International Journal of Infectious Diseases (2005) **9**, 3—14

ELSEVIER

INTERNATIONAL SOCIETY FOR INFECTIOUS DISEASES

http://intl.elsevierhealth.com/journals/ijid

REVIEW

Hand hygiene: simple and complex

P.A. Jumaa*

Department of Medical Microbiology, Faculty of Medicine and Health Sciences, United Arab Emirates University, P.O. Box 17666, Al Ain, United Arab Emirates

Received 5 April 2004; received in revised form 22 May 2004; accepted 24 May 2004

Corresponding Editor: Michael Ellis, Al Ain, UAE

KEYWORDS
Hand hygiene;
Handwashing;
Hand drying;
Cultural;
Compliance;
Behaviour

Summary This review gives an overview of hand hygiene in healthcare and in the community, including some aspects which have attracted little attention, such as hand drying and cultural issues determining hand hygiene behaviour. Hand hygiene is the most effective measure for interrupting the transmission of microorganisms which cause infection both in the community and in the healthcare setting. Using hand hygiene as a sole measure to reduce infection is unlikely to be successful when other factors in infection control, such as environmental hygiene, crowding, staffing levels and education are inadequate. Hand hygiene must be part of an integrated approach to infection control. Compliance with hand hygiene recommendations is poor worldwide. While the techniques involved in hand hygiene are simple, the complex interdependence of factors which determine hand hygiene behaviour makes the study of hand hygiene complex. It is now recognised that improving compliance with hand hygiene recommendations depends on altering human behaviour. Input from behavioural and social sciences is essential when designing studies to investigate compliance. Interventions to increase compliance with hand hygiene practices must be appropriate for different cultural and social needs. New strategies to promote hand hygiene worldwide include the formation of public—private partnerships.

Introduction

Hands play a major role in the transmission of infection in healthcare institutions, in industrial settings such as the food industry and also in all community and domestic settings.[1—3] The importance of hand hygiene in the control of infection cannot be underemphasised. Recognition of the importance of hand hygiene in the control of the spread of infectious diseases is reflected in the increased number of publications in the medical literature during the last few years, including major articles on hand hygiene in prominent general medical journals.[4—6] Using 'handwashing' as a keyword in PubMed showed that from 1968—1983 there were 187 citations, compared with 1535 citations from 1990—2003.

* Tel.: +971 3 7039481; fax: +971 3 7671966.
E-mail address: pauline.jumaa@uaeu.ac.ae.

1201-9712/$30.00
doi:10.1016/j.ijid.2004.05.005

In spite of the increased attention directed at hand hygiene in the medical literature, many issues remain unexplored and unresolved. Although many countries have guidelines regarding hand hygiene for healthcare settings, overall compliance among healthcare workers (HCWs) remains poor.[7] Improving hand hygiene remains a challenge for infection control practitioners in healthcare institutions and in the community. Most of the medical literature, including guidelines for hand hygiene, concerns healthcare institutions in developed countries. While the spread of infection in developed countries remains a serious problem, especially in high-risk settings such as hospitals, the threat of infectious disease in developing countries remains extremely high.

There are 2—3 million deaths worldwide each year from diarrhoeal diseases, many of which could be prevented. It has been estimated that handwashing with soap could save a million lives a year.[2,8] Developing countries present extra hurdles when trying to increase handwashing. A public health infrastructure including access to basic sanitation may be limited or non-existent in a developing country. Increasing handwashing in developing countries therefore requires a different approach to that in developed countries.

There have been many public health campaigns worldwide to address hand hygiene. Few, however, have been successful. A new campaign led by the World Bank and the Water and Sanitation Programme, in collaboration with many other partners, has been set up to promote handwashing in India and Ghana.[9] This is a global public—private partnership which aims to address the lack of success of many public health campaigns in increasing handwashing by combining both the public and the private sector. The private sector will gain from the increased use of soap.

Aim and scope

The aim of this paper is to review hand hygiene from a worldwide perspective, to explore some areas of hand hygiene practice which have attracted little attention so far, to focus on cultural and behavioural issues related to hand hygiene, and to highlight areas needed for further research. A detailed discussion of surgical hand antisepsis as a specialised area of hand hygiene is beyond the scope of this review.

Historical perspectives in hand hygiene

Although handwashing has been considered a measure of personal hygiene for centuries, the specific link between handwashing and the spread of infectious diseases has been reported only during the last 200 years. Ritual handwashing was part of religious or cultural practice but cleaning hands was concerned with aesthetics rather than the prevention of infection. Bad smells were thought to spread infections such as the plague.[10] Interestingly, during the Black Death in the 14th century, it was noted that Jews seemed to have a lower mortality rate than other groups. The ritual handwashing of the Jewish faith probably protected Jews during the epidemic, though the focus of the ritual washing was spiritual rather than infection control.[11] In 1846, Semmelweis reported a reduction in the number of deaths from puerperal infection by the implementation of hand hygiene.[12] However, the establishment of handwashing as an intervention to prevent the spread of infection did not occur for many more years and it is only during the last few decades that written guidelines for hand hygiene have emerged. In 1961 in the US, there were recommendations that healthcare workers (HCWs) should wash their hands with soap for one to two minutes before and after patient contact.[13] Formal written guidelines on handwashing practices in hospitals were published by the CDC in 1975 and 1985.[14,15] Further guidelines from other professional bodies emerged. While the earlier guidelines recommended the use of soap and water in preference to waterless antiseptic solutions, recent guidelines have included more widespread use of waterless antiseptic agents in preference to handwashing with soap and water.[16—18]

Definitions

The word hygiene is derived from the name *Hygeia*, who was the Greek goddess of healing.[19] In modern usage hygiene usually refers to cleanliness and especially to any practice which leads to the absence or reduction of harmful infectious agents. There is great variation in the terminology used in hand hygiene and this is reflected in the various spellings of terms such as 'handwashing', 'hand washing', 'hand-washing' in the medical literature. Such variations may introduce inconsistencies in archiving articles. The definitions of the terms used are important because valid comparisons between studies depend on the standardisation of definitions.[20] Also, there is evidence that precise definitions of the terms are important in facilitating the effective use of hand hygiene guidelines.[20,21]

For this review the term hand hygiene includes handwashing (washing hands with non-antimicrobial soap), antiseptic handwash (washing hands with

water and soap or another detergent containing an antiseptic agent), antiseptic hand rub (rubbing hands with an antiseptic hand rub) and surgical hand antisepsis (preoperative antiseptic handwash or hand rub performed by surgical personnel.)[18] These terms also include hand drying following handwashing.

