier status, and relapse of carrier status occurs even after the patient has been declared healthy. The virus may occasionally be detected in tissues in the body such as in the eye, lungs, testicles—with relapse of the infection observed several times, last with a Scottish nurse who became ill again, “Post-Ebola Syndrome” [26].

There is increasing scepticism regarding the management of the Ebola epidemic, also from the WHO internal evaluation group [38]. Airborne infection and re-aerosols from equipment and bedclothes and textiles cannot be ruled out, which means that personnel and others who treat such patients must use a better protection [21, 28, 32, 39–43] (Fig. 88.2).

During formation of aerosols, including production of re-aerosols, all types of viruses can become airborne. Therefore, all high-risk virus with high mortality, “biohazard-level 4” should be treated as *strict isolation*—(air, contact, blood,

secretions, tissue, etc.); the most advanced infection control regime available! There is, however, a high risk of self-contamination during PPE donning and doffing, mainly because of protocol deviations, even for doffing assistants and trained observers [32, 44–46].

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Abstract

Anthrax is still endemic or hyperendemic on all continents in the world, mainly as a zoonose among unvaccinated cattle. Natural anthrax in human is associated with contact with sick animals and animal products. The bacterium *Bacillus anthracis* is producing lethal toxins and spores that can survive in the environments for hundred years or more. Minimum infectious dose is 1–3 spores, and toxin-producing anthrax may cause cutaneous, lung or intestinal anthrax, dependent on transmission via contact, air or food. The non-cutaneous anthrax has a very high lethality. In the Middle Age epidemics of anthrax, called “Black Bane” (black poison), caused a large number of deaths among humans and animals in Europe and killed half of the sheep livestock in Europe during the 1800th century. Today, about 2000 people are infected each year, mostly cutaneous and some oropharyngeal or intestinal cases, from eating or handling infected meat. During peace time, there are few incidents of threats using bioterror weapons like anthrax. However, in autumn 2001 anthrax was spread in the United States by “powder letters” (US Postal Service) to congress represented with spread of aerosols through the mail distribution systems. In all 22 cases were registered; 11 lung anthrax (5 died) and 11 cutaneous anthrax (all survived), mostly postal service-associated workers, and 32,000 persons got prophylaxis with antibiotics for many weeks. In this chapter, cases with suspected anthrax—randomly or intentionally—admitted to hospitals are described according to handling, treating and infection control.

Keywords

Anthrax · *Bacillus anthracis* · “Splenic fever” · Malign pustule · Biological terror · “Powder letters” · Zoonosis · Toxins · Spores · Infection control · Hygiene Isolation · Disinfection

89.1 Purpose

- To describe some measures to handle persons who are suspected infected/contaminated with biological terror agents, like anthrax, when admitted to hospital [1–3].
-

89.2 Comprise

- All health workers handling/taking care of persons/patients and equipment associated with suspected infection/contamination with biological terror agents.
-

89.3 Responsibility

The hospital's management provides written plans for how to react in situations where personnel and others may be exposed to known/unknown serious communicable disease and a practical arrangement for how to handle the situation.

The *infection control officer* at the level of where the problem occurs, and at the departments/ward where the infection may spread, is responsible for following local emergency plans.

Personnel who unprotected have come in a seriously contagious situation and may have been exposed to infectious agents are responsible for contacting the nearest responsible/infectious unit for advice and of following written guideline and practical advice.

Note! No admission via main reception!

89.4 Practical Measures [4–8]

In connection with the threat of using biological weapons, the following measures should be taken internally:

- *Emergency plan: isolate capacity, transport, PPE, disinfectants, other equipment, personnel, etc.*—see emergency preparedness plan, disaster plan, hygiene instructions and infection protection.
- *Patient with symptoms possible anthrax or similar biological weapon [9–11]:*
 - Placed directly (not via reception!) in isolate—for airborne infections with strict isolation measures (contact, air, blood and tissue, etc.).
 - Check that ambulance personnel/porter/primary contacts are monitored for exposure to this type of infection (see emergency preparedness plan, hygiene manual, etc.).

89.4.1 Suspected Anthrax

In general, risk of spread of anthrax infection between patients is very small, regardless of type of anthrax, wounds, lung or intestinal affection. Anthrax spores live for many decades in the environment but are not defined as normal biological microbes in the environment in most countries in Europe, today [12, 13].

- *Patient with symptoms/suspicion of anthrax* is admitted directly into isolate for airborne infections (air and contact isolation) through direct external access from outside of the isolate.
- *Patient detected with suspected anthrax after admittance to hospital (inpatient, outpatient clinic)* is a seldom and unexpected discovery. In this situation infection control measures are usually not in place. This may be biological terrorism or other suspicion of anthrax infection.
 - *Example:* Random discovery of possible anthrax in wound from a patient in a four-bed room. The patient has been hospitalized for 3 days due to a deep purulent wound, fever and respiratory symptoms. A variety of contacts with personnel/visitors and a possibility that personnel, patients and visitors may have been exposed to bacteria/spores.
 - Verify the diagnosis “suspected anthrax” with clinical and microbiological findings.
 - If confirmed diagnosis, consider following measures in consultation with *infection control personnel* who have the advisory and coordinating responsibility for the infection control at the hospital.
 1. *Report and inform the manager in charge;* see reports; contact infection control personnel.
 2. *Personnel who have been in contact with the patient/equipment,* immediately wash hands. Then disinfect the hands in 5% chloramine (effect on spores). Take so on surgical mask, cap, gown and gloves prior to further care and treatment of the index patient and roommates in the same room. Be careful with bedding so that no spores/bacteria are released to the air.
 3. *The room closes,* signs are put on the door. Nobody leaves the department until registered and informed about what to do. If biological terror of anthrax is suspected, room disinfection is awaited until examinations and samples are taken from the patient’s and any co-worker’s equipment (possibly powder).
 4. *Patients in the same room—roommates—of the index case* are isolated in a separate room, transferred in a clean bed with surgical mask if coughing and should undergo wash/shower with Hibiscrub if possible in new room.
 5. *The index patient is isolated* (air and contact isolate). Prior to transfer to the isolate, the patient is placed in a clean bed, and a surgical mask is placed on the patient if he is coughing. The patient should undergo wash/shower with Hibiscrub if possible in the isolation unit.
 6. The bed and all of the patient’s equipment are left in the first room and the room is closed.

