of care for the patient's medical condition. Most physicians do not know the full costs of caring for a patient, thus they lack the information to make real efficiency improvements.

Outcomes measurement is critical to driving rapid improvements in health care. Without a feedback loop that includes the outcomes achieved, providers lack the information they require to learn and improve. Effective outcome measurement is hampered by several problems. First, there is a lack of consensus as to what constitutes an outcome. Second, electronic medical record (EMR) systems often do not facilitate the capture of longitudinal outcomes measures with appropriate scope; these systems may focus too narrowly or too broadly, giving only a partial view of patient outcomes. Third, outcomes such as infection rates may vary substantially by medical condition. Finally, true outcome measurement has been limited because the cost of gathering longitudinal patient results is high, due in part to fragmented organizational structures and poor EMR interoperability.

Cost is the most pressing issue in health care. Current cost measurement approaches have not only hampered our understanding of costs but also contributed to approaches involving cost-containment. A focus on cost-containment rather than value improvement can be dangerous and is often self-defeating. Two major problems associated with cost measurement include: (a) cost aggregation, wherein we often measure and accumulate costs based on how care is organized and billed for, that is, costs for departments, discrete service areas, and line items such as supplies or drugs and (b) cost allocation where the costs of healthcare delivery are shared costs, involving shared resources and as such are normally calculated as the average cost over all patients for a department. A good example of this is the hourly charge for the OR. However, to truly understand costs, they must be aggregated around the patient, rather than discrete services, and shared costs must be allocated to individual patients on the basis of each patient's actual use of the resources involved. Finally, the perspective used to calculate costs matters and patient costs including lost work may not be included in the analysis.

Proper measurement of outcomes and costs is the single most powerful lever for improving healthcare delivery and although current measurements are highly imperfect, the process of measurement has begun. As Michael Porter outlines in the framework papers underpinning his value commentary in the *New England Journal of Medicine*,[18] if all the stakeholders in health care were to embrace value as the central goal and measure it, the resulting improvements would be enormous.

## Quality Improvement Measures and Tools

The concept of using measurement to drive improvement has its origins in both medicine and industry. The use of data to improve patient health originated in the mid-1800s with two pioneers, Florence Nightingale and John Snow. Nightingale used data on mortality among British soldiers to drive improvements in sanitation in field hospitals. Similarly, Snow used data on the incidence and geographic location of cholera to make the connection between the incidence of the disease and water obtained from the Broad Street water pump. In the early 20th century, Ernest Codman, a surgeon at Massachusetts General Hospital, was the first to advocate tracking of patient outcomes so that adverse events could be identified and improvements in care made for future patients.[19] In the 1960s, Avedis Donabedian emphasized the importance of measurement and described a model for evaluating quality of health care based on structure, process, and outcomes—*structure* being the environment in which health care is provided, *process* being the method by which it is provided, and *outcomes* being the result of the care provided.[20] More recently, in 1991, Paul Baltaden and Don Berwick developed the IHI, which has become one of the leading organizations in the application of improvement science to health care.[21]

In QI, measurement can serve many purposes. It can be used to identify problems and establish baseline performance, inform and guide QI projects, select and test changes for improvement, and assess and align progress with organizational goals. Selecting and developing measures that are useful can be challenging. Optimal measures must be comprehensive, carefully defined, tailored to the target audience, and involve minimal measurement burden. Target audiences usually include clinical staff, so measures should address and align with clinical targets for specific patient populations with whom the staff work. Measures should pass the face validity test with clinical practitioners delivering care. National or organizational measures, if applicable, can also be used, but they may not always be relevant or credible to the local target audience. Within an organization, target audiences should include system leaders, so measures should also align with organizational priorities and strategic goals.

### PROCESS AND OUTCOME MEASURES

Measures should include the following:

1. Process measures that address the processes of healthcare delivery (e.g., perioperative β-adrenergic blocker administration for patients, antibiotic administration for prevention of surgical site infection)
2. Outcome measures that address patient outcomes from delivery of these services, such as clinical and functional outcomes or satisfaction with health (e.g., morbidity, mortality, length of stay, quality of life)
3. Balancing measures that address the possible consequences of changes in the process (e.g., when process improvements are made to improve efficiency, other outcomes, such as patient satisfaction, should not be adversely affected)

Each of these measures has advantages and limitations.[22] A comprehensive set of measures should include at least one process, outcome, and balancing measure. In addition, structural measures, such as ICU nurse-to-physician staffing ratios, can be important to include when appropriate.[23,24]

Healthcare providers readily accept process measures because they demonstrate the degree to which caregivers can influence a process with the intention to improve patient outcomes. Practitioners generally feel more accountable for the process of care than its outcomes, because outcomes may be affected by many other variables.[22] An obstacle to using process as a measure of quality is sustainability; frequent updating is required as the science of medicine advances.

Process measures, which evaluate how care is delivered, may be easier to measure and implement than outcome measures and can provide important insight into care.[25] Process measures can provide immediate feedback regarding performance, allowing for rapid improvements in care. If an outcome occurs infrequently, providers will be unable to obtain meaningful feedback on outcomes on a timely basis. For example, evidence of improved rates of catheter-related bloodstream infections (CRBSI; an outcome measure) may require 12 to 24 months of data (because few patients develop infections), whereas improved adherence to evidence-based practices to reduce infections (process measures) may be observed within a week (because all patients can be evaluated to determine whether they received the intervention).

Process measures have two other important advantages. First, they generally have face validity for providers, meaning that providers believe they can use the data to improve care; and second, because risk adjustment is less important, broad implementation is feasible. Moreover, joint efforts among providers, professional societies, and external government or payer agencies have made process measures more feasible.[25]

To be valid, process measures should have causal links to important outcomes; a change in the process should produce a desired change in outcome. One of the best opportunities to improve patient outcomes may well come from discovering how to deliver therapies (processes) that are known to be effective in producing a desired outcome.[26] For example, hand hygiene and application of chlorhexidine to sterilize the skin site before insertion of a central venous catheter (CVC) are two of five processes known to reduce CRBSI.[27] Process measures such as these are indicators of whether patients reliably receive evidence-based interventions known to prevent complications.

Although process measurement is useful and should continue, there is no substitute for measuring outcomes, whose principal purpose is not comparing providers but enabling innovations in care. Process measurement should largely be an internal effort, but should not be the means of external measurement and reporting of quality and value. As mentioned above, measuring value requires measuring actual outcomes over time.