The hands as vectors of microorganisms

The microbial population of the skin is divided into resident flora and transient flora.[22] The resident flora are associated with the deeper layers of the skin such as the sebaceous glands and these organisms are inaccessible to hand hygiene preparations. The resident flora consist mainly of coagulase-negative staphylococci, *Corynebacterium* spp. and anaerobes such as *Propionibacterium* spp. and rarely cause infection unless the skin is breached by a device such as a central venous catheter. The transient flora colonise the superficial layers of the skin and are less adherent. They are more easily removed by handwashing and may be transferred by direct hand contact between human skin and the inanimate environment such as work surfaces or food, hence the term transient. The transient flora include microorganisms which are frequently associated with nosocomial infection. Viruses are not considered part of normal flora and are therefore included as transient or contaminating flora which should be removed during hand hygiene practices.[23] The number of microorganisms on intact areas of skin in the same person can vary from $100-10^6/cm^2$.[22] The range of microorganisms can vary from person to person and HCWs may have different hand flora from ordinary members of the public and become permanently colonised with pathogenic flora acquired from the hospital environment.[24,25]

Hospitalised patients can also become colonised with microorganisms which survive well in the hospital environment including *Staphylococcus aureus*, enterococci, and Gram-negative bacilli such as *Pseudomonas* spp, *Klebsiella* spp, and *Acinetobacter* spp.

There is evidence that although the skin flora vary considerably from person to person, the transient and resident flora remain uniform for an individual.[18]

In a healthcare setting, data are limited on the types of activities which are most likely to result in the contamination of hands and the transmission of the pathogens to patients. Nosocomial pathogens can be recovered from body fluids or infected areas of skin in patients, but also from intact skin of hospitalised patients. Nurses can contaminate their hands with nosocomial flora even when performing clean procedures involving direct patient contact such as taking blood pressure or touching a patient's hand or shoulder.[26] Healthcare workers may also contaminate their hands by contact with a patient's inanimate environment.[27] The level of contamination depends on the duration and nature of the activity, though it is not known how many organisms are required for transmission or which activities are most likely to result in transmission.[18,27]

Preparations and equipment used in hand hygiene

Hand hygiene preparations

There are insufficient data to make definitive recommendations as to which hand hygiene products should be used. No one product is ideal and all of them have advantages and disadvantages. There are extensive reviews of hand hygiene products available.[18] Here is a summary of some of the current issues.

The aims of hand hygiene practices are to eliminate rapidly, as far as possible, the transient (contaminating) flora and also to have persistent antimicrobial activity on the resident flora. In the context of a healthcare setting, this means decontaminating the hands of transient flora before the next patient contact. The prolonged activity of hand hygiene preparations between use is particularly important in healthcare settings, where clean hands are required for prolonged periods of time.

Hand hygiene preparations should also not damage the skin. Apart from the discomfort associated with skin conditions such as contact dermatitis and eczema, and there will be a reluctance to perform hand hygiene practices. Damaged skin can also be more heavily colonised with pathogenic organisms and it is therefore possible that handwashing with soap may result in damaged skin and an increase in the number of flora over time.[28] Handwashing damaged skin is also less effective in reducing the number of microorganisms than in healthy skin.[29] Soap consists of esterified fatty acids with sodium hydroxide or potassium hydroxide. Soap preparations include bars, liquids and leaflets. Plain soaps have little or no antimicrobial activity and their cleaning activity is mainly detergent or mechanical where dirt and other organic substances are removed from the hands and the transient flora, which are not strongly adherent to the skin.

In several studies, handwashing with plain soap did not remove pathogens from the hands of HCWs.[30,31] Both bar soaps and liquid soaps may

become contaminated with bacteria during use, with bar soaps being associated with heavier contamination compared to liquid soaps.[32–34] However, other studies have suggested that while they may become contaminated with bacteria, these bacteria are unlikely to be transferred to hands.[35] Soap may also result in skin irritation and dryness, as mentioned previously.[36]

The alcohols used in alcohol-based hand antiseptics are ethanol, isopropanol, and n-propanol. These have been studied alone, in combinations of two alcohols and also in combination with other disinfectants such as hexachlorophene, quaternary ammonium compounds, povidone-iodine, triclosan or chlorhexidine gluconate.[36–38] The antimicrobial activity of alcohols is attributed to their ability to denature proteins. A concentration of 60–95% is most effective. Higher concentrations are less effective because water is needed for the denaturation of proteins.[18] Alcohols have a wide antimicrobial spectrum including Gram-positive bacteria, Gram-negative bacteria, mycobacteria, fungi and some enveloped viruses, but poor activity against bacterial spores, oocysts and some non-enveloped viruses. Alcohols have the most rapid bactericidal activity compared with other disinfectants when applied to the skin. However, there is little residual activity. Adding a disinfectant such as chlorhexidine, triclosan, or quarternary ammonium compounds increases the persistence of antimicrobial activity on the skin.

Hand rubs with an alcohol base have recently been recommended as being more effective in reducing hand contamination compared with handwashing with an antiseptic soap, where hands are not macroscopically contaminated.[39] Their use has been recommended for years because of their increased convenience compared with handwashing and they have become widely promoted in hand hygiene practice in clinical settings.[40,41] They have a wide antimicrobial spectrum, they act rapidly, they spread easily without friction which damages skin, they evaporate rapidly, there is no need for a sink or drying facilities and they save time when compared with conventional handwashing. There is also evidence that HCWs are more likely to use them than to wash hands with soap and water.[5,42] In a healthcare setting they may also be cost effective in terms of the number of nosocomial infections prevented, though further anlayses are necessary to substantiate this.[5]

Sinks and taps

Sinks contain stagnant water, which supports the growth of microorganisms. Therefore sinks themselves can be sources of pathogenic bacteria which can in turn be transferred to hands during hand hygiene practices.[43–45] Given the potential risks of hand contamination associated with sink contact, no-touch taps and automated sinks have become more common both in the healthcare setting and in public toilet facilities.[46,47] However, while these may have the potential to improve the effectiveness of hand hygiene practices, automated sinks may still become contaminated with pathogenic organisms if not maintained properly.[46,48]

Hand drying

Hand drying is an essential component of effective handwashing. It is universally accepted that the transmission of microorganisms is more effective in wet environments than in dry environments.[49] In spite of this, guidelines generally direct little attention to the importance of hand drying when recommending handwashing and there have been very few articles in the medical literature which focus on hand drying. Hand drying should be effective in drying hands without contaminating them further.[45] Damp hands as a result of ineffective hand drying can lead to skin excoriation which in turn leads to higher numbers of bacteria colonising the skin and facilitation of the spread of blood-borne viruses as well as other microorganisms.[28] Sore hands will also lead to decreased compliance with handwashing programmes.[28]

There are three methods of hand drying: cloth towels, paper towels and hot air dryers. Hands can also dry by evaporation. There has been much debate regarding the efficacy of these methods in terms of hand hygiene and the results of investigations have been conflicting. One report compared four methods of hand drying: cloth towels from a roller, paper towels left on a sink, hot air dryer and leaving hands to dry by evaporation.[50] No significant differences in the efficacies of each method were noted. However, cloth towels are not recommended for use in healthcare settings because of evidence that microorganisms are less effectively removed. There is also the risk of cross-infection.[51,52]