7. *Disinfection.* Bed and entire room with equipment may be disinfected first with hydrogen peroxide gas by robot, then with 5% chloramine for at least 1 h; see point 10.
8. *The department is closed* for entry of new patients and personnel.
9. *Samples* of roommates and exposed persons; nose, throat and wounds. Notify the microbiological department.
10. *Exposure to infection—removal of possible contaminants.* Exposed persons/personnel who have been in contact with the index patient should wear a clean gown over their clothes and shoe covers and go directly to a designated wardrobe. Take off clothing and shoes carefully to avoid transmitting contaminants to the air. The used clothes are placed in an infection waste bag. Shoes are put in a separate waste bag for disinfection. Everything is treated as infectious. Shower with soap/Hibiscrub and water. Change to new clothes in a clean place in the wardrobe.
11. *Disinfection of rooms*—use P3 mask, cap, goggles, long-sleeved waterproof gown, double gloves and shoes that can be autoclaved/burned. All disposal barrier equipment is treated as infected waste that is burned - or autoclaved. Remember disinfection of fixtures and equipment. Hydrogen peroxide dry gas robot can be used first (with spore tests) in all relevant rooms before chloramine 5% disinfection with effect for at least 1 h, before ordinary cleaning.
12. Consider the need for *environment tests before decontamination* (swabbing with sterile gas moistened with sterile saline/water on suspected areas—biological terrorism?).
13. *Registration*—Personnel at the department and other personnel who have been in contact with the patient are registered (as for MRSA). Exposed persons who have been in the actual patient rooms are registered. The department's management is responsible for registration and to report to potentially exposed persons.
14. *Exposed persons* contact infectious outpatient clinic after appointment. Samples are taken from the throat, nose and wounds for cultivation. Microbiological laboratory is notified.
15. *Protection during further work at the department/ward before microbiological clarification.* Use surgical mask, cap, gown and gloves for all patient care (as in MRSA). Each patient is protected with a separate barrier.
16. *Further working situation for exposed personnel*, while the test result is not available, can work, but use masks, cap, gloves and gowns. Do not work at other departments (like MRSA).
17. *Positive tests of anthrax*—Personnel and others start treatment and possible vaccination and leave the work. Further follow-up of infection specialist.
18. *Treatment*—Upon detection of *Bacillus anthracis* in personnel and others is treatment with Ciprofloxacin 500 mg × 2 started for 60 days, alternatively doxycycline 100 mg × 2 for 42–60 days, possibly penicillin (in most cases penicillin sensitivity).

89.4.2 Information

- The Director is informed on a regular, daily basis.
- Information to cooperating and surveying health authorities, the media, etc. is due to the fact that managers, by virtue of their position, are responsible within their field of medicine cf. the hospital's procedure for statement to the press/media. The information director coordinates and facilitates this work.

89.5 Background Information

Anthrax is still endemic or hyperendemic on all continents in the world, mainly as a zoonose among unvaccinated cattle. Natural anthrax in human is associated with contact with sick animals and animal products [12]. *Bacillus anthracis* is producing lethal toxins and spores that can survive in the environments for hundred years or more. Minimum infectious dose is 1–3 spores, and toxin-producing anthrax may cause cutaneous, lung, or intestinal anthrax, dependent on transmission via contact, air or food [13]. The non-cutaneous anthrax has a very high lethality. In the Middle Age, epidemics of anthrax, called “Black Bane” (black poison), caused a large number of deaths among humans and animals in Europe and killed half of the sheep livestock in Europe during the 1800th century [12]. Today, about 2000 people are infected each year, mostly cutaneous and some oropharyngeal or intestinal cases, from eating or handling infected meat [12, 13]. During peace time, there are few incidents of threats using bioterror weapons like anthrax. However, in autumn 2001 anthrax was spread in United States by “powder letters” (US Postal Service) to congress represented with spread of aerosols through the mail distribution systems [12]. In all 22 cases were registered; 11 lung anthrax (5 died) and 11 cutaneous anthrax (all survived), mostly postal service-associated workers. Thirty-two thousand persons got prophylaxis with antibiotics for many weeks [12].

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Preparedness in Connection with Biological Weapons

90

Biological sabotage-treatment of post-mail

Abstract

During autumn 2001, anthrax was spread in the United States by “powder letters” (US Postal Service) to congress represents with spread of aerosols through the mail distribution systems. As a result of this happening, a lot of fake “powder letters” and parcels were sent to—and within many countries, also in Norway. Official and large company buildings with many people present are most often the goal by this form of bioterrorism, therefore preparedness plans must be in order.

Keywords

Biological sabotage · Bioweapon · Preparedness · Infection control · Hygiene Disinfection · Infected post-mail

90.1 Purpose

Describe a scenario in the primary phase of dangerous transferable diseases, like biological sabotage of post-mail and practical measures to avoid spread of infectious agents from post-mail.

90.2 Comprise

All persons that have been in contact with contaminated post-mail and/or contaminated environment where spread of biological weapons and/or dangerous microbes are suspected.

90.3 Responsibility

The hospital's management provides written plans for how to react in situations where personnel and others may be exposed to known/unknown serious communicable disease, including bioweapon, and a practical arrangement for how to handle the situation.

Infection Control Officer at the level of where the problem occurs, and at the departments/ward where the infection may spread, is responsible for following local emergency plans.

Personnel who unprotected has come in a seriously contagious situation are responsible for contacting (per telephone) the nearest responsible/infectious unit for advice and of following written guideline and practical advice.

90.4 Practical Measures for Treatment of Suspected Mail: During Threats [1]

In connection with the threat of using biological weapons, the following measures should be taken internally regarding the handling of mail/parcels:

Unopened mail: Suspicious, unknown package mail/letter from abroad with content other than regular sheets/journals and more:

- Do not open; gently put it into a yellow, transparent plastic bag.
- Throw away promotional materials unopened.
- Contact the addressee internally at the hospital.
- If unknown to the addressee, put it aside in an infection container, and contact eventually the police (to check sender, redirects, etc.)

Opened mail: If any suspicious material is found, powder and the like from an unknown addressee, it may be dangerous:

- Leave the envelope with material lying on the bench—*do not sniff/smell on the contents!*
- Wash your hands immediately, disinfect with chlorine/alcohol before doing anything else.
- Place a clean plastic bag all over the shipment.
- Report to the department management who contact the police and report to infection control personnel. The department management register persons exposed to the material (persons in the same room). The extent of measures is decided by the infection control physician.
- Exposed persons take off clothes on site. Cloths are placed in a waste bag that closes and is stored for microbiological test response. Then the hands are washed/disinfected.

- Exposed persons (in the same room) go to the nearest wardrobe, take off the rest of the clothes, put it into a new waste bag and shower. Reapply clothes and continue working as usual.
- The suspected mail will be removed by the police/healthcare staff; microscopy of powder is done, and samples are cultured at microbiological laboratory or what is determined according to plan.
- Samples of exposed persons are relevant: nose, throat, hands and any clothes if spilled outwards.
- The room closes. If the activity is to be maintained, immediately disinfect the room. Equipment that cannot be disinfected is packed into waste bags for infectious agents.
- *If positive test of the mail-parcels:* Exposed person is tested and immediately treated prophylactically. Other people who were in the room are being tested and prophylactically treated at the infectious outpatient clinic. In addition, consider vaccination of infected persons, if inhalation is not excluded.