Outcome measurement refers to the actual results of care in terms of patient health over time; for each medical condition there is a set of multidimensional outcomes that together constitute patient benefit. These include survival, functional status, and sustainability of recovery. Outcome measures relate directly to the health status of the patient. Patient satisfaction with care is a process measure, not an outcome. Patient satisfaction with health is an outcome measure. However, current measures for outcome often focus on the immediate results of particular procedures or interventions rather than on the overall success of the full cycle of care of a medical condition.

The relative focus on outcome and process measures will depend on balancing the collection of data between that which is scientifically sound and that which is feasible. In general, a balanced set of process and outcome measures helps inform improvement efforts and provides evidence that efforts have made a difference in the lives of patients.

For measurement to be effective, the following principles are important. First, measures should focus on something that the improvement team has the power to change and should initially be simple, small-scale measures that focus on the process itself and not on people. Second, measures should be practical, seek usefulness—not perfection—and fit the work environment and cost constraints. Third, data for measurement should be easy to obtain; finding ways to capture data while the work is getting done allows measures to be built into daily work. Fourth, qualitative data (e.g., reasons for patient dissatisfaction in the patients' own words, observations to contextualize quantitative data) are highly informative and should complement quantitative data (e.g., percentage of patients satisfied with care). Finally, when using measures, balance is key; a balanced set of measures can help answer the question, "Are we improving parts of our system at the expense of others?"

Measurement should not overwhelm the change process. Improvement teams should minimize the burden of measurement whenever possible. Measurement can have both direct and indirect consequences on resource use, provider behaviors, and patients.[28] Measurement of performance and outcomes of care can be costly, especially if the data collection process is manual and involves chart reviews. The burden of measurement is reduced with an EMR system and computerized order entry, although these information technology systems are costly to implement and maintain. Additionally, these resources may not be equally available throughout a system or organization, leading to disparities in the care provided.

Measurement fixation is an unintended consequence on healthcare staff behavior that may occur with the use of process measures. For example, when a process measure such as "the percentage of diabetic patients who received an action plan" is used rather than an outcome measure such as "improved patient understanding about diabetic management," the measure is perceived by the clinician as defining what is important. Thus, measurement of the process becomes the priority, rather than the intended outcome.[28] Alternatively, the clinician may become so focused on what is being measured that different aspects of care are not equally prioritized. In addition, a predominance of process rather than outcome measures can stifle innovation by scripting a process, thus inhibiting process-level innovation. Practice variation does have some utility because medical practice is dynamic, and it is through the trial of new methods of care that innovation occurs. Finally, QI performance measures may not match patient preferences for clinical care. Performance measures that do not take patient preference into account can lead to decreased patient satisfaction, trust, and confidence in their healthcare practitioners and system.[28] Thus, selection of a set of appropriate measures with the attributes described previously can be a balancing act that includes weighing the tradeoffs involved.

Consumers, payers, and employers are increasingly requesting outcome measures to both improve care and decrease cost. Even national governmental bodies are influencing the measurement and reporting of quality in health care. In the United States, the Centers for Medicare and Medicaid Services (CMS), the single largest healthcare purchaser, requires hospitals and physicians to participate in the Quality Payment Program (QPP). This program requires providers to demonstrate quality by either participating in an Advanced Alternative Payment Model (akin to a quality collaborative or participants in a bundled payment model) or by accumulating points through the Merit-based Incentive Payment System.[29] The United Kingdom Quality and Outcomes framework[30] is an analogous system. These quality mandates have fundamentally changed the ways that clinicians, hospitals, and health systems engage in and report QI activities.

## ANALYSIS AND DISPLAY OF QUALITY IMPROVEMENT DATA

Interpretation of data and understanding of process variation are fundamental to QI work. Data elements central to improvement are first and foremost—those data are collected as a basis for action. Second, interpretation of data is made within the context of the process. Last, the analysis technique should filter out noise in the process. Aggregate data or summary statistics typically do not filter out noise in the system and do not present a broad enough context to point practitioners in the direction of proper action or process improvement.

Shewhart postulated that data contain both signal and noise; to be able to learn, one must separate the signal from the noise.[31] CQI science defines two types of variation within a process: random variation and specific variation. Random variation, also known as common-cause variation, results from differences in the inputs that a process receives or inherent factors in the process itself. Random variation is the random background noise within a system and occurs in the process all the time. Specific variation, also known as special-cause or attributable variation, is not present all of the time as background noise, but rather arises from one or more specific causes that are not part of the system. A process is considered to be unstable when specific variation exists, and efforts should be made to learn about the special causes for this variation. A stable process exists when specific variation no longer occurs, leaving only random or common variation.[9] CQI aims to eliminate specific variation for every process so that only random variation remains. A standards-based QA system fails to distinguish random cause from special cause and attempts to correct all variation. Attempts to correct random variation will necessarily fail—a process CQI defines as "tampering." When a process exhibits only random variation, the process should be evaluated to determine whether it is functioning at an acceptable level. If it is not, the process will need to be changed so that the average is moving in the desired direction. Standardization of a process is often the key to reducing random variation and improving a process.

### Run Charts and Control Charts

Run charts and control charts are graphic displays of data that enable observation of trends and patterns over time. They are the best tools for determining whether improvement strategies have had an effect. A run chart (see Fig. 5.2), also called a time series chart, plots the variable or measure being studied on the vertical axis and plots the time on the horizontal axis. The average, or centerline, is the median. At least 12 data points are required to establish a baseline, and at least 20 to 25 data points are required to detect trends and patterns. Run charts should be annotated with tests of change to provide the context within which data can be interpreted. Four rules can be used with run charts to determine whether nonrandom patterns exist or to detect whether the change has led to an improvement:

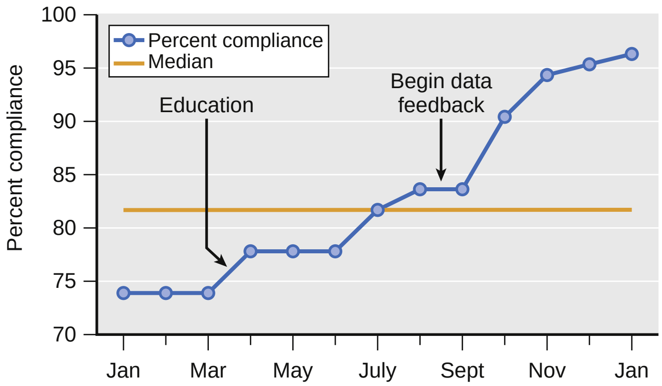


**Fig. 5.2 Example of a run chart.** This chart shows the plot of a performance measure over time. The horizontal (*x*) axis represents time in months, and the vertical (*y*) axis represents the performance measure—the percentage of compliance with the timing of preoperative antibiotics.