Differing results have been obtained when comparing paper towels and hot air dryers. It has been suggested that hot air dryers may disperse microorganisms by the airborne route and hand towels are usually considered safer in a clinical area.[53,54] However a recent paper did not find that hand dryers were more likely to contaminate the environment with air-borne microorganisms than drying with paper towels.[55]

The maintenance of a clean environment around paper towels is essential for non-hazardous hand

drying. This includes the choice of dispenser allowing ease of delivery, correct use of the dispenser, jamming of the dispenser, site of dispenser in relation to sinks and splash zones. The dispenser itself may be the source of microorganisms if it becomes contaminated.[45,56] Damp towels left in the dispenser may also pose an infection risk.[56]

The quality of the paper towels is also important; poor quality towels may damage skin by abrasion and ineffective drying.[57] Soft, absorbent paper towels are more acceptable to users and may contribute to compliance with hand hygiene recommendations.[57]

Other issues relating to hand hygiene in the healthcare setting

Gloves

The use of gloves in healthcare settings has increased during the last two decades, particularly following the increased awareness of blood-borne viruses, especially HIV, and the subsequent promotion of universal precautions.[58] The use of gloves is recommended to reduce contamination of the hands with flora which may be transferred to patients, to prevent the flora of HCWs from being transferred to patients and to protect HCWs from acquiring infections from patients. Evidence that gloves can prevent hands from becoming contaminated with microorganisms both from the patients and the inanimate environment is provided by several studies.[59] It is important that hands are prevented from becoming contaminated because hand hygiene practices are not always successful in removing all pathogenic organisms when hands are heavily contaminated.[60–62] Also, in the absence of macroscopically visible contamination it is not usually possible to know how many organisms have been acquired and the subsequent risk of transmission.

Gloves have been used to reduce the transmission of pathogens in clinical settings and to help control outbreaks.[59]

Glove wearing may also influence the hand hygiene behaviour of HCWs. In some studies this has meant healthcare personnel being less likely to wash their hands following patient contact.[62] In another, glove wearing increased the compliance with hand hygiene practices.[63] It is important to remind HCWs that hands must still be decontaminated following glove wearing as gloves do not give complete protection against contamination with patients' flora.[64,65] Gloves may in turn contribute to the spread of pathogens if not used correctly.[66] They should be changed between patients and should not be washed or reused. Also, transmission of hepatitis B and herpes simplex to HCWs wearing gloves has been reported.[67,68] The route of transmission while wearing gloves may result from contamination when removing gloves or from small defects in the gloves and subsequent loss of the integrity of the physical barrier.

It is important that the gloves are well-tolerated by the wearers and that they are strong but also give good sensitivity. Studies have shown that there is considerable variation in the gloves available for clinical use.[65,68,69] Gloves may be made from natural latex or synthetic materials such as vinyl or nitrile and it is important that more than one type is available because latex sensitivity among HCWs is more commonly reported.[18,70] There have also been differences in the reported tendency of barrier protection for vinyl gloves compared with latex gloves; vinyl gloves being less reliable than latex gloves in some studies.[68] Double gloving is sometimes practised to increase the barrier protection. One study examined the gloves after use and tested them for leaks and found that double layers provided little advantage over a single layer, especially if latex gloves were used.[71]

Recent developments in glove technology have included the incorporation of microspheres into gloves which release chlorine dioxide when activated by light or moisture and double-layered gloves which give extra protection while retaining sensitivity.[72,73] It is not yet known what impact these innovations will have on future hand hygiene recommendations.

Hand creams and emollients

Sore, dry hands is a frequently reported problem among HCWs who are required to wash or decontaminate their hands frequently.[70,74] Lipids contribute to the barrier function of the skin and skin creams, lotions and emollients may increase the skin hydration and further add to the protection of skin. A double-blind, randomised trial of a barrier cream and an oil-based lotion demonstrated that scheduled use of either preparation significantly protected the hands of HCWs who already had severe skin irritation.[75] The same study also showed that improvement of the skin was associated with an increase in handwashing. However it is not yet known whether barrier creams make a significant contribution to the overall prevention of skin problems. There is also concern that oil-based products may inhibit the barrier function of latex gloves and the effectiveness of antimicrobial agents used in hand hygiene practices.[75]

Rings

The skin underneath rings has more microorganisms than control sites.[76–78] The number of microorganisms increases with the number of rings worn.[78] In one study, multivariate analysis suggested that wearing rings was a major risk factor for carrying Gram-negative bacilli and *S. aureus* on hands, both being important nosocomial pathogens.[76,78] There is also evidence that the organisms found under rings may be carried for many months.[76] In an experimental model using food handlers as subjects, handwashing was slightly less effective in ring wearers, but this was in hands which were artificially contaminated, not in a real life situation.[79] There is little evidence to suggest that handwashing is ineffective in ring wearers, with most reports showing similar bacterial counts in ring wearers and non-ring wearers.[80] There is little evidence relating the wearing of rings to patient outcome, such as the incidence of nosocomial infection.[81]

Wrist watches and bracelets

It seems obvious that hand hygiene practices in clinical areas cannot be adequate if a wrist watch or bracelet is worn. Most hospital infection control guidelines recommend that wrist watches and bracelets are removed before hand hygiene practices are performed. A Medline search of 'hygiene' and 'wrist watches' found only two citations concerning hand hygiene and no citations using 'bracelet' and 'hygiene' as keywords.[77,82] A study investigating 20 volunteer dentist and 20 non-clinical volunteers found that skin underneath a wrist watch was more heavily colonised with microorganisms than control sites, in common with the skin underneath rings.[77] While the microorganisms were unlikely to cause infection in a routine dental setting, they were well-recognised nosocomial pathogens. However, there is almost no other evidence to support the recommendation not to wear a wrist watch and compliance is poor.[82]

Sleeves and cuffs

Hand hygiene policies recommend that sleeves should be rolled up before hand hygiene procedures. Most uniform policies also recommend short sleeves, though short sleeves are not usually enforced for HCWs who do not wear uniforms. It would be expected that wet sleeves, in common with any moist surface, could act as a reservoir for microorganisms, which could then be transferred to hands by direct contact. The visible macroscopic contamination of cuffs during the normal wear highlights their potential for transmitting pathogens. But evidence in the medical literature to support short sleeves is lacking.

Fingernails, nail technology and nail polish

The subungual region contains large numbers of bacteria which are largely inaccessible during hand hygiene practices and are therefore difficult to clean compared with the rest of the hands.[83] Most infection control guidelines recommend that fingernails are kept short. This facilitates cleaning but it has also been shown that longer nails have increased numbers of microorganisms.[84] Long nails are also more likely to tear gloves, thereby breaking the barrier.