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Dangerous Infectious Agents Combined with Hazardous Chemicals

91

Abstract

In extreme situations during war and terror, and also during peacetime, there may be sudden outbreaks of unknown illness with a high lethality. In addition, there may be a larger number of healthy people who may be exposed to the harmful agent(s) and yet with no symptoms. This situation may be caused by dangerous, high-risk microbes or by dangerous chemical agents and gases or by microbes and chemicals in combination—if intended action. The exposure may happen via aerosol, dust/dirt, food or water, etc. and may involve wounds and other injuries that need treatment (injuries from explosions, bombs, etc.). Patients may be highly contaminated by infectious agents/chemicals on clothing and skin when coming for further treatment in hospitals. This chapter describes the first steps of taking care of exposed persons: how to handle, decontaminate and remove dangerous agents and give first help.

Keywords

High-risk microbes · Hazardous microbes · Hazardous chemicals
Decontamination · Infection control

Intent, scope and responsibility, see serious, common contagious scenarios, Chap. 82.

91.1 Purpose

To handle persons exposed to dangerous agents like microbes and/or chemical agents without spreading the contamination.

To protect patients, personnel and others against spread of infection and contamination.

91.2 Comprise

All health care workers that are handling heavily contaminated (infectious agents and/or chemicals) persons or equipment during the first steps when admitting to hospitals.

91.3 Responsibility

The hospital's management provides written plans for how to react in situations where personnel and others may be exposed to known/unknown serious communicable disease, including bio-weapon, and a practical arrangement for how to handle the situation.

Infection Control Officer at the level where the problem occurs, and at the departments/ward where the infection may spread, is responsible for following local emergency plans.

Personnel who unprotected has come in a seriously contagious situation and may have been exposed to infectious agents is responsible for contacting (per telephone) the nearest responsible/infectious unit for advice and for following written guideline and practical advice.

91.4 Practical Measures [1, 2]

Healthy people who have been exposed to the harmful agent(s) and yet with no symptoms may perform a rapid decontamination with showering, bathing, changing clothes, medical prophylaxis, etc. outside the hospitals. Here the civil defence has a high responsibility to assist the population.

91.4.1 Hazardous Microbial Contamination: With or Without Hazardous Chemicals

91.4.1.1 Preparedness

Notify the person in charge at reception, who further communicates messages according to emergency preparedness plan. Infection control personnel are contacted to protect personnel, other patients and the environment.

Decide as far as possible if the patient is highly contaminated by infectious agents on clothing and skin (aerosol, dust/dirt, water) and/or of chemically dangerous agents. In case of suspected chemical agents, diagnostic equipment is prepared for the detection of hazardous chemical agents (CAM). CAM can be used on the patient before entering the hospital.

1. *Reception* redirects transport of the suspected case to external access to the isolate for airborne infections with negative air pressure. All intensive treatment takes place at this isolate (respirator treatment and more).

2. *Isolates for airborne infections* are prepared with decontamination rooms and sluice function. The negative pressure ventilation must be checked, and there must be protective equipment for a minimum of ten persons.
3. *Consider* the need to empty the isolation unit for other patients (if there are other patients isolated).
4. *Persons in charge (two persons)* take on protective equipment: respiratory protection, cap, tight-wearing glasses, double gloves, special waterproof gown or overalls, phantom hood (with surgical cap below), shoe covers and other disposable equipment. Additionally raincoats and boots when showering the patient. Eventually fresh air systems.
5. *Assistance (one to two persons)* prepares with PPE in the same way but stays outside the isolate/in the sluice and takes care of the in-and-out delivery of equipment and contaminated waste, as well as checking the proper removal of PPE.

91.4.2 Biological Dangerous Agent: Not Chemical

1. *Patient infected with dangerous agent but not contaminated on clothing or skin* is admitted directly through external access into the isolate. Diagnostics, treatment and registration are put into effect. Continue isolation treatment for clarification/treatment effect, etc.
2. *Patient infected via contaminated aerosols, dust, dirt and water* (for instance, biological weapons) on clothing and skin.
 - Place the patient in airborne isolation with direct access from outside or in a preinstalled decontamination tent placed outside the isolation unit.
 - Ask the patient to close the eyes and mouth and breathe calmly through the nose. Meanwhile wash the face gently and quickly with water and hibiscrub (chlorhexidine wash) or chloramine 5% (remove infectious tissue around the nose/mouth/eyes).
 - Respiratory protection (P3 mask) should be applied to the patient before quickly and carefully (re-aerosols) taking off the clothes before showers/whole body wash with hibiscrub. Remove the mask while the patient showers and start washing/showering the head. Finally put on a new respiratory protection.
3. *After decontamination*, the patient is moved in a clean bed with new equipment and with P3 mask on a new isolate, while the first isolate may be decontaminated or clarified to the next patient.
4. *The patient is treated and taken care of in the isolate*. Continue isolation treatment for clarification/treatment effect, etc. Intensive treatment is carried out in this isolate. *Surgery*, preferably in airborne isolation, see below and separate chapter.

91.4.3 Biological Infection: Suspected Combined with Chemical Dangerous Substances

Person exposed to—or possibly contaminated by—dangerous microbes and/or hazardous chemical agents. The hazardous chemical substance may damage the skin

and mucous membranes of the patient but will not cause a danger to personnel if personal protective equipment/chemical barrier equipment is used.

Use chemical protective clothing outside of PPE. Otherwise, follow treatment as above: Sect. 91.4.2, 1–4.

91.4.4 Surgical Treatment: Infectious Agent: High Risk with or Without Chemical Agent

91.4.4.1 Emergency Operation

Reception clarifies diagnostic equipment for detection of hazardous chemical agents (CAM).

Patient decontaminates as described above.

After decontamination, the patient is moved to a new bed with P3 mask to an isolate or to an operating room equipped for infectious surgery. Avoid transport through patient wards; clean the bed throughout, and place a clean sheet over the bed before transport. The decontamination room is cleaned/decontaminated.

Preparation of the operating room: Optimally, the operating room should have direct access from the outside and be a complete separate unit. The unit should have a sluice system, negative air pressure and disinfected air and waste water. If not present, consider the following solution:

1. Use the operation department's "infectious room"—preferably with negative air pressure, 15 pascal or lower. Current system today is "multiresistant tuberculosis" scheme (see separate chapter). All unnecessary equipment is removed, and all openings and valves are taped over with plastic. The ventilation is turned off. Separate air extractor aggregate disinfect air out from the room. HEPA filters are put on all technical equipment that is air-cooled. Exhaust gases and ventilation air from the patient are directed directly into the extractor unit.
2. *If there is no time or situation to prepare the operating room*, use a peripherally located operating room that is closed and sealed and the ventilation is turned off (PPE for ten people).
3. Personnel for cleaning and internal service are notified.
4. It may be appropriate with a separate transport of contaminated waste, etc.; internal service is notified.
5. Evaluate the stop of the operating program of the whole operation department, and empty the operating department for unauthorized persons.