1. A shift is indicated by six or more consecutive points above or below the median.
2. A trend is indicated by five or more points all increasing or all decreasing.
3. A run is defined as a series of consecutive points on the same side of the median line.
4. An astronomical data point is an unusual point that is obviously different in value (an outlier).[7]

Because change is by nature temporal, run charts in which data are presented over time are powerful tools for interpreting data within the context of the process.

A control chart (see Fig. 5.3),[32] also known as a Shewhart chart,[7,11] is an extension of a run chart and is used to distinguish between specific and random variation. As on a run chart, the variable is plotted on the vertical axis and time on the horizontal axis. However, with a control chart the centerline or average is the mean, rather than the median, and the upper control limit (UCL) and lower control limit (LCL) are calculated. The UCL and LCL correspond to ±3 sigma from the mean. A process is considered to be "in control," or stable, when data points are within these control limits.[11] Random variation, or variation that is the result of the regular rhythm of the process, produces a stable process. However, in an unstable process that contains variation from special causes, data points exceed the UCL or LCL.[33]

### Failure Modes and Effects Analysis

A failure modes and effects analysis (FMEA) is a tool to help identify problems in a process before they occur and cause harm.[7] An FMEA can help you decide where to target your improvement efforts. In addition, the proactive approach makes it especially useful before implementing a new process.

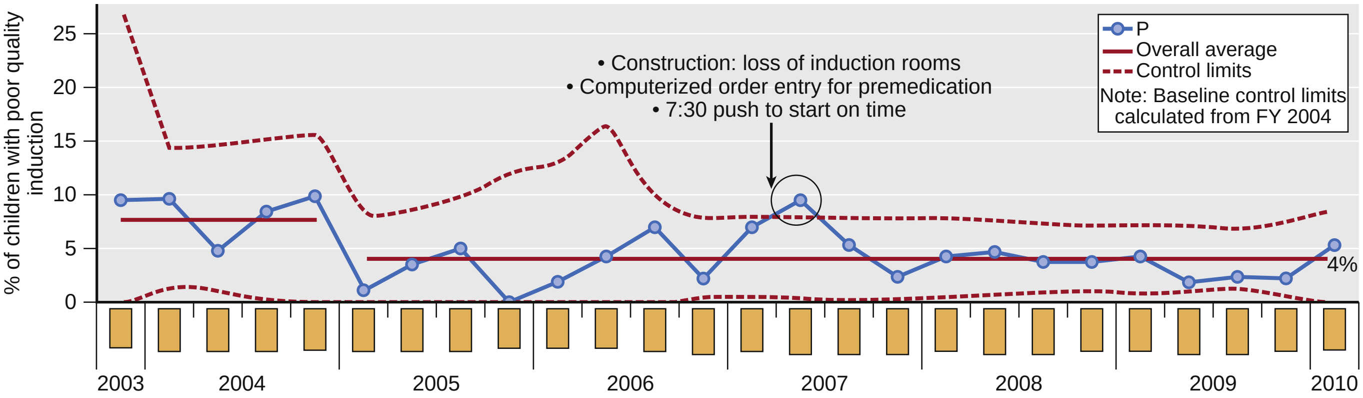


**Fig. 5.3** Example of a control chart that monitors the quality of the anesthesia induction process, as measured by an induction compliance checklist. The solid red line marks the mean, and the dashed lines indicate the upper control limit and lower control limit, which are ±3 standard deviations from the mean. The circled point represents a single special cause variation in quality of induction. (From Varughese AM. Quality in pediatric anesthesia. *Paediatr Anaesth.* 2010;20:684–696.)

An FMEA reviews the steps in a process, the potential failure modes (what could go wrong), failure causes (why would the failure happen?), and failure effects (what would be the consequences?). (IHI, QI Essentials Toolkit) After listing the steps in a process, a risk profile number is calculated based on the likelihood of occurrence, likelihood of detection, and severity. Improvement efforts are then targeted at the steps with the highest risk profile number.

A simplified FMEA is a quicker version of the FMEA that can help guide improvement work. A simplified FMEA consists of listing the steps in a process, listing potential failures that could go wrong for each step, and brainstorming interventions for each of those possible failures. Below is an example simplified FMEA for programming infusion pumps that was used in an improvement project to reduce medication errors.

## Putting It All Together: An Example Quality Improvement Project

The following is an example of how the QI methodology previously discussed could be used to address a practical problem. A hypothetical example of reducing medication errors in an anesthesiology department is described.

An anesthesia group was concerned over the large number of medication errors that were occurring in their department. They formed a multidisciplinary group including an anesthesiologist, nurse anesthetist, anesthesia resident, and pharmacist. They addressed the first question in the Model for Improvement—"What are we trying to achieve?"—by writing a SMART aim. Their SMART aim was to reduce medication errors in the Department of Anesthesiology from three errors per month to one error per month within 12 months.

The next question in the Model for Improvement is "How will we know that a change will result in an improvement?" In order to monitor their progress, they constructed a run chart of medication errors per month in their department. They captured data through a previously existing self-reporting system.

The last question of the Model for Improvement is "What changes can we make that will result in an improvement?" To better understand the errors that were occurring, the group categorized the medication errors into categories and constructed a Pareto Chart. A Pareto Chart is a bar chart in which categories are listed in descending order. The group learned that three categories of errors accounted for about 80% of the total number of errors. These categories were infusion pump errors, acetaminophen errors, and antibiotic errors. They decided to focus their initial efforts on these three categories. They created process maps for these three categories to better understand the current process and develop possible interventions. Finally, to help organize their theory of improvement, they created a key driver diagram listing the drivers they thought would affect their aim, as well as possible interventions targeting the drivers.

Now that they had a theory of improvement, they started testing their interventions. They tested their ideas using PDSA cycles. They adopted the successful tests, adapted tests with mixed results, and abandoned the failed tests. Some of their tests included requiring a sticker from pharmacy and requiring a two-person double check of infusion pumps. As their testing and implementation continued, they saw the centerline, or median, of the run chart decrease from three to two. The run chart rules indicated this was a significant change. The group was excited that they had decreased the number of medication errors in their department, but they had not yet reached their aim of no more than one medication error per month. They decided to continue testing new ideas until the median decreased to less than one error per month.