Artificial nails are increasingly reported as having the potential to transmit infections in the healthcare setting. Artificial nails are more likely to be colonised with Gram-negative bacilli and yeasts than natural nails.[85,86] In one study, although artificial nails were more likely to be colonised with Gram-negative bacteria and yeasts, the overall numbers of organisms did not differ.[86] Pathogens were also more likely to be isolated the longer the nails were worn.[86] There is evidence that washing artificial nails is not as effective as for natural nails.[85,87] A study comparing hand hygiene using soap or an alcohol gel found that HCWs with artificial nails had more bacteria remaining after cleansing than those with natural nails.[87]

There are several reports linking fingernails with the transmission of nosocomial infection.[88–90] One study linked an outbreak of postoperative *Serratia marcescens* infection with a nurse, suggesting that artificial fingernails may have facilitated the transfer of *S. marcescens* from home.[88] In another study, an outbreak of *Pseudomonas aeruginosa* in a neonatal intensive care unit was associated with two nurses with long fingernails, one artificial and one natural.[89] An outbreak of *Candida albicans* infection following laminectomy was epidemiologically linked to an operating room technician wearing artificial fingernails.[90] In this investigation, though *C. albicans* was not isolated from her nails, no new cases occurred following her treatment and her removal from duty. There is now sufficient evidence to recommend that artificial nails constitute an infection risk in high-risk areas and should not be worn in clinical areas, though further investigations are necessary to better define the risks involved.

Other forms of nail art and technology have become popular in many countries and have recently been reviewed in the context of hand hygiene in HCWs.[91] Practices include applying artificial material to the nails for extensions, nail sculp-

turing, protecting nails by covering them with a protective layer of an artificial material and nail jewelry, where decorations such as stones may be applied to the nails or the nails are pierced. While there are many potential health problems, including local infection for individuals who have undergone some form of nail technology, there is also the potential risk that these practices may pose a threat to patients and in other critical areas such as the food industry. Apart from artificial nails, data linking the other forms of nail art and nail technology with hand hygiene and the spread of infection are lacking, but this may change in the future. Given the evidence accumulated so far, it would seem appropriate to restrict artificial nails and nail art from high-risk areas.

Although most hand hygiene policies recommend that nail polish is not worn in clinical areas, there has been little work to investigate the effect of nail polish on the flora of fingernails and none linking nail polish with hospital-acquired infection.[81] A study on the fingernails of operating room nurses found increased bacterial counts associated with chipped nail polish or nail polish that had been worn for more than four days compared with fresh, intact polish.[92] Freshly applied nail polish on natural nails did not result in increased bacterial counts compared with unpolished natural nails.

Hand art-tattoos

Temporary tattoos on the hands, made with henna, are very popular in the Middle East, parts of Asia and Africa and it is not unusual for female HCWs in these countries to be found wearing such hand tattoos. The practice is also becoming more widespread in western countries. No hand hygiene issues for any type of tattoos could were found in the literature.

The importance of hand hygiene outside the healthcare setting

Although most of the medical literature concerning hand hygiene refers to healthcare settings, the potential of hand hygiene as an achievable and viable option to reduce the global burden of infectious disease has been recognised for years.[8,93] Diarrhoeal illness is common and is a major cause of death in children worldwide.[7] Contact with human excreta is the main factor in the spread of diarrhoeal illness and washing hands after possible contact with faeces is the major intervention for breaking the chain of transmission of infectious agents. While it is known that compliance with hand hygiene guidelines is poor in a healthcare setting, it is also known from worldwide studies that hands are washed with soap less than 20% of the time.[8] For example, workers in the UK found that in the home environment carers washed their hands on only 42% of occasions when they changed a child's dirty nappy.[94] Only 34% of male and 56% of female members of the public washed their hands after using a public toilet in a train station in the UK.[95] In other countries, handwashing after cleaning a child following defecation occurred in a minority of cases.[96,97] However, increasing handwashing frequency worldwide, when only 60% of the world's population have adequate sanitation, is a major challenge.[8]

The effectiveness of handwashing programs in reducing diarrhoeal cases in developed and developing countries has been reviewed recently.[2] The results suggest that handwashing may reduce the incidence of diarrhoea by 42—47%, which worldwide could reduce the number of deaths by about one million. However, further studies are necessary to identify the best way to achieve this in different geographical and cultural settings. The formation of public—private partnerships is an important development.

Scientific evidence and the organisational complexity of hand hygiene studies

One reason cited for the lack of compliance with hand hygiene recommendations is the lack of scientific evidence for many of the issues concerned with hand hygiene practices.[98] There are many basic questions, such as when should hands be washed, how they should be washed, which product should be used and for how long, which have not been resolved.

Hand hygiene practices are the result of a complex interaction of many factors and this makes designing methodologies for hand hygiene studies especially challenging. There are almost no standardised methods for many aspects of hand hygiene and therefore it is very difficult to make comparisons between studies. Most hand hygiene data concerning microorganisms are for bacteria. While these are among the most frequent causes of community and hospital infection, viruses are also extremely important and are far more difficult to investigate.[99]

Studies on hand hygiene have been mainly observational and may be subject to reactive biases because of the presence of an observer.[94] Blinding, randomisation and controlling for confounding variables may not be feasible. For example, studies

comparing handwashing and waterless hand rubs are impossible to test blind since it will always be obvious to the subject which product was being used. There is rarely just one intervention in studies of hand hygiene behaviour. Many studies involve small numbers of subjects and therefore lack statistical power.[94] There has been little or no follow-up in hand hygiene studies and so it may not be known if any beneficial effect of an intervention to improve hand hygiene behaviour has resulted in sustained improvement with compliance.

One of the most challenging aspects of hand hygiene study design is trying to reflect what happens in a real life situation, whether it is in a ward or in the home. Experimental models are an artificial medium. It is difficult to perform investigations in a real life setting without disrupting normal practice or the smooth running of a clinical area. For example, most handwashing guidelines recommend that hands are washed vigorously for 15 seconds.[18] In reality, in a working situation, hands are generally washed for less than 15 seconds. Most evaluations of hand rubs recommend 3 mL for 30 seconds.[100] HCWs do not necessarily use hand rubs in this way. It is very difficult to control how much of a product is used, its contact time with the skin and the rinsing time. All of these introduce variability into hand hygiene studies.

The overall aim of hand hygiene studies is to provide evidence that adherence to hand hygiene practices results in a decrease in infection. There are few studies which have focused on patient outcomes such as surgical wound infection rates. The diagnosis of infection is limited by the recognition of symptoms and is therefore not straightforward and may be variable.