After surgery, the patient wakes up in the operating room and is transferred into a new bed that is covered with a clean bed sheet, and use respiratory protection on the patient during transport to airborne isolate. Avoid transport through patient areas; prefer external transport to isolate.

The operation unit is decontaminated as usual after high-risk infections. Machinery and other technical equipment which inner parts cannot be heat disinfected or treated with 5% chloramine may be gas sterilized—considered by

infection control personnel. Hydrogen peroxide dry gas can be used for disinfection of equipment, ducts, etc., which are hardly available with common surface disinfection. The equipment must then be started so that the gas is pulled through internal parts. Use spore control to document the effect. Gas disinfection has killing effect on most bacteria, bacterial spores and virus after approximately 3 h of disinfection (no effect on *Mycobacteria*). After gas disinfection, disinfect surfaces with 5% chloramine- for one hour.

91.4.5 Not Infectious, Only Dangerous Chemical Agent: Hospital Emergency Preparedness Plan

Chemical agent: liquid, powder and gas (respiratory system and/or the skin).

Decontamination room may be in close proximity to reception; must have direct access from outside, negative air pressure and separate exhaust duct to remove toxic gases, and should have quality bathroom, equipped with shower and wash on stretcher and with separate ventilation. Alternatively, a separate tent outside can be used. Also a *negative air pressure isolate* with separate entrance and disinfection room can be used for decontamination of chemical agents, if separate air extraction does not access other ventilation systems.

The patient is treated immediately in the decontamination room, and, if appropriate, the extent of injury and measures recorded.

After decontamination, the patient follows the usual procedures in the hospital, depending on the condition. Further treated as non-infectious.

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Abstract

Healthcare-associated infections (HAIs) constitute major additional costs for the health service and society as a whole and unnecessary suffering and death among patients. Resources put in place to combat hospital infections appear to reduce infections by 30–70% and at the same time are very profitable. In high-income countries, the prevalence of healthcare-associated infections in mixed patient populations may be 7–10%. During the last 20 years, HAIs have become more dangerous with more resistant microbes, associated with indefensible use of antibiotics. The nexus of cause and effect is the use of antibiotics like “sweets,” both in human and animal medicine, combined with a great neglect of hygiene and infection control, “to treat bad hygiene and lack of infection control by bad antibiotics”. Today there is a short stay in hospitals. A high burden on each patient bed; overcrowding, and on each personnel; understaffing, results in a higher risk of HAIs. By establishing at least one infection control nurse (ICN) per 250 somatic patient beds and one infection control physician (ICD) per 1000 beds, hospital infections have been reduced by one-third. However, the number of infection control personnel should be assessed by number of admissions and other activities of the hospital. Investments in infection control personnel, statistics, technical equipment, etc. for monitoring and preventing of hospital infections pays for hospitals, patients and society as a whole. It is a clear cost-benefit measure.

Keywords

Infection control · Infection control nurse (ICN) · Infection control doctor (ICD) · Healthcare-associated infection (HAI) · Resources · Surveillance · Prevention · Containment · Resistant microbes · Epidemics · Nosocomial infections · Hygiene nurse · Hygiene

92.1 Purpose

- To protect the patient, personnel, environment, healthcare institution and the society in general, against spread of healthcare-associated infections, by the presence of competent and updated infection control personnel (ICP):
 - That are working with the hospital staff to establish relevant infection control routines, guidelines, hygienic measures, surveillances and practical solutions during outbreaks
 - Participate in planning and working with emergency measures concerning infectious outbreaks
-

92.2 Comprise

- All ICP responsible for the infection control work at the hospital
 - All personnel and leaders working together with ICP during preventive controls, surveillances, reports, methods and emergency situations
-

92.3 Responsibility

The hospital's management is responsible for ensuring enough resources, including infection control personnel, for proper infection control work at the hospital and for the presence of an updated Infection Control Programme, updated internal guidelines, surveillance systems, quality of hygienic standard and for other control and prevention of infections at the hospital, according to guidelines, activity and actual laws.

The infection control management is responsible for updating and implementing the Infection Control Programme at the hospital, for surveillances, control and prevention of spread of infections and for emergency plans and guidelines concerning outbreaks of infections. Infection control reports to the hospital management: hygienic problems, outbreaks, deviations from procedures etc., that may result in infection risk for patients, personnel or others.

Department management provides implementation of routines concerning hygiene, control and prevention of infections, according to the infection control programme, and contacts infection control concerning hygienic issues, questions and information concerning infectious diseases.

Staffs follow routines concerning hygiene and infection control. Deviations from internal guidelines and procedures should be reported to the management and to infection control unit.

92.3.1 Burden of Hospital-Associated Infections

Hospital infections constitute major additional costs for the health service and society as a whole and unnecessary suffering and death among patients [1–30].

Resources put in place to combat hospital infections appear to reduce infections by 30–70% and at the same time are very profitable [1–13, 24].

92.3.1.1 Cost of Some Hospital-Associated Infections

Central line-associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), surgical site infection (SSI), catheter-associated urinary tract infection (CAUTI) and *Clostridium difficile* infection (CDI) are estimated to cost:

One case of	was in the USA (2013) estimated to [17]
• CLABSI	• 45,800 USD
• VAP	• 40,145 USD
• SSI	• 20,785 USD
• <i>C difficile</i>	• 11,285 USD
• CAUTI	• 900 USD

92.3.2 The Need for Infection Control Resources

Hayley et al. (1985) showed that by establishing an infection control nurse (ICN/ICP) per 250 somatic patient beds and an infection control physician (ICD) per 1000 beds, hospital infections were reduced by one-third (32%), postoperative wound infections by 20–35%, urinary tract infection by 38%, sepsis by 35%, and pneumonia by 13–27% and other types by 32% [2].

Investments in personnel, statistics, technical equipment, etc., work on prevention, monitoring and follow-up of hospital infections pays for hospitals, patients and society as a whole. It is a clear cost-benefit measure [2–17].

During the last 30 years, different needs for infection control personnel have been calculated in relation to the number of somatic beds or the number of hospitalizations, see table below [2, 3, 6, 7, 12, 16, 19–31]. Number of personnel should be assessed by number of admissions and other activity of the hospital. This is important because of shorter stay, more and more patients (also risk patients) pass the hospital admission and discharge systems, and there is a higher burden on each patient bed.