## Dashboards and Scorecards

A dashboard of measures functions like an instrument panel for an aircraft or automobile and provides real-time feedback on what is happening. Balanced *scorecards*, or "whole system measures," are similar to dashboards and are used to provide a complete picture of quality. Developed by Kaplan and Norton, the balanced scorecard is defined as a "multidimensional framework for describing, implementing, and managing strategy at all levels of an enterprise by linking objectives, initiatives, and measures to an organization's strategy."[34] A set of measures should reflect the culture and mission of an organization. Viewed collectively, this set of measures provides a gauge of current performance and can also guide the direction for future organizational improvement efforts. A balanced set of measures is critical to ensure

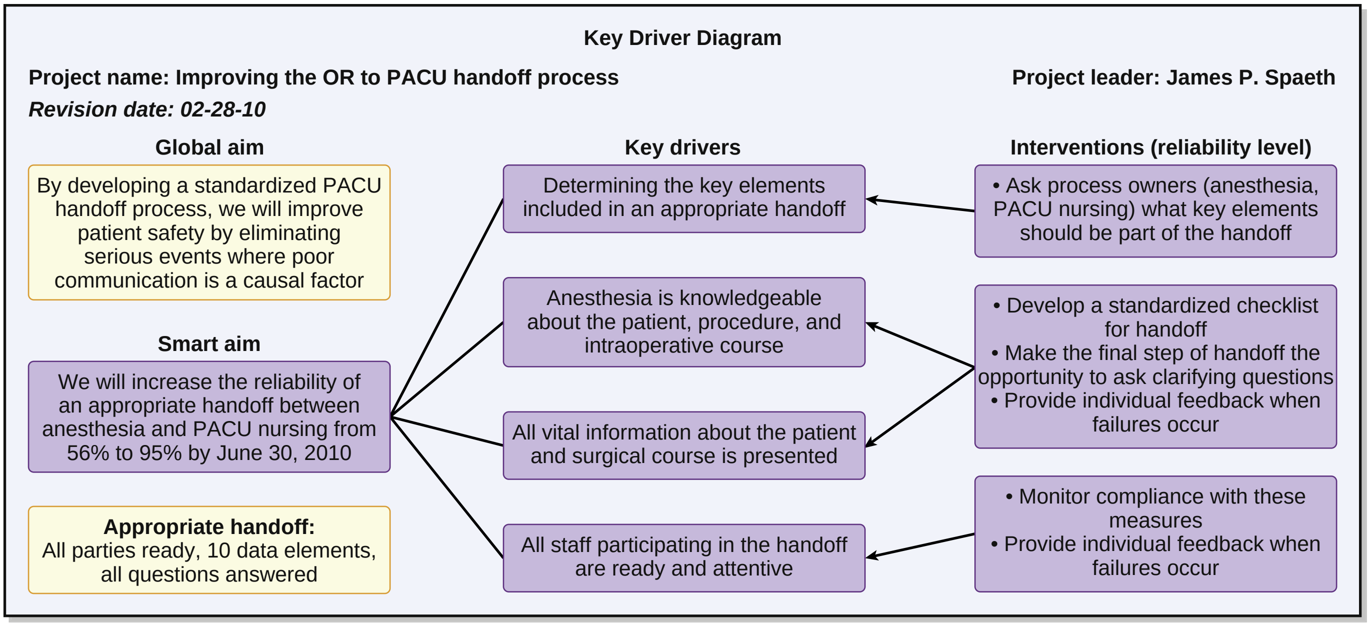


**Fig. 5.4** Example of a key driver diagram developed to improve the operating room *(OR)* to postanesthesia care unit (*PACU*) handoff process. This diagram incorporates the global and smart aim of the project, the key drivers inherent to the process, and specific interventions targeting each of the key drivers. (From Boat AC, Spaeth JP. Handoff checklists improve the reliability of patient handoffs in the operating room and postanesthesia care unit. *Paediatr Anaesth.* 2013;23(7):647-654.)[93]

that improvement efforts in one area do not adversely affect outcomes in other areas.

### Additional Quality Improvement Evaluation and Communication Tools

In most situations, QI frameworks such as the Model for Improvement or Lean Sigma are sufficient to help guide the development, testing, implementation, and spread of improvement. However, to better understand problems within a system or process, QI professionals have developed or adapted a number of methods and tools. Some of these methods and tools help with viewing systems and processes and organizing and communicating information. These are described in the following section.

Understanding how a process or system works is fundamental to improving it. Process mapping is a method to gain this understanding. A flow diagram, or flow chart, is an improvement tool used during process mapping; it provides a visual picture of the process being studied, wherein the series of activities that define a process is graphically represented. Flow charts identify and clarify all steps in the process. They also help the team understand the complexity of the process and identify opportunities for improvement.

Failure mode and effects analysis is a systematic, proactive method of identifying and addressing problems associated with a process. It uses a standardized approach to analysis that includes identifying the various steps in a process and addressing their failure modes, effects, and possible interventions.

A key driver diagram (KDD) (Fig. 5.4)[35] is another approach to organizing the theories and ideas for improvement that a team has developed. The KDD presents the aim or outcome of the project with both the theories (key drivers) behind the improvement and ideas for test of change.[7] Initially, the driver diagram helps lay out the descriptive theory behind the improved outcomes. As these theories are tested, the driver diagram is updated and enhanced to develop a predictive theory. KDDs are extremely useful because they provide a shared mental model for the team during its improvement efforts.

## IMPROVEMENT INTERVENTION TOOLS

Efforts in QI and patient safety have produced tools with which to reorganize the way care is delivered. QI intervention tools are used to improve communication and teamwork. Examples of these tools include daily goals sheets, briefings/debriefings, and checklists.

### Daily Goals Sheet

For nearly 20 years, documentation of daily goals as either a hand-written sheet or a whiteboard have been used to improve communication during multidisciplinary rounds in adult and pediatric ICUs.[36,37] As a one-page paper checklist, this tool would be completed every morning to establish the care plan, set goals, and review potential safety risks for each patient (Fig. 5.5).

Before implementation of the daily goals sheet in an adult ICU, an initial survey showed that ICU team members were unable to answer two simple questions after rounding at each patient's bedside: "Do you understand the patient's goals for the day?" and "Do you understand what work needs to be accomplished on this patient today?" Fewer than 10% of the residents and nurses knew the care plan for the day—a finding that was not surprising because traditional bedside rounds tended to focus on teaching the staff about disease processes rather than focusing on the work that was necessary to treat the patient. Approximately 4 weeks after the daily goals sheet was implemented, 95% of residents and nurses understood the goals for each patient. Moreover, after the daily goals sheet was implemented, length of stay in the