It is therefore a challenge, given all these methodological limitations, to provide convincing evidence for all the recommendations laid down in guidelines for hand hygiene. Nonetheless, despite these limitations, there is more evidence supporting the benefit of hand hygiene in breaking the chain of transmission of infection in both the healthcare setting and in the community than there is for some widely accepted clinical practices.[1]

Compliance with hand hygiene practices — behavioural and cultural factors

It is widely known that compliance with hand hygiene recommendations is poor.[8,18] Improving compliance is about altering human behaviour and therefore studying compliance with hand hygiene recommendations includes input from a wide range of disciplines, including behavioural and social sciences. Hand hygiene behaviour is a complex interaction of many factors and no one behavioural theory can reliably predict hand hygiene behaviour.[101] Improving compliance with hand hygiene practices requires an understanding of what motivates hand hygiene behaviour and this will vary from culture to culture. The main factors affecting compliance are summarised in Table 1. Some religions recommend when washing with water should be performed. The aim of this ritual cleansing is spiritual and there is no mention of the use of cleansing agents such as soap nor is there any precise association of ritual cleansing with infectious disease.[11,102,103]

In the healthcare setting there is a dichotomy between hand hygiene knowledge and hand hygiene behaviour. HCWs are aware of recommendations regarding hand hygiene, but knowledge and education do not in themselves motivate hand hygiene behaviour, hence the low compliance. Self-reported rates and observed rates of compliance with hand hygiene practices also differ. There is evidence that HCWs may be unaware of their poor compliance when the intention to perform hand hygiene is there but other factors result in non-adherence.[101]

Concern for third party opinion seems to be an important factor in determining hand hygiene beha-

Table 1 Factors influencing compliance with hand hygiene*.

Material factors
- Convenient and accessible hand hygiene facilities e.g. fast-drying hand rubs, no-touch sinks, hand rubs at patients' bedsides, hand rubs outside patients' rooms, hand rubs on the patients' notes trolley during a ward round
- Preparations which do not cause skin irritation
- Preparations which are aesthetically acceptable

Behavioural and social factors
- Perceived danger for carer of omitting hand hygiene practices
- Perceived benefit for dependent or patient
- Concern for third party opinion e.g. peer pressure, conforming to social ideals
- Gender
- Educational background

Factors in a healthcare institution
- Avoid overcrowding and understaffing
- Rewards and sanctions
- Promotion of a positive culture for hand hygiene
- Provision of reminders for hand hygiene
- Encourage active participation in the design of hand hygiene programmes at all levels

* Adapted from[18,20,57,100,104,107].

viour. For example, reasons given for performing handwashing following changing a soiled nappy in the UK included giving a good impression as well as aesthetics and the promotion of the well-being of the child.[94] In Botswana and Burkino Faso, for example, conforming to social ideals is also an important motivating factor for handwashing.[97,104] In the healthcare setting it is essential to have strong commitment from management and superiors to change hand hygiene behaviour.[105]

Another approach to increasing compliance, is patient pressure. The 'Speak Up' campaign sponsored by the Joint Commission on Accreditation of Healthcare Organizations in the US encourages patients to observe whether HCWs wash their hands and to remind them to perform hand hygiene where necessary.[106] It will be interesting to see the effect that this programme has on hand hygiene and nosocomial infection rates in participating healthcare institutions.

While peer pressure and conforming to social ideals are important in motivating hand hygiene behaviour, a culture of hand hygiene cannot be created by force or mandate. The acceptance of a new value system is necessary and the introduction of such changes is a major challenge.

The acceptability of hand hygiene preparations to the users is important when considering compliance.[57] Although the provision of adequate hand hygiene facilities and easy access to hand hygiene preparations and equipment, such as the number of sinks, placing alcohol hand rubs at patients' bedsides, would seem obvious in improving compliance, the effects of improving facilities have led to conflicting results on compliance with hand hygiene recommendations.[105,107–109] A recent study found that increasing the number of sinks was not effective in increasing the frequency of handwashing when this was the only measure to improve compliance and that a key factor for adherence to hand hygiene practice was the behaviour of other HCWs, particularly superiors.[105]

For many years, the message regarding hand hygiene has been to promote handwashing. Recently, to complicate the issue of compliance further, the message has changed to handrubbing with alcohol-based preparations.

As mentioned, what motivates hand hygiene behaviour is a complex interdependence of many factors including cultural factors. In a UK hospital trust with a sizeable number of Muslim patients and staff, the infection control team has encountered refusal from staff and patients' families to use alcoholic hand rubs on religious grounds (personal communication, Mr Paul Hateley). Interestingly, in a tertiary referral hospital in the United Arab Emirates where more than 95% of patients are Muslim and Muslim staff form a majority, refusal to use alcohol hand rubs on religious grounds has been encountered only once in the last three years (personal communication, Ms Sue Bacon). It is not yet clear whether this represents a serious issue for the future but it does illustrate the importance of external factors in determining hand hygiene behaviour in a healthcare setting and the need for a broad-based approach involving professionals other than HCWs when trying to understand and improve compliance.

Hand hygiene as part of an integrated approach to reducing infection

It is being recognised in the healthcare setting that adequate hand hygiene as an isolated intervention will not interrupt the spread of infectious disease if other aspects of hygiene are not adequate or if there is overcrowding and understaffing.[107,110] Effective hand hygiene practices are impossible without clean environmental surfaces and adequate hand hygiene facilities and this is relevant both in the healthcare setting and in the community.[44,45,110,111]

Future

There are many issues concerning all aspects of hand hygiene which remain unresolved. While hand hygiene practices are simple, compliance with hand hygiene is about human behaviour and altering human behaviour is complex and constitutes an enormous challenge. This is reflected in the lack of success so far.

This promotion of hand hygiene cannot be confined to a healthcare setting. There must be the creation of a culture promoting hand hygiene at all levels of society to provide a foundation on which to establish a structure promoting compliance. It is impossible to make global recommendations regarding hand hygiene practices because what works in one culture may not work in another and all recommendations must take geographical and cultural factors into account.

There is not enough evidence to recommend one preparation over another. Standardised protocols and definitions are required both for laboratory investigations of hand hygiene preparations and for the study of hand hygiene behaviour. More well-designed studies are necessary. The establishment of the cost-effectiveness of recommendations is particularly important where resources are limited.

But the promotion of hand hygiene should not go too far and it raises the question: can clean be too clean? Exposure to environmental flora is important in the development of a normal immune system.[112,113] In the domestic setting the message regarding hand hygiene practices should be focused on interrupting the transfer of microorganisms and the spread of infection rather than just killing microorganisms per se. In the high-risk healthcare setting, then the need to reduce the overall microbial load in the hospital environment becomes important.

Conflict of interest: No conflict of interest to declare.