Minimum requirements are [32]:

- Infection control doctor (ICD)/epidemiologist
- Infection control nurse (ICN) (hygiene nurse)
- Bioengineer, medical microbiologist and specialist in infection medicine
- Mercantile personnel for prevalence and incidence surveys, reports, routines and messages
- Data and statistics. Continuous access to microbiological findings at the hospital
- Technical equipment (instruments for detecting of microbes, dirt, particles, ventilation conditions, air pressure conditions, etc.)
- Training, knowledge and experience; hospital staff, as well as internal updating of knowledge

- Work descriptions and functions
- Mandate descriptions for infection control personnel
- Organization and position/responsibility in the hospital
- Hygiene Committee
- Antibiotics Committee, Building Committee, Purchasing Committee, etc.
- Infection control laboratory, including microbiology and study of environmental microbes [32]

In 2005, the number of infection protection personnel per 1000 beds in 12 countries in Europe are as follows [26]:

- | |
|--|
| • 1.2 ICD ^a |
| • 3.4 ICN |
| • 1 computer engineer |
| • 1 epidemiologist |
| • 1 administrative/mercantile support |
| • 1 technique, monitoring |
| • SUM: At least 9.3 full-time positions per 1000 patient somatic beds. |

^aAt least 6 years postgraduate training with specialty/subspecialty in infection control [26]

92.3.2.1 Infection Control Nurses (ICN): Hygiene Nurse

Needs relative to the number of somatic beds vary from one ICN per <100 patient beds to one ICN per 365 beds (see Table 92.1). The ratio of personnel to numbers of somatic patient beds depends on complexity, acute activity and patient categories.

92.3.2.2 Infection Control Physician (ICD, Infection Control Doctor)

The need of ICDs in somatic departments is calculated to one ICD per 800–1000 somatic hospital beds; see Table 92.2. In Belgium, ICD is a separate medical specialty. The Netherlands required in 2007 one medical microbiologist per 806 patient beds or one per 25,000 admissions [27].

Consensus reports for infection control generally lack specific recommendations regarding staffing of infection control nurses [3–36]. This may lead to a lack of follow-up and implementation of infection prevention [33–36].

The need for infection protection personnel and technical assistance is increasing in somatic emergency hospitals. Scheckler et al. wrote already in 1998 that “the old ratio of one ICP per 250 beds is no longer adequate”. “In most acute care hospitals today, the scope of work of ICP is much greater than that provided by the old ratio” [31]. The Delphi project from 2002 has made a graded staffing plan in relation to the hospital type and nursing home [24]. From Canada, ICP is proposed and assessed by workload in both hospitals (1:100) and nursing homes (1:250), and similar is recommended in France (1:100) [3, 25]. A recent systematic study of hospital organization, management and structure of infection protection in Europe supports this assessment [37].

Table 92.1 Needs for infection control nurse (ICN-ICP) in hospitals per number of beds in somatic hospitals

Hygiene nurse, infection control nurse (ICN), infection control personnel (ICP) in relation to somatic beds

ICN/ICP number	Per number of patient beds	Comment	Country	References
1	250	SENIC	United States	Haley et al. [2]
1	700		Belgium	Mertens et al. [19]
1	386		United Kingdom	Emmerson et al. [12]
0.2–0.75	250		Switzerland	Pittet et al. [20]
1.5	200		United States	JCAHO [21]
1	150		United States	US Navy
1.5	200		United States	Hoffman and Grant [22]
1.1	250		Canada	Zoutman et al. [23]
1	100 first	1/250 next	United States	Klevens et al. 2002/[16]
0.8–1	100	“Delphi”	United States	O’Boyle et al. [24]
1	133	2003	Quebec, Canada	Publ. Hlth Canada [3]
1	100	2003 special	Quebec, Canada	Publ. Hlth Canada [3]
3	500		Canada	Health Canada [25]
1	150–250	LTCF	Canada	Health Canada [25]
3.4	1000		Europe 12 countries	Voss et al. [26]
1	178		Netherlands	van den Broek et al. [27]
3	1000 ^a	1995–2007	Norway	Andersen et al. [28]
1	100		France	Carlet et al. [6]
1	400	“historic”	France	RAISIN [7]
1	167	average	USA NNIS	Stone et al. [29]
0.6	250	LTCF	Canada	Zoutman et al. [30]

LTCF long-term care facilities, Nursing Home, SENIC Great American Study, NNIS hospital network in the United States

^aIn addition, more than 200 psychiatric patients

92.3.3 Education and Responsibility for ICN/Hygiene Nurses [38]

In accordance with the Act on Specialist Health Care Services §§ 2-1 a, 3 -3,3-4, and Regulations on infection protection in the health service of 17 June 2005, pursuant to Law 5 August 1994 no. 55 on protection against communicable diseases §§ 4-7,7-11, the following mandate is made for ICN/hygiene nurses in Norway:

- Hygiene nurse (ICN) shall have formal education such as hygiene nursing care, administrative experience, management training, teaching competence and good written and oral ability. Experience and special education in surgery, intensive medicine or emergency medicine is the basis for further education as a hygiene nurse.

Table 92.2 Needs for infection control doctor (ICD) in hospitals per number of somatic beds or admissions

Infection control doctor (ICD) in relation to somatic beds				
ICD number	Per number of patient beds	Comment	Country	References
1	1000	SENIC	United States	Haley et al. [2]
1	1700		Belgium	Mertens et al. [19]
1.2	1000		Europe 12 countries	Voss et al. [26]
1	806	1/25,000 admissions	Netherlands	van den Broek et al. [27]
1	800		France	Carlet et al. [6]
1	800		France	RAISIN [7]
1	1000 ^a	1995–2007	Norway	Andersen et al. [28]

SENIC Great American Study

^aIn addition, more than 200 psychiatric patients

- Hygiene nurse is responsible for the ongoing functions/tasks that can naturally be linked to hospital hygiene work in accordance with the hospital's infection control program.
- Examples of important tasks:
 - Advice and information on hospital hygiene work
 - Prevalence and incidence surveys, follow-up and feedback
 - Participate in infection tracing, infection monitoring and infection control measures
 - Participate in infection control procedures and guidelines
 - Work with quality assurance of sterile equipment, other equipment, textiles, cleaning, etc.
 - Teach and arrange further education of health professionals
 - Participate in development and research work
 - Provide advice, guidance and information to other hospitals and municipalities
 - Attend hygiene forums, relevant building/rebuilding committees, working environment, meetings and emergency preparedness groups
 - Attend regional and international infection control meetings

92.3.4 Responsibility, Mandate, Education and Work for Infection Control Doctor (ICD) (Hospital Hygienists) [36]

In accordance with the Act on Specialist Health Care Services §§ 2-1 a, 3 -3,3-4, and Regulations on infection protection in the health service of 17 June 2005, pursuant to Law 5 August 1994 no. 55 on protection against communicable diseases §§ 4-7,7-11, the following mandate is made for ICDs in Norway:

- ICD should be a specialist in medical microbiology or infectious medicine, and in the long term, a speciality in infection control should be established.