| | Room Number ______________ | Shift: ❒ AM / ❒ PM |
|---|---|---|
| Safety | What needs to be done to d/c patient from the ICU? | |
| | Patient's greatest safety risk? How can we ↓ risk? | |
| | What events or deviations need to be reported?<br>ICUSRS issues? | |
| Patient Care | Pain & Sedation Management | Pain goal ____ /10 |
| | Cardiac<br>Review ECGs | HR goal ____ ❒ at goal<br>❒ ↑ ❒ ↓ β-blockade |
| | Volume status<br><br>Net goal for midnight | Even ❒ Pos ❒ Neg ___<br>Net ___ (cc)<br>❒ Patient determined |
| | Pulmonary: Ventilator, ventilator bundle, HOB ↑, wean | ❒ OOB/pulmonary toilet/ambulation |
| | SIRS/Infection/Sepsis evaluation<br>Temp >38°C or <36°C; HR >90<br>RR >20 or $Pa_{CO_2}$ <32<br>WBC >12000 < 4000 or >10% bands | ❒ No current SIRS/sepsis issues<br>❒ Known/suspected infection<br>❒ Culture blood ×2/urine/sputum<br>❒ Antibiotic changes<br>❒ Discontinue sepsis bundle |
| | Can catheters/tubes be removed? | Y/N |
| | GI/Nutrition/Bowel regimen:<br>TPN catheter, ND tube PEG needed? | ❒ TPN<br>❒ NPO/Advance diet |
| | Is patient receiving DVT/PUD prophylaxis? | Y/N |
| | Can meds be discontinued, changed to PO, adjusted? | |
| To Do | Tests/Procedures today | |
| | Scheduled labs | |
| | AM labs needed/CXR? | |
| | Consultations | |
| Description | Has primary service been updated? | |
| | Has family been updated?<br>Social issues addressed?<br>Long-term/Palliative care | |

**Fig. 5.5** Example of an intensive care unit *(ICU)* daily goals sheet. *CXR*, Chest radiograph; *d/c*, discharge; *DVT*, deep vein thrombosis; *ECG*, electrocardiogram; *GI*, gastrointestinal; *HOB*, head of bed; *HR*, heart rate; *ICUSRS*, ICU self-reporting system; *ND*, naso-duodenal; *NPO*, nothing by mouth; *OOB*, out of bed; *PEG*, percutaneous endoscopic gastrostomy; *PUD*, peptic ulcer disease; *RR*, respiratory rate; *SIRS*, severe infectious respiratory syndrome; *temp*, temperature; *TPN*, total parenteral nutrition; *vent*, ventilator; *WBC*, white blood cell count.

surgical ICU decreased from a mean of 2.2 days to only 1.1 days.[38] These results have been reproduced in ICUs with nurses, physicians, and pharmacists. Interviews supported that communication, patient care, and education were enhanced by providing a structured, thorough, and individualized approach to the patient's care. The daily goals checklist helped to identify new patient care issues and sparked management discussions, especially for sedation, weaning, and medications.[36] Additionally, a QI intervention using daily goals checklists in 118 ICUs in Brazil improved the use of low tidal volumes, avoidance of heavy sedation, use of CVCs, use of urinary catheters, perception of teamwork, and perception of patient safety climate, but did not reduce in-hospital mortality.[37]

A further improvement was implemented in a pediatric cardiac ICU using a whiteboard for visual display of the daily goals.[39] Use of the whiteboard increased the percent agreement among the patient care team for patient goals from 62% to over 87%.[37] The goals were updated as needed and used as an information source for all staff involved in the patient's care as well as for the patient's family. A daily goals display such as this can be modified for use on other nursing units or during OR sign-out or emergency department rounds.

## Checklists

Checklists have been used in health care and other industries to ensure that important steps in a process are not forgotten. The Food and Drug Administration recommends that a checklist be used when checking out and inspecting an anesthesia machine before use to ensure that the equipment and monitors are functioning properly.[40,41] Checklists have been shown to be effective in reducing central line associated blood stream infections (CLABSI) by standardizing practice, reducing complexity, and providing a redundant safety check. The idea behind having a person, such as a nurse or another physician, be responsible for actually reading the checklist also empowers that person or anyone involved to stop the procedure if the checklist is not followed or if sterile technique is compromised. An early study showed that use of a central line insertion checklist and bundle resulted in a 66% reduction in the overall CLABSI rate; the median rate was reduced from 2.7 per 1000

**Surgical Safety Checklist**

**Before induction of anaesthesia** → **Before skin incision** → **Before patient leaves operating room**

**Before induction of anaesthesia**
(with at least nurse and anaesthetist)

Has the patient confirmed his/her identity, site, procedure, and consent?
- ☐ Yes

Is the site marked?
- ☐ Yes
- ☐ Not applicable

Is the anaesthesia machine and medication check complete?
- ☐ Yes

Is the pulse oximeter on the patient and functioning?
- ☐ Yes

Does the patient have a:

Known allergy?
- ☐ No
- ☐ Yes

Difficult airway or aspiration risk?
- ☐ No
- ☐ Yes, and equipment/ assistance available

Risk of >500 mL blood loss (7 mL/kg in children)?
- ☐ No
- ☐ Yes, and equipment/ assistance available

**Before skin incision**
(with nurse, anaesthetist, and surgeon)

- ☐ Confirm all team members have introduced themselves by name and role.
- ☐ Confirm the patient's name, procedure, and where the incision will be made.

Has antibiotic prophylaxis been given within the last 60 minutes?
- ☐ Yes
- ☐ Not applicable

Anticipated critical events

To surgeon:
- ☐ What are the critical or nonroutine steps?
- ☐ How long will the case take?
- ☐ What is the anticipated blood loss?

To anaesthetist:
- ☐ Are there any patient-specific concerns?

To nursing team:
- ☐ Has sterility (including indicator results) been confirmed?
- ☐ Are there equipment issues or any concerns?

Is essential imaging displayed?
- ☐ Yes
- ☐ Not applicable

**Before patient leaves operating room**
(with nurse, anaesthetist, and surgeon)

Nurse verbally confirms:
- ☐ The name of the procedure
- ☐ Completion of instrument, sponge and needle counts
- ☐ Specimen labeling (read specimen labels aloud, including patient name)
- ☐ Whether there are any equipment problems to be addressed

To surgeon, anaesthetist and nurse:
- ☐ What are the key concerns for recovery and management of this patient?

This checklist is not intended to be comprehensive. Additions and modifications to fit local practice are encouraged.

**Fig. 5.6 World Health Organization Safe Surgery Checklist.** (Reproduced with permission from World Health Organization. WHO Surgical Safety Checklist.)

catheter days before the intervention to 0 by month 3 and through month 18 of the postintervention.[42] A central line insertion checklist has since been adopted by institutions, safety groups, and regulatory agencies as a tool to ensure compliance with the best practices for CVC placement and prevent CLABSI. Checklists and central line insertion bundles are widely available online; one such resource is the IHI (http://www.ihi.org).