References

1. Aiello AE, Larson EL. What is the evidence for a causal link between hygiene and infections? *Lancet Infect Dis* 2002; **2**:103—10.
2. Curtis V, Cairncross S. Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. *Lancet Infect Dis* 2003;**3**:275—81.
3. Larson EL, Gomez-Duarte C, Lee LV, Della-Latta P, Kain DJ, Keswick BH. Microbial flora of the hands of homemakers. *Am J Infect Control* 2003;**31**:72—9.
4. Teare EL. Hand washing- a modest measure with big effects. *BMJ* 1999;**318**:686.
5. Pittet D, Hugonnet S, Harbarth S, Morouga P, Sauvan V, Touveneau S, et al. Effectiveness of a hospital-wide programme to improve compliance with hand hygiene. *Lancet* 2000;**356**:1307—12.
6. Trampuz A, Widmer AF. Hand hygiene: a frequently missed life saving opportunity during patient care. *Mayo Clin Proc* 2004;**79**:109—16.
7. Wendt C. Hand hygiene-comparison of international recommendations. *J Hosp Infect* 2001;S23—8.
8. WHO. World Health Report 2000. Geneva: World Health Organization; 2000:164.
9. WHO. The global water supply and sanitation assessment 2000. Geneva: World Health Organization; 2000:74.
10. Healy M. Epidemic disease in London. Champion JAI, ed. Centre for Metropolitan History. Working papers series No. 1 London; 1993. p 19—34.
11. Straub E. *The roots of evil. The psychological and cultural origins of genocide*. Cambridge: Cambridge University Press; 1992.
12. De Costa CM. 'The contagiousness of Childbed Fever': a short history of puerperal sepsis and its treatment. *Med J Aust* 2002;**177**:668—71.
13. Coppage CM. *Handwashing in patient care (Motion Picture)*. Washington, DC: US Public Health Service; 1961.
14. Steere AC, Mallison GF. Handwashing practices for the prevention of nosocomial infections. *Ann Intern Med* 1975;**83**:683—90.
15. Garner JS, Favero MS. CDC Guideline for handwashing and hospital environmental infection control. *Infect Control* 1986;**7**:231—43.
16. Recommendations for preventing the spread of vancomycin resistance. Hospital Infection Control Practices Advisory Committee (HICPAC). *Infect Control Hosp Epidemiol* 1995;**16**:105—13.
17. Garner JS. Hospital Infection Control Practices Advisory Committee. Guideline for isolation precautions in hospitals. *Infect Control Hosp Epidemiol* 1996;**17**:53—80.
18. Centers for Disease Control and Prevention. Guideline for Hand Hygiene in Health-Care settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene task Force. MMWR 2002; 51 (No. RR-16):1—48.
19. Encyclopaedia Britannica Online. www.britannica.com.
20. Pittet D. Improving adherence to hand hygiene practice: A multidisciplinary approach. *Emerg Infect Dis* 2001;**7**:234—40.
21. Bissett L. Interpretation of terms used to describe handwashing activities. *Br J Nurs* 2003;**12**:536—42.
22. Noble WC, Somerville DA. *Microbiology of human skin*. Philadelphia: WB Saunders; 1974.
23. Sattar SA, Ansari SA. The fingerpad protocol to assess hygienic hand antiseptics against viruses. *J Virol Methods* 2002; **103**:171—81.
24. Guenther SH, Hendley JO, Wenzel RP. Gram negative bacilli as nontransient flora on the hands of hospital personnel. *J Clin Microbiol* 1987;**25**:488—90.
25. Strausbaugh LJ, Sewell DL, Ward TT, Pfaller MA, Heitzman T, Tjoelker R. High frequency of yeast carriage on hands of hospital personnel. *J Clin Microbiol* 1994;**32**:2299—300.
26. Casewell M, Phillips. Hands as a route of transmission of *Klebsiella* species. *BMJ* 1977;**2**:1315—7.
27. Pittet D, Dharan S, Touveneau S, Sauvan V, Perneger TV. Bacterial contamination of the hands of hospital staff during routine patient care. *Arch Intern Med* 1999;**159**:821—6.
28. Larson EL, Hughes CA, Pyrek JD, Sparks SM, Cagataz EU, Bartkus JM. Changes in bacterial flora associated with skin damage on hands of health care personnel. *Am J Infect Control* 1998;**26**:513—21.
29. Larson E. Skin hygiene and infection prevention: More of the same or different approaches? *Clin Infect Dis* 1999;**29**:1287—94.
30. McFarland LV, Mulligan ME, Kwok RYY, Stamm WE. Nosocomial acquisition of *Clostridium difficile* infection. *N Engl J Med* 1989;**320**:204—10.
31. Ehrenkranz NJ, Alfonso BC. Failure of bland soap handwash to prevent hand transfer of patient bacteria to urethral catheters. *Infect Control Hosp Epidemiol* 1991;**12**: 654—62.
32. McBride ME. Microbial flora of in-use soap products. *Appl Environ Microbiol* 1984;**48**:338—41.
33. Karbara JJ, Brady MB. Contamination of bar soaps under 'in-use' conditions. *J Environ Pathol Toxicol Oncol* 1984; **5**:1—14.
34. Sartor C, Jacomo V, Duvivier C, Tissot-Dupont H, Sambuc R, Drancourt M. Nosocomial *Serratia marcescens* infections associated with extrinsic contamination of a liquid nonmedicated soap. *Infect Control Hosp Epidemiol* 2000;**21**: 196—9.
35. Heinze JE, Yackovich F. Washing with contaminated bar soap is unlikely to transfer bacteria. *Epidemiol Infect* 1988; **101**:135—42.
36. Winnefeld M, Richard MA, Drancourt M, Grob JJ. Skin tolerance and effectiveness of two hand decontamination procedures in everyday hospital use. *Br J Dermatol* 2000; **143**:546—50.
37. Ayliffe GAJ, Babb JR, Davies JG, Hilly HA. Hand disinfection: a comparison of various agents in laboratory and ward studies. *J Hosp Infect* 1988;**11**:226—43.
38. Pereira LJ, Lee GM, Wade KJ. An evaluation of five protocols for surgical handwashing in relation to skin condition and microbial counts. *J Hosp Infect* 1997;**36**:49—65.