- ICD coordinates the infection protection work in the hospital and should in such cases be directly subject to the management at the hospital, lead the infection prevention work, and be the adviser to the hospital's management and towards the different departments at the hospital.
- ICD is the head of the department for hygiene and infection protection and organizationally associated with quality and patient safety.
- The hospital management, director of the hospital, has overall responsibility for the infection control program at the hospital, while the ICD has the medical professional responsibility for designing and maintaining the program as part of the hospital's internal control system.
- Responsibility for implementing the program lies with the line manager.
- The infection control program contains two organizational and medical professional parts that constitute measures within (a) infection monitoring and (b) infection prevention.
- The ICD/ICN should be represented in the hospital's quality committee, building committees and other committees to ensure and improve the hospital hygiene standard (e.g., new building/rebuilding, purchasing of medical equipment, practical methods and new techniques, routines, products, etc.).
- ICD shall have a *professional free and independent position* that allows for quick, effective and independent advice regarding infection prevention and infection control measures.
- Internal reporting regarding hospital infections or suspected hospital infections shall be directed to infection protection personnel and through the usual reporting obligation for deviations to quality department. This applies to all departments at the hospital, both in terms of prevalence, incidence investigations and reporting of single cases according to reporting routines included in the infection control program.
- ICD reports to the Director of the hospital, to the National Institute of Public Health and the Public Health Authority in the County for major outbreaks and particularly hazardous infections/situations. In addition, the ICD reports to the Director on deaths due to hospital infection and/or resource-intensive measures [38]. Prevalence and incidence of hospital infections are reported to the health authorities on an ongoing basis.
- ICD and ICN shall have free access to information, use and processing of, for example:
 - Microbiological results (daily, weekly and monthly annual reports, etc.)
 - Other patient data (clinical data, prevalence and incidence)
 - Consumption of antimicrobial agents (weekly reports, defined daily doses (DDD)/department)
 - Staff data, if actual for infection tracing and environmental measures
- ICD shall—in collaboration with the microbiological department—have access to the necessary laboratory capacity and technical staff in the work with infection-preventive measures and tracing of outbreaks.
- ICD and ICN shall contribute to the planning and teaching of hospital hygiene and infection control to medical students and physicians and to other healthcare personnel in the hospital hygiene.
- A hygienic forum, or similar like that, should be an advisory board headed by the ICD.

92.3.5 Organization, Management, Staffing and Part-Time Work

Infection control work depends not only on a functional infection control team but also on the organization and management of the hospital, burden on patient beds, staffing and workload [28, 37]. MRSA infections are spread by understaffed personnel in intensive care units, new-born departments and many other types of hospital departments [28, 37, 39–54].

Intensive care units An increase of MRSA cases in intensive department is most often related to increased work pressure among nurses [39–41]. Such outbreaks can be controlled by avoiding overcrowding [40]. A study demonstrated that MRSA infection increased significantly among hospitalized patients when more than seven out of eight beds were in use (87%) [41]. The intensive patient is usually critically ill. In case of high work pressure, the number of infections in such patients increases [42]. Among 1800 intensive patients, a higher staffing level was associated with over 30% reduction of the infection risk. By keeping nursing/patient ratio of more than 2.2, a reduction of infections of 27% was calculated. Too low staffing in intensive departments has been linked to 50% increase in hospital infections [43]. Overcrowding and understaffing have also been associated with blood catheter infections from central catheters and with hepatitis C transmission during dialysis [44–46].

New-born intensive units At Ullevål University Hospital, MRSA outbreaks occurred in the new-born intensive care department in 2002 [47]. This department was understaffed with many part-time employees who worked at several hospitals at the same time (especially at hospitals in Sweden). There was a chronic overcrowded unit; small patient space and isolates were missing, and patients from different parts of the ward were gathered in fewer rooms to save personnel night-time and weekends. This led to a larger spread of infection [47]. Later on, in 2010, the condition and management were unchanged at new-born, while at the same time, there was a large overcrowding, heavy undercapacity, mixing of patients from different patient rooms and at the same time spread of a serious infection with gentamicin-resistant *S. aureus* among the children [48].

A study of 3.65 million paediatric patients in California showed that resource-based nurse staffing was related to significantly reduced cases of postoperative lung complications, including pneumonia and postoperative sepsis [49].

Other departments in hospitals Overcrowding is an important factor for the transmission of MRSA and other MDRO-bacteria also within other parts of the hospital [50]. An occupancy rate above 85% of patient beds causes a rapid turnover of patients and shorter stay time per patient and is significantly associated with MRSA proliferation in Northern Ireland and in England [51–53]. A Finnish study showed that the overall risk of hospital infections increases during long working time, high levels of work pressure and poor cooperation between staff [54].

Good organization and management can reduce hospital infections [55–57].

92.4 Background Information

92.4.1 The Burden of Infections That Can Be Prevented

Infections are very common both outside and inside healthcare institutions—move between institutions and between the community and institutions, following patients, personnel, visitors and equipment. Globally, it is, for example, estimated that two out of seven people in the world have infections with *Staphylococcus aureus* each year.

Healthcare-associated infections (HAIs) constitute major additional costs for the health service and society as a whole and unnecessary suffering and death among patients [1–30]. Resources put in place to combat hospital infections appear to reduce infections by 30–70% and at the same time are very profitable [1–13, 24].

Studies have shown that in high-income countries, the prevalence of healthcare-associated infections in mixed patient populations may be 7–10% [58]. The burden is higher in the developing world. Prevalence studies show a large variation between hospitals and between countries, with a pooled prevalence of 10.1% HAI [58]. The prevalence is significantly higher in high- and then in low-quality studies, 15.5% versus 8.5%, respectively, and is very high in intensive care units, 30% or more [58].

During the last 20 years, there has been a change in HAIs towards more dangerous infections, more resistant microbes, associated with indefensible use of antibiotics. The nexus of cause and effect is the use of antibiotics like “sweets,” both in human and animal medicine, combined with a great neglect of hygiene and infection control in developed countries. It is the same as “to treat bad hygiene and lack of infection control by bad antibiotics.”

WHO summarizes this problem in 2014 [59]:

1. High proportions of resistance were reported in all regions to common treatments for bacteria causing infections in both healthcare settings and in the community.
2. Antibacterial resistance has a negative effect on patient outcomes and health expenditures.
3. Treatment options for common infections are running out.
4. Despite limitations, the report demonstrates worldwide magnitude of antibacterial resistance and surveillance gaps [59].

The overall economic impact of this situation is very high, with reduced consumer income, employment and savings, and increased national investment and spending in healthcare delivery [60]. The result for most developed countries is a reduced gross domestic product (GDP) by 1.4–1.6% [60].

- In the United States, 1.7–2 million healthcare-associated infections are calculated each year (population 300 million), which leads to 99,000–103,000 deaths (5.8%) and direct extra costs of 20–40 billion USD each year [1, 4, 14–16, 58].