In addition to standardizing technical tasks, checklists are also used to standardize communication. Haynes and colleagues[43] described the use of a checklist to guide the perioperative time-out, briefing, and debriefing process. They showed that implementing the World Health Organization Surgical Safety Checklist (Fig. 5.6) reduced mortality and inpatient complications.[43] The use of surgical checklists is now widespread and is standard of care in most OR settings around the world. Numerous studies related to surgical checklists either as a tool or a process have shown their effectiveness, while some studies have reported limited impact. A review of 25 highly cited research papers on surgical safety checklists from 2009 to 2016 showed the complexity of standardizing, implementing, and sustaining the use of surgical safety checklists.[44] Complexities include variations in the environment, distribution of staff, timing of when the checklist is actually used, relationship between those using the checklist, and the culture of the institution.[44] These complexities may undermine the effectiveness of checklists and should be considered prior to checklist implementation.

## Briefings and Debriefings

The surgical checklist is part of the Universal Protocol, which was created to prevent wrong person, wrong procedure, and wrong site surgery. In order to address many of the other important safety issues, such as antibiotic needs, deep vein thrombosis prevention, fire prevention, special equipment needs, and blood product availability, many institutions have implemented OR briefings or huddles, as well as debriefings at the end of surgery. Preoperative briefings have been shown to improve team communication, improve compliance with best practices, and enhance the overall perception of the safety climate in the OR.[45]

Briefing and debriefing tools are designed to promote effective interdisciplinary communication and teamwork.

| | Briefing: Before Every Procedure |
|---|---|
| | Team introductions: First and last names, including roles; write names on board |
| | Verify: Patient ID band, informed consent (read out loud), site marking, OR posting, patient's verbalization of procedure (if patient awake), H&P or clinic note |
| | Are there any safety, equipment, instrument, implant, or other concerns? |
| | Have antibiotics been given, if indicated? |
| | What are the anticipated times of antibiotic redosing? |
| | Is glucose control or β-blockade indicated? |
| | Is the patient positioned to minimize injury? |
| | Has the prep solution been applied properly, without pooling, and allowed to dry? |
| | Have the goals and critical steps of the procedure been discussed? |
| | Is the appropriate amount of blood available? |
| | Is DVT prophylaxis indicated? If yes, describe. |
| | Are warmers on the patient? |
| | Is the time allotted for this procedure an accurate estimate? |
| | Have the attendings reviewed the latest laboratory and radiology results? |
| | **Debriefing: After Every Procedure** |
| | Could anything have been done to make this case safer or more efficient? |
| | Has the Surgical Site Infection data collection form been completed? |
| | Are the patient's name, history number, surgical specimen name, and laterality on the paper work? (must be independently verified by the surgeon) |
| | Did we have problems with instruments? Were they reported? |
| | Plan for transition of care to postop unit discussed?<br>❐ Fluid management?<br>❐ Blood transfusion paperwork in chart?<br>❐ Antibiotic dose and interval to be continued postop?<br>❐ Pain management/PCA plan?<br>❐ New medications needed immediately postop?<br>❐ β-blockers needed?<br>❐ Glucose control?<br>❐ DVT prophylaxis? |

**Fig. 5.7 Example of an operating room briefing and debriefing tool.** *DVT,* Deep vein thrombosis; *H&P,* history and physical; *ID,* identification; *OR,* operating rooms.

Both have been used in the OR, during sign-out from the ICU nursing staff to the intensivist, and between OR nursing and anesthesia coordinators.[40,46,47] A briefing is a structured review of the case at hand that takes place among all team members before the start of an operative procedure. A debriefing occurs after the procedure; the team reviews what worked well, what failed, and what could be accomplished better in the future (Fig. 5.7).

An example of an OR briefing includes introduction by name (first and last) and role of each team member, confirmation of the correct patient, confirmation of the site/side and procedure (time-out), and a verbal assurance that all team members agree that they understand the procedure and what is required to ensure its success. A check of all necessary equipment, medications (e.g., appropriate antibiotic), and blood availability is performed. The question, "If something were to go wrong, what would it be?" is asked, and plans to mitigate or respond to the potential hazard are discussed.

A collaborative effort by the Agency for Healthcare Research and Quality (AHRQ) and the Department of Defense adopted crew resource management strategies for OR briefings and produced an evidence-based resource called Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) www.ahrq.gov. This team approach in the OR encourages situational awareness and communication among all members of the healthcare team.[48-51]

## Sources of Quality Improvement Information

Development of a QI project first requires that an issue be identified. Baseline data are then collected and an improvement intervention instituted, often using one of the approaches described earlier. Data are re-collected after the intervention. If the intervention is found to be effective, ongoing monitoring or audits are instituted to ensure that the change is sustained. As part of the audits, feedback must be given to the providers. Healthcare providers traditionally have had limited ability to obtain feedback regarding performance in their daily work, in part because of a lack of information systems and a lack of agreement on how to measure quality of care.[52]

Ideas for QI projects can be identified from a multitude of sources, but they typically start with surveys and input from local medical staff and reviews of reported incidents. Additional information is gathered from the literature, review of national guidelines and quality metrics, and information obtained from external or internal reviews.

Sources of QI data that span both the clinical and administrative arenas include evidence-based medicine and evidence-based clinical practice guidelines, alerts from accrediting agencies and nonprofit safety organizations, standards and guidelines put forth by medical specialty associations, closed claims databases, and government agency administrative databases. United States governmental agencies, including the AHRQ, CMS, and the National Quality Forum (NQF), promote the development and reporting of healthcare quality measures.[53]

## INCIDENT REPORTING

Voluntary incident reporting capturing hazardous conditions has been successfully used to improve patient care and foster QI programs.[54] As the potential of voluntary incident reporting is being realized in health care, this reporting has become less punitive and more focused on systems rather than on individuals. Voluntary incident reporting, when appropriately applied, helps identify hazards to patients that can then become the focus of QI efforts that seek to mitigate those hazards.[55] Unlike other methods that evaluate harmed patients, voluntary incident reporting provides the potential to also learn from near misses—incidents that did not lead to harm but were potentially hazardous. These near misses and potential hazards are a rich source for QI projects highlighting the importance of preventing harm.

All anesthesiology departments should have a process in place for capturing adverse events and near misses. Although most departments have a process for reporting, many incidents go unreported for a variety of reasons. Departments should encourage voluntary reporting without threat of punishment. Electronic capture of adverse events, near misses, and complaints can provide data that can subsequently be analyzed to identify trends and assess the degree of harm that a hazard poses to patients.

Events that occur frequently with low harm can be just as important as an event that occurs rarely with high harm. At the local level, it is more effective to focus on a more frequently occurring adverse event (e.g., perioperative skin abrasions, mislabeling of laboratory specimens) or on a process that can be measured with high frequency (e.g., hand hygiene, administration of antibiotic prophylaxis). For rarely occurring harmful events, a QI initiative may encompass a more expansive analysis of a national adverse-event database with multicenter participation.