39. Girou E, Loyeau S, Legrand S, Oppein F, Brun-Buisson C. Efficacy of handrubbing with alcohol-based solution versus standard handwashing with antiseptic soap: randomized clinical trial. *BMJ* 2002;**325**:362—6.
40. Teare EL, Cookson B, Stone S. Hand hygiene-use alcohol handrubs between patients: they reduce the risk of transmission of infection. *BMJ* 2001;**323**:412—3.
41. Larson EL, Eke PI, Laughton BE. Efficacy of alcohol-based hand rinses under frequent-use conditions. *Antimicrob Agents Chemother* 1986;**30**:542—4.
42. Mody L, McNeil SA, Sun R, Bradley SE, Kauffman CA. Introduction of a waterless alcohol-based hand rub in a long term care facility. *Infect Control Hosp Epidemiol* 2003;**24**:157—9.
43. Bloomfield SF, Scott EA. Developing an effective policy for home hygiene: a risk-based approach. *Int J Environ Health Res* 2003;S57—66.
44. Sattar SY, Jacobsen H, Springthorpe VS, Cusack TM, Rubino JR. Chemical disinfection to interrupt transfer of rhinovirus Type 14 from environmental surfaces to hands. *Appl Environ Microbiol* 1993;**59**:1579—85.
45. Griffith CJ, Malik R, Cooper RA, Looker N, Michaels B. Environmental surface cleanliness and the potential for contamination during handwashing. *Am J Infect Control* 2003;**31**:93—6.
46. Naikoba S, Hayward A. The effectiveness of interventions aimed at increasing handwashing in healthcare workers- a systematic review. *J Hosp Infect* 2001;**47**:173—80.
47. Wilson P. No touch taps help cut infection. *Health Estate* 2003;**57**:46.
48. Halabi M, Wiesholzer-Pittl M, Schoberl J, Mittermayer H. Non-touch fittings in hospitals: a possible source of *Pseudomonas aeruginosa* and *Legionella* spp. *J Hosp Infect* 2003;**49**:117—21.
49. Patrick DR, Findon G, Miller TE. Residual moisture determines the level of touch-contact-associated bacterial transfer following hand washing. *Epidemiol Infect* 1997;**119**:319—25.
50. Knights B, Evans C, Barrass S, McHardy B. Hand Drying; Assessment of Efficiency and Hygiene of Different Methods. Survey by the Applied Ecology Research Group at the University of Westminster, London; 1993.
51. Ansari SA, Springthorpe VS, Sattar SA, Tostowaryk W, Wells GA. Comparison of cloth, paper and warm air drying in eliminating viruses and bacteria from washed hands. *Am J Infect Control* 1991;**19**:243—9.
52. Larson EL, McGinley KJ, Foglia A, Leyden JJ, Boland N, Larson J, et al. Handwashing practices and resistance and density of bacterial hand flora on two pediatric units in Lima Peru. *Am J Infect Control* 1992;**20**:65—72.
53. Ngeow YF, Ong HW, Tan P. Dispersal of bacteria by an electric air hand dryer. *Malays J Pathol* 1989;**11**:53—6.
54. Gould D. The significance of hand drying in the prevention of infection. *Nurs Times* 1994;**90**:33—5.
55. Taylor JH, Brown KL, Toivenen J, Holah JT. A microbiological evaluation of warm air hand driers with respect to hand hygiene and the washroom environment. *J Appl Microbiol* 2000;**89**:910—9.
56. Harrison WA, Griffith CJ, Ayers T, Michaels B. Bacterial transfer and cross contamination potential associated with paper-towel dispensing. *Am J Infect Control* 2003;**31**:387—91.
57. Gould D. Hand decontamination: nurses'opinions and practices. *Nurs Times* 1995;**91**:42—5.
58. Centers for Disease Control and Prevention. Perspectives in disease prevention and health promotion update: universal precautions for prevention of transmission of human immunodeficiency virus, Hepatitis B virus and other blood-borne pathogens in health-care settings. *MMWR* 1988; **37**:377—88.
59. Harstein AI, Denny MA, Morthland VH, LeMonte AM, Pfaller MA. Control of methicillin-resistant *Staphylococcus aureus* in a hospital and an intensive care unit. *Infect Control Hosp Epidemiol* 1995;**16**:405—11.
60. Kjolen H, Andersen BM. Handwashing and disinfection of heavily contaminated hands: effective or ineffective? *J Hosp Infect* 1992;**21**:61—71.
61. Ehrenkranz NJ, Alfonso BC. Failure of bland soap handwash to prevent hand transfer of patient bacteria to urethral catheters. *Infect Control Hosp Epidemiol* 1991; **12**:654—62.
62. Thompson BL, Dwyer DM, Ussery XT, Denman S, Vacek P, Schwarz B. Handwashing and glove use in a long-term care facility. *Infect Control Hosp Epidemiol* 1997;**18**:97—103.
63. Zimakoff J, Stormark M, Larsen SO. Use of gloves and handwashing behaviour among health care workers in intensive care units. A multicentre investigation in four hospitals in Denmark and Norway. *J Hosp Infect* 1993;**24**:63—7.
64. Tenorio AR, Badri SM, Sahgal NB, Hota B, Matushek M, Hayden MK, et al. Effectiveness of gloves in the prevention of hand carriage of vancomycin-resistant Enterococcus species by health care workers. *Clin Infect Dis* 2001;**32**:826—9.
65. Kotilainen HR, Avato JL, Gantz NM. Latex and vinyl nonsterile examination gloves: status report on laboratory evaluation of defects by physical and biological methods. *Appl Environ Microbiol* 1990;**56**:1627—30.
66. Patterson JE, Vecchio J, Pantelick EL, Farrel D, Mazon D, Zervos MJ, et al. Association of contaminated gloves with transmission of *Acinetobacter calcoaceticus var anitratus* in an intensive care unit. *Am J Med* 1991;**91**:479—83.
67. Reingold AL, Kane MA, Hightower AW. Failure of gloves and other protective devices to prevent transmission of hepatitis B virus to oral surgeons. *JAMA* 1988;**259**:2558—60.
68. Kotilainen HR, Brinker JP, Avato JL, Gantz NM. Latex and vinyl examination gloves. Quality control procedures and implications for health care workers. *Arch Intern Med* 1989;**149**:2749—53.
69. Korniewicz DM, Kirwin M, Cresci K, Larson E. Leakage of latex and vinyl exam gloves in high and low risk clinical settings. *Am Ind Hyg Assoc J* 1993;**54**:22—6.
70. Hunt LW, Fransway AF, Reed CE, Miller LK, Jones RT, Swanson MC, et al. An epidemic of occupational allergy to latex involving healthcare workers. *J Occup Environ Med* 1995; **37**:1204—9.
71. Korniewicz DM, Kirwin M, Cresci K, sing T, Choo TE, Wool M, et al. Barrier protection with examination gloves: double versus single. *Am J Infect Control* 1994;**22**:12—5.
72. Barza M. Efficacy and tolerability of ClO_2-generating gloves. *Clin Infect Dis* 2004;**38**:57—63.
73. www.infectiontoday.com/hotnews/43h19103524.html.
74. Gould D, Gammon J, Donnelly M, Batiste L, Ball E, De Melo AM, et al. Improving hand hygiene in community healthcare settings: the impact of research and clinical collaboration. *J Clin Nurs* 2000;**9**:95—102.
75. Mc Cormick RD, Buchman TL, Maki DG. Double-blind, randomized trial of scheduled use of a novel barrier cream and an oil-containing lotion for protecting the hands of health care workers. *Am J Infect Control* 2000;**28**:302—10.
76. Hoffman PN, Cooke EM, McCarville MR, Emmerson AM. Micro-organisms isolated from skin under wedding rings worn by hospital staff. *BMJ Clin Res Ed* 1985;**290**:206—7.
77. Field EA, McGowan P, Pearce PK, Martin MV. Rings and watches: should they be removed prior to operative dental procedures? *J Dent* 1996;**24**:65—9.