- A meta-analysis of costs and financial impact during the period 1986–2013 in the United States showed that hospital infections were a “major supplier” of illness and death that could be prevented [17]. Five types of hospital infections, catheter-associated sepsis (CLABSI), ventilator-associated pneumonia (VAP), postoperative wound infection (SSI), *Clostridium difficile* infections and catheter associated urinary tract infections (CAUTI), amounted to 400,000 infections and ten billion USD, annually [17].
- CDC’s annual HAI progress reported 722,000 HAIs and 75,000 deaths during stay in US acute care hospitals in 2011 [61]. One in every 25 patients caught infection in hospitals. There was a 50% decrease in CLABSI between 2008 and 2014, 17% decrease of SSI, 8% decrease of CDI, 13% decrease of MRSA bacteraemia and no change in CAUTI [61].
- Estimated burden of *antibacterial resistance* in the United States was in 2013 more than 23,000 deaths, more than two million illnesses and overall social costs up to 20 billion USD direct and up to 35 billion indirect [59].
- In Europe (population, 500 million), HAI may cause 16 million extra days of hospital stay and 37,000 attributable deaths and contribute to additional 110,000 annually [58]. Annual direct cost is estimated to seven billion Euro [58].
 - Estimates between 2011 and 2012 from data from 1150 hospitals in 30 European countries resulted in more than 2.5 million HAIs with estimated deaths in 90,000 people, annually [62]. One in every 20 patients caught an infection during stay in hospital. Cassini et al. estimated that around a third of infections were preventable through better hygiene, detection and improved infection control [62]. Pneumonia, SSI and urinary tract infections had the highest numbers of cases per year, while bacteraemia and pneumonia had the highest death rate [62].
 - Estimated burden of *antibacterial resistance* in Europe is 25,000 deaths per year, 2.5 million extra hospital days and approximately 1.5 billion Euro per year [60].
- In Thailand (population, 70 millions), the burden of *antibacterial resistance* results in >3.2 million extra hospital days, >38,000 deaths and >1.5 billion USD in direct and indirect costs per year [59].
- In Norway (population, five million), the four types of HAIs registered, urinary tract infection, lower respiratory tract infection, SSI and bacteraemia, may cause infections in 5–10% of admitted somatic patients [1, 18, 63, 64]. These four types amount to approximately 45,600 patients with HAIs each year [1, 63]. With five extra hospital days (900–1000 Euro/day), the four HAIs may cost at least 205 million in direct annual additional hospital expenses [1, 63].

92.4.2 The Quantitative Need for Infection Prevention Staffing

As shown in the tables above, the quantitative needs assessment is varying between countries and hospitals and may be results of knowledge, mandate, responsibility, resources, patient categories, meaningfulness and organization of infection

prevention. Recently, a systematic study was done to quantify infection prevention staff and coverage needs in five states (34 hospitals, 583 ambulatory sites, 26 in-home and long-term care programs) in the United States [65]. When the need of infection control personnel was aggregated across the organization, “the comprehensive review results yielded a new benchmark of 1.0 infection prevention full-time equivalent per 69 beds if ambulatory, long-term care or home care are included” [65].

Since the patients are staying shorter and shorter time in hospitals and return back to primary healthcare or to other hospitals with infections/carrier state, they may spread infections to others that in turn are seeking medical help in the healthcare. This is to create an “evil circle” of preventable and expensive infections in the healthcare and society. The study of Bartles et al. puts focus on this problem and proposes an even more effective and comprehensive way to reduce preventable infections [65].

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Definitions

Infection: Invasion or presence of microbes that damage the tissue or tissue function—with or without symptoms. The infection may be acute with symptoms or chronic with or without symptoms.

- *Colonization* is when microbes are present without damaging tissues or functions.
- *Infection carriers:* Persons who are carriers of potentially infectious microbes without being clinically ill (colonized or symptomless infection).
- *Hospital-associated infection* is infection—due to treatment or stay at a hospital—and not present or in the incubation phase upon admission. Usually, hospital infection is registered:
 - Up to 30 days after discharge from the hospital
 - By implanted prosthesis/foreign body up to 1 year
- *Nosocomial (“house common”) infection:* Hospital-associated infection and divided into 12 disease groups developed by the Centers for Disease Control and Prevention, CDC, Atlanta, USA, 1988 and later revisions [1–4]. The following are listed:
 1. Urinary tract infections (symptomatic)
 2. Upper and lower respiratory tract infection
 3. Gastroenteritis
 4. Surgical site infections: superficial and deep
 5. Infection in burns, other skin and soft tissue infection
 6. Intra-abdominal infection
 7. Osteomyelitis
 8. Septicaemia (bacteraemia)
 9. Meningitis
 10. Infection associated with intravascular tracheal intubation/canula equipment
 11. Infection in new-borns within 4 weeks, staphylococci
 12. Infections not covered by the points aboveMany nosocomial infections are easily spread between patients, personnel and the environment in the “common house”.
- *HAI* healthcare-associated infections are associated with infections encountered in treatment and stay in the health service, hospitals, nursing homes, home care facilities, outpatient clinics, medical centres, etc.

- *CLABSI* Central line-associated bloodstream infection
- *SSI* Surgical site infection
- *VAP* Ventilator-associated pneumonia
- *UTI* Urinary tract infection
- *CAUTI* Catheter-associated urinary tract infection
- *PIVC* Peripheral intravenous catheter
- *CVC* Central intravascular catheter
- *HD* Haemodialysis
- *PD* Peritoneal dialysis
- *Point Prevalence*: point registration of a given indicator, for example, number of patients with hospital infection at a predetermined time and date, expressed as percentage of the total number of patients in attendance [4]. The prevalence of hospital infections may be somewhat higher than the incidence. At the completion of point prevalence only four times a year, the result will be approximately results in the case of incidence. Short stay at the hospital.
- *Incidence*: continuous registration over time intervals, for example, the number of patients with hospital infections within 3 months expressed as percentage of the total number of patients in the same period of time.
- *Infection control* program: a program that includes all necessary measures to prevent and counter hospital infections and for the management and follow-up of outbreaks of such infections [1–4]. It shall contain necessary measures for (a) infection monitoring, (b) infection prevention, (c) measures for control of outbreaks, and (d) emergency preparedness for serious/extensive infection.
- *Municipal infection control unit*: healthcare unit designated by the municipality to provide infection control assistance to healthcare institutions at municipal level. The unit may be located in hospitals and staffed with infection control nurses and infection control doctor (specialist in medical microbiology or infectious medicine).
- *Infection control* is a second-line special function associated with hospitals/ healthcare enterprises.
- *Medical microbiology*: the teaching of micro (small) organisms that can cause disease in humans.
- *Bacteria* are prokaryotic cells without core membranes, with many mitochondria, active mitosis systems and contain both DNA and RNA.
- *Viruses* are not living organisms, actively infectious nucleic acids, either DNA or RNA.
- *Prions* are not living, do not have DNA or RNA and are actively infectious protein molecules.
- *Medical parasitology*: the teaching of protozoans (single-celled organisms) and helminths/worms (multicellular organisms) that affect human beings. A parasite lives on another living creature.
- *Fungi* are yeast and a variety of other fungi, occasionally associated with allergies and serious infections, especially in patients with a defect of normal immune system.