With multiinstitutional event reporting systems, events that would rarely be seen in a single institution can be collected in larger numbers. Such systems allow analysis for common causes that increase our knowledge base for prevention initiatives. Larger multiinstitutional data gathering systems include the Vizient collaborative (the former University HealthSystem Consortium), which supports event reporting and databases that can be used to develop QI programs, benchmarking, and evidence-based practice.[56] Reporting systems that have been developed specifically to investigate rarely occurring anesthesia-related events include the Anesthesia Incident Reporting System (AIRS) created by the Anesthesia Quality Institute (AQI)[57] and Wake Up Safe, a QI initiative of the Society for Pediatric Anesthesia.[58] The AIRS program publishes a learning case each month in the *ASA Newsletter,* including a summary of a reported case with learning points.

More expansive international incident-reporting systems that are anonymous and voluntary have also been analyzed in the literature and have provided important information. Examples are the United Kingdom's Serious Incident Reporting and Learning Framework[59] and the Australian Incident Monitoring Study.[60] These incident registries do not require that the events be considered human error or preventable to merit reporting and are a source of ideas for QI projects.

Although voluntary systems often prove fruitful, many events and near misses still frequently go unreported. One way to capture these incidents is to survey local medical staff members to obtain their thoughts on how the last patient was harmed or how the next patient might be harmed. This process of performing a staff safety assessment survey is described in two later sections of this chapter (see "Collaborative Programs" and "Comprehensive Unit-Based Safety Program"). Staff safety assessment surveys can be particularly helpful for identifying issues for QI projects. Additionally, if staff members identify the issue, the likelihood is greater that they will have a vested interest in participating in the QI efforts.

## PUBLISHED LITERATURE

Literature reviews offer ideas for QI topics in specific areas and information to guide interventions. For example, if the QI project plan is to reduce hazards in cardiac anesthesia, a literature review will provide reports of various cardiac anesthesia risks. Once a topic within a clinical area is selected, a literature search should be performed again to determine whether similar QI projects have been performed and whether they were successful. Such information will help with the design of a future initiative. The literature also provides published reports that identify guidelines and/or evidence-based practices that can be the basis for future programs.[61,62]

## NATIONAL INITIATIVES AND QUALITY METRICS

The AHRQ is the source for both the U.S. National Quality Measures Clearinghouse and the National Guideline Clearinghouse. Professional organizations, such as the American Society of Anesthesiologists (ASA) and the World Federation of Societies of Anesthesiologists, offer field-specific guidelines. The ASA has supported the review and development of many important guidelines that can serve as a rich source of QI initiatives. These guidelines cover a range of practices and include guidelines for the placement of central venous access,[63] management of patients with obstructive sleep apnea,[64] and management of preoperative fasting.[65] For those who are also involved in critical care medicine, guidelines and protocols do improve performance with specific care processes such as sedation and ventilator weaning protocols in ICUs. Such protocols decrease the duration of mechanical ventilation and ICU length of stay.[66,67]

Review of national quality metrics is another source of ideas for QI topics. National initiatives from CMS, such as the QPP (described earlier in "Quality Improvement Measures and Tools") and Surgical Care Improvement Project (SCIP), provide quality metrics and are associated with pay for performance. Most of the SCIP measures, which predominantly

**TABLE 5.3** Nonprofit and Governmental Quality Improvement Organizations Pertinent to Anesthesia

| Quality Improvement Organization | Website | Description |
|---|---|---|
| Agency for Healthcare Research and Quality (AHRQ) | www.ahrq.gov | Lead federal agency charged with improving the quality, safety, efficiency, and effectiveness of health care |
| American Health Quality Association (AHQA) | www.ahqa.org | Represents quality improvement organizations and professionals working to improve the quality of health care |
| Anesthesia Patient Safety Foundation (APSF) | www.apsf.org | Promotes investigations and programs that will provide a better understanding of anesthetic injuries |
| Centers for Disease Control (CDC) | www.cdc.gov | One of the major operating components of the U.S. Department of Health and Human Services |
| Emergency Care Research Institute (ECRI) | www.ecri.org | Uses applied scientific research to discover which medical procedures, devices, drugs, and processes are best |
| Institute for Healthcare Improvement (IHI) | www.ihi.org | Health care improvement organization based in Cambridge, Massachusetts |
| Institute for Safe Medication Practices (ISMP) | www.ismp.org | The nation's only 501(c)(3) organization devoted entirely to medication error prevention and safe medication use |
| Medicare Quality Improvement Community (MedQIC) | www.medquic.org | A national knowledge forum for health care and quality improvement professionals |
| National Quality Forum | www.qualityforum.org | Created to develop and implement a national strategy for health care quality and reporting |
| National Patient Safety Foundation (NPSF) | www.npsf.org | An independent 501(c)(3) organization with a mission to improve the safety of patients |

measure processes of care, are topped out (nearly 100% in all hospitals) and have therefore been retired from active surveillance. The Joint Commission (TJC) website (www.jointcommission.org) lists United States National Patient Safety Goals and national quality core measures that are surveyed during site visits for accreditation. In 2004, TJC partnered with CMS to align measures common to both organizations in an initiative called Hospital Quality Measures. These measures are also endorsed by the NQF, a private, nonprofit membership organization created to develop and implement a national strategy for healthcare quality measurement and reporting (www.qualityforum.org). One of NQF's functions is to endorse quality and safety measures (consensus standards), which are then incorporated into other national quality initiatives. The goal for NQF-endorsed standards is that they become the primary standards used to measure the quality of health care in the United States. Increasingly, anesthesia programs are focusing on the standards that are relevant to the specialty because facilities are being evaluated on compliance with regulations and are required to report their performance regarding these standards to the governing bodies.

An increasing number of regional and national organizations are developing initiatives that are stimulating the reporting of specific evidence-based practices and outcomes. These initiatives are also determining the local selection of areas for QI (Table 5.3). As described earlier, reporting of these measures to CMS is being incentivized by performance-based payment. National professional organizations such as the ASA are developing metrics specific to the field.

## OUTCOMES RESEARCH

The comparison of outcomes associated with different process decisions, or variations in care delivery, is the basis for outcomes research. Outcomes research offers a potential to identify these variations in care and to determine whether they improve outcomes for patients undergoing anesthesia. One of the key issues in outcomes research is risk adjustment, a challenging goal that requires a robust dataset. Using administrative data to identify patient risk factors has many limitations.[68] Registries designed specifically for research, benchmarking, and QI are good sources for this purpose.