78. Trick WE, Vernon MO, Hayes RA, Nathan C, Rice TW, Peterson BJ, et al. Impact of ring wearing on hand contamination and comparison of hand hygiene agents in a hospital. *Clin Infect Dis* 2003;**36**:1383—90.
79. Salisbury DM, Hutfilz P, Treen LM, Bollin GE, Gautam S. The effect of rings on microbial load of health care workers' hands. *Am J Infect Control* 1997;**25**:24—7.
80. Montville R, Chen Y, Schaffner DW. Risk assessment of handwashing efficacy using literature and experimental data. *Int J Food Microbiol* 2002;**73**:305—7.
81. Arrowsmith VA, Maunder JA, Seargent RJ, Taylor R. Removal of nail polish and finger rings to prevent surgical infection. Cochrane Database Syst Rev 2001; 4:CD003325.
82. Hartley JC, Mackay AD, Scott GM. Wrist watches must be removed before washing hands. *BMJ* 1999;**318**:328.
83. McGinley KJ, Larson EL, Leyden JJ. Composition and density of microflora in the subungual space of the hand. *J Clin Microbiol* 1988;**26**:950—3.
84. Lin CM, Wu FM, Kim HK, Doyle MP, Michael BS, Williams LK. A comparison of handwashing techniques to remove *Escherichia coli* and caliciviruses under natural or artificial fingernails. *J Food Prot* 2003;**66**:2296—301.
85. Pottinger J, Burns S, Manske C. Bacterial carriage by artificial versus natural nails. *Am J Infect Control* 1989; **17**:340—4.
86. Hedderwick SA, McNeil SA, Lyons MJ, Kauffman CA. Pathogenic organisms associated with artificial fingernails worn by healthcare workers. *Infect Control Hosp Epidemiol* 2000; **21**:505—9.
87. McNeil SA, Foster CL, Hedderwick SA, Kauffman CA. Effect of hand cleansing with antimicrobial soap or alcohol-based gel on microbial colonization of artificial fingernails worn by healthcare workers. *Clin Infect Dis* 2001; **32**:362—72.
88. Passaro DJ, Waring L, Armstrong R, Bolding F, Bouvier B, Rosenberg J, et al. Post operative *Serratia marcescens* wound infections traced to an out of hospital source. *J Infect Dis* 1997;**175**:992—5.
89. Moolenaar RL, Crutcher JM, San Joaquin VH, Sewell LV, Hutwagner LC, Carson LA, et al. A prolonged outbreak of *Pseudomonas aeruginosa* in a neonatal intensive care unit: did staff fingernails play a role in disease transmission?. *Infect Control Hosp Epidemiol* 2000;**21**:77—9.
90. Parry MF, Grant B, Yukna M, Adler Klein D, McLeod GX, Taddorio R, et al. Candida osteomyelitis and diskitis after spinal surgery: an outbreak that implicates artificial nail use. *Clin Infect Dis* 2001;**32**:352—7.
91. Jeanes A, Green J. Nail art: a review of current infection control issues. *J Hosp Infect* 2001;**49**:139—42.
92. Wynd CA, Samstag DE, Lapp AM. Bacterial carriage on the fingernails of OR nurses. *AORN J* 1994;**60**:796—805.
93. Feachem RG. Interventions for the control of diarrhoeal diseases among young children. Promotion of personal and domestic hygiene. *WHO Bulletin* 1984;**62**:467—76.
94. Curtis V, Biran A, Deverell. Hughes C, Bellamy K, Drasar B. Hygiene in the home: relating bugs and behaviour. *Soc Sci Med* 2003;**57**:657—72.
95. Hateley PM, Jumaa P. Hand washing is more common among healthcare workers than the public. *BMJ* 1999; **319**:519.
96. Omotade OO, Kotode CM, Adeyemo AA, Oladepo O. Observations on handwashing practices of mothers and environmental conditions in Ona-Ara local government area of Oyo State, Nigeria. *J Diarrhoeal Dis Res* 1995;**13**:224—8.
97. Kaltenthaler EC, Drasar BS. Understanding of hygiene behaviour and diarrhoea in two villages in Botswana. *J Diarrhoeal Dis Res* 1996;**14**:75—80.
98. Weeks A. Why I don't wash my hands between each patient contact. *BMJ* 1999;**319**:518.
99. Sattar SA, Springthorpe VS, Tetro J, Vashon R, Keswick B. Hygienic hand antiseptics: Should they not have activity and label claims against viruses? *Am J Infect Control* 2002; **30**:355—72.
100. Widmer AF. Replace hand washing with use of a waterless alcohol hand rub? *Clin Infect Dis* 2000;**31**:136—43.
101. O'Boyle CA, Henley SJ, Larson E. Understanding adherence to hand hygiene recommendations: The theory of planned behaviour. *Am J Infect Control* 2001;**29**:352—60.
102. Katme MA. Muslim teaching gives rules for when hands must be washed. *BMJ* 1999;**319**:519.
103. Akhtar G. Nursing with dignity. Part 8 Islam. *Nurs Times* 2002;**98**:40—2.
104. Curtis V, Kanki B, Cousens S, Sanou A, Diallo I, Mertens T. Dirt and diarrhoea: formative research in hygiene promotion programmes. *Health Pol Plan* 1997;**12**:122—31.
105. Lankford MG, Zembower TR, Trick WE, Hacek DM, Noskin GA, Peterson LR. Influence of role models and hospital design on hand hygiene of healthcare workers. *Emerg Infect Dis* 2003;**9**:217—23.
106. www.jcaho.org/accredited+organizations.
107. King S. Provision of alcohol hand rub at the hospital bedside: a case study. *J Hosp Infect* 2004;**56**:10—2.
108. Kaplan LM, McGuckin M. Increasing hand washing compliance with more accessible sinks. *Infect Control* 1986;**7**:408—10.
109. Vernon MO, Trick WE, Welbel SF, Peterson BJ, Weinstein RA. Adherence to hand hygiene: does the number of sinks matter? *Infect Control Hosp Epidemiol* 2003;**24**:224—5.
110. Harbarth S, Sudre P, Dharan S, Cadenas M, Pittet D. Outbreak of *Enterobacter cloacae* related to understaffing, overcrowding and poor hygiene practices. *Infect Control Hosp Epidemiol* 1999;**20**:598—603.
111. Dancer SJ. How do we assess hospital cleaning? A proposal for microbiological standards for surface hygiene in hospitals *J Hosp Infect* 2004;**56**:10—5.
112. Strachan DP. Hay fever, hygiene and household size. *BMJ* 1989;**299**:1259—60.
113. Matricardi PM, Rosmini F, Riondino S, Fortini M, Ferrigno L, Rapicetta M, et al. Exposure to foodborne and orofecal microbes versus airborne viruses in relation to atopy and allergic asthma: epidemiological study. *BMJ* 2000; **320**:412—7.