- *Infections* are microorganisms such as bacteria, viruses, fungi, parasites and prions that can cause disease or unfortunate carrier status in humans.
- *The source of infection* is usually a patient, convalescent or healthy carrier but may also be infected animals (*Salmonella*, *E. coli*, *Listeria*, *Brucella*, etc.), fish, insects or contaminated food, water and environment.
- *Infection transmission* can occur directly and indirectly by contact, blood and secretions/excretions, stab injuries, and via air, drops of varying size, droplets (aerosols) and skin and dust particles. Infection can also be transmitted via infected food and water.
 - *Contact contamination*: when the infectious agent is deposited on or in the environment around the patient (e.g., diarrhoea) and includes all direct contact with the infected patient or indirect contact, with equipment and fixtures in the patient's room (via hands, equipment, clothes, etc.)
 - *Airborne/droplet contamination (including contact)*: when contaminant spread into the air as drops of different size and weight or as small, droplet nuclei (dried drops, <5 µm). Also contagious (bacteria, viruses, etc.) skin or dust particles can float in the air for hours around the patient and partially fall down on the surfaces and furniture of the room. *Note!* *Droplet contamination* is airborne and must be treated as such. Some may separate drop from airborne contamination, which does not occur in real life.
 - *Re-aerosolization*: when contaminants present in the environment are blown up in the air by shaking/blowing, for instance, during bed making, rapid door movements or with heavy air stream in the room.
 - *Blood-borne infection*: certain types of infections that can be introduced directly through the skin or through damaged mucous membranes. This can happen in case of stab or sharp injury, sexual contact, infection from mother to child during childbirth, intravascular drug use, direct contact with open wounds (if you have open wounds or eczema) and rarely by contaminated transfusions or contaminated medical equipment.
- *Droplet nuclei* are microscopic particles less than 5 µm that are residues of dried drops, for example, produced when a person coughs, sneezes, cries, sings or "speaks loudly". Droplets are floating in the air for many hours to days and can follow air currents out of the patient's room and via air vents.
- *Epidemiologically important microbes*: (a) easily transmissible - infectious, (b) make outbreak of infections, (c) may cause serious disease, (d) can contribute to treatment problems, (e) are often long-term survivors in the environment, (f) are often affected by and selected by antimicrobial consumption; type and amount, and (g) usually robust against heat and chemicals.
 - Bacteria: MRSA, VRE, and ESBL-, CRE-, CP- and NDM-1 producing Gram-negative rod bacteria, *Clostridium difficile*, other MDROs, *Klebsiella* sp., *Enterobacter* sp., *Serratia* sp., *Pseudomonas aeruginosa*, *Acinetobacter* species, *Burkholderia cepacia*, *Stenotrophomonas maltophilia*, *Listeria monocytogenes*, *Legionella* sp., *Mycobacterium tuberculosis* and other mycobacteria, etc.

- Virus: influenza virus, parainfluenza virus, avian influenza virus group, respiratory syncytial virus (RSV), metapneumovirus, enterovirus group, adenovirus group, norovirus, rotavirus, sapovirus, hemorrhagic virus, and coronavirus such as SARS and MERS.
- Fungi: *Aspergillus* and others that specifically infect immunosuppressed.
- Parasites: *Giardia* and other parasites that are contaminating drinking water.
- **Virulence** is the ability of microbes to cause disease when the infection is deposited at an appropriate recipient site (receptor, for example, lung tissue) in a person susceptible to infection (not immune). Virulence is usually related to low dose of the agent and long-term survival in the environment. Particularly low infection doses are well known for lung tuberculosis (one bacterium), EHEC (about 10 bacteria), shigella (about 100 bacteria) and norovirus (about 10 virus particles).
- **Resistant**: a bacterium may be resistant (survive), for example, to penicillin. This treatment has no effect on the bacterium (survives) or on the infection (ongoing).
- **Sensitive**: a bacterium may be sensitive to penicillin, and this treatment causes the bacteria to be killed and the infection disappears.
- **ESBL**: “extended spectrum beta-lactamases”. Bacteria that produce special enzymes that make them particularly resistant to all beta-lactam antibiotics such as penicillin, cephalosporins and eventually carbapenems.
- **MDROs**: multidrug-resistant organisms – microbes that are resistant to many antimicrobial medicaments.
- **MDR**: “multidrug-resistant” resistance to many types of antibiotics.
- **MRSA**: meticillin-resistant *Staphylococcus aureus*.
- **VRSA**: vancomycin-resistant *Staphylococcus aureus*.
- **VRE**: vancomycin-resistant enterococci.
- **CP**: carbapenem resistant to imipenem, meropenem, etc. by producing special enzymes that breaks down carbapenem antibiotics, among others.
- **CRE**: carbapenem-resistant *Enterobacteriaceae*.
- **NDM-1**: New Delhi metallo-beta-lactamase 1, a resistance gene that can be transmitted between gram-negative rod bacteria and elicit complete antibiotic resistance.
- **CD**: *Clostridium difficile*—gram-positive spore-forming bacterium that provides diarrhoea—selected by antibiotics that inhibit other intestinal flora. High carrier rate without symptoms—easily transmitted—nosocomial outbreaks.
- **CDI**: *Clostridium difficile* infection.
- **SARS**: Severe acquired respiratory syndrome. Epidemic and “pandemic” coronavirus, transmitted from animals, in 2003, started in China, Guangdong, and ended after approximately 6 months. Since then, no outbreaks have occurred. Nosocomial outbreaks are very important and easily transmitted to staff.
- **MERS**: Middle East respiratory syndrome coronavirus. Epidemic coronavirus, probably transmitted from animals and bats, started in the middle of spring 2012. Nosocomial outbreaks are very important and may be transmitted to staff.
- **CJD**: Creutzfeldt-Jakob disease. Prion disease with variants “mad cow disease”.

- *CDC*: Centres for Disease Control and Prevention. State Centre in the United States for the prevention and control of infections.
- *ICN/ICP*: infection control nurse/infection control personnel and hygiene nurse.
- *ICD*: infection control doctor and infection control physician.
- *PPE*: personal protective equipment, respiratory equipment such as gloves, surgical mask, cap, gown, etc.
- *HEPA filter*: high-efficiency particulate air filter. The filter removes 99.97% of all particles larger than equal to 0.3 µm at a defined air flow. There are a number of virus particles less than 0.3 µm, but these are still caught in the filter.
 - HEPA filter is used for respiratory protection—like P3 masks and portable respiratory systems, as protection against infectious agents.
 - Used to shield patients who are highly immunosuppressed (air overpressure with HEPA filters on the inlet air).
 - Use on air outlets/recirculation from isolates for infectious disease to catch adverse contaminants.
 - Used as LAF (laminar air flow) ceilings or other types of filters in the operating room to get clean enough air into the room and to the surgical site.

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