The Society of Thoracic Surgeons (STS) and the National Surgical Quality Improvement Programs (NSQIP) are examples of outcomes research registries. Established in the early 1990s, the STS database now includes participation by nearly all U.S. cardiac surgery centers and has developed robust risk-stratification models. Findings from this database have led to initiatives associated with significant reductions in mortality; examples include the use of β-adrenergic blockers and aspirin perioperatively and the use of internal mammary arteries for coronary artery bypass grafting. NSQIP is a newer registry that was developed by the U.S. Department of Veterans Affairs (VA). Findings from this risk-adjusted outcomes database were used to identify variations in care. The changes that were instituted based on these findings resulted in improved surgical outcomes throughout the VA network. NSQIP has been adopted by the American College of Surgeons to provide comparisons among hospitals. Currently, more than 350 general surgery centers participate.[69] Hospitals that participate submit detailed data on a sample of general surgical patients for a number of common surgical procedures. They then receive a graphic display that compares their outcomes with those of the entire cohort. Surgery centers then use these data to identify areas in which they might be able to make improvements and initiate QI projects with that focus. As an example, the Kaiser Permanente group used this information to develop a QI program focused on reducing the percentage of patients with prolonged perioperative intubation.[69]

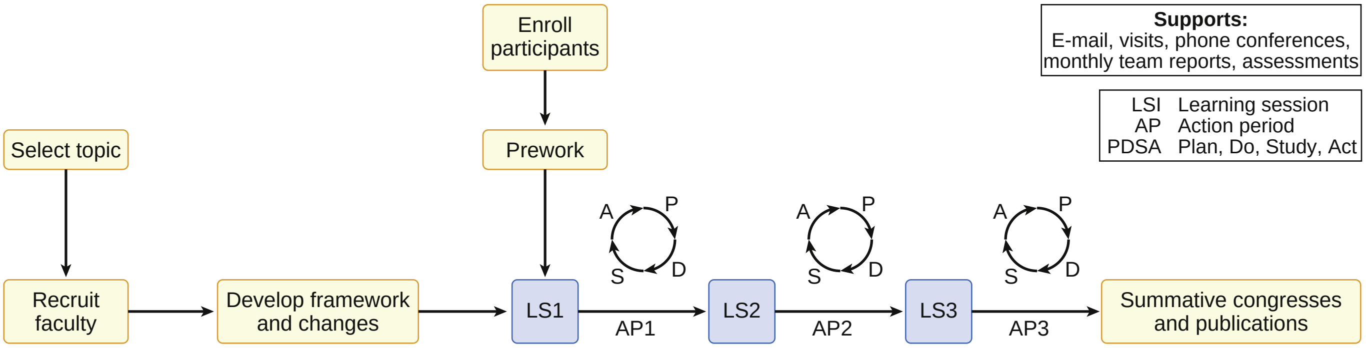


**Fig. 5.8 Breakthrough series collaborative model.** (Reproduced with permission from Institute for Healthcare Improvement: The Breakthrough Series: IHI's Collaborative Model for Achieving Breakthrough Improvement. IHI Innovation Series white paper, Boston, 2003. *PDSA*, Plan, Do, Study, Act. http://www.ihi.org/knowledge/Pages/IHIWhitePapers/TheBreakthroughSeriesIHIsCollaborativeModelforAchievingBreakthroughImprovement.aspx.)

The ASA created the AQI and the National Anesthesia Clinical Outcomes Registry with the goal of improving anesthesia outcomes through capture of case-specific data directly from electronic anesthesia data systems.[70,71] These resources are still evolving and moving forward to improve outcomes in anesthesia. Another important effort in anesthesia is the Multicenter Perioperative Outcomes Group (MPOG), which is led by researchers at the University of Michigan.[72] MPOG has established a national network of anesthesia practice groups that contribute data to a unified database. The goals of MPOG are to develop a structure for multiinstitutional collaboration and data sharing, to develop the information technology infrastructure to pool a wide variety of perioperative data for patient-centered research, to develop the statistical infrastructure to analyze the data, and to provide an academic venue in which faculty from multiple institutions will be able to collaborate in outcomes research (http://mpog.med.umich.edu).[72]

### INTERNAL OR EXTERNAL INSTITUTIONAL REVIEWS

Internal or external institutional reviews of healthcare processes can provide important insights and ideas for QI initiatives. In addition to the external regulatory reviews, institutions are expected to perform internal reviews of quality and identify areas for improvement. These reviews are often used for QI projects at the institutional level.

## Examples of Quality Improvement Programs

Examples of QI frameworks and tools have been discussed. This section addresses broad initiatives for quality and safety improvement that have used some of the methodologies and tools detailed earlier in this chapter.

### COLLABORATIVE PROGRAMS

Use of a collaborative is one approach to improving broad areas of care. A QI collaborative involves the participation of two or more healthcare teams working toward a shared goal. In healthcare, a set of multidisciplinary representatives (from all of the clinical and administrative areas that are linked to the area of focus) should participate in the collaborative. A collaborative can be developed within a single organization and/or across multiple healthcare organizations. Collaborative programs are typically led by a team that is responsible for the following:

1. Determining the evidence-based interventions to be used and presenting these to the participants (if evidence-based interventions are not available, the team will generate interventions based on local and broad expert consensus)
2. Establishing the data collection approach (defining measures, collection methods, and feedback mechanism)

A key element to the success of collaboratives is an established process for educating members and for sharing interventions and obstacles. Through group discussions (meetings and/or conference calls), teams can learn about best practices and innovative methods used by other teams to approach a problem. In addition, collaboratives bring a shared momentum and enthusiasm that can increase sustainability.[24,73,74]

### INSTITUTE FOR HEALTHCARE IMPROVEMENT BREAKTHROUGH SERIES COLLABORATIVES

QI collaboratives provide an opportunity to learn from other teams, work collaboratively, and spread change on a larger scale. The IHI has used a collaborative model for improvement, called the Breakthrough Series Model, for more than a decade. Collaboratives run from 12 to 160 teams across multiple organizations. Successful IHI collaboratives have included reducing waiting times by 50%, reducing ICU costs by 25%, and reducing hospitalizations of heart failure patients by 50%.[75]

In the Breakthrough Series Model, a topic is selected and participating teams are enrolled (Fig. 5.8). Expert faculty from across the country, or even internationally, are recruited for an expert meeting to develop a framework for change called a "change package." The change package describes interventions for improvement based on available evidence. Next, team members from all groups attend collaborative learning sessions where they learn the model for improvement and share their progress implementing the change package. At the end of the collaborative, a summative meeting and publications are used to share the findings with others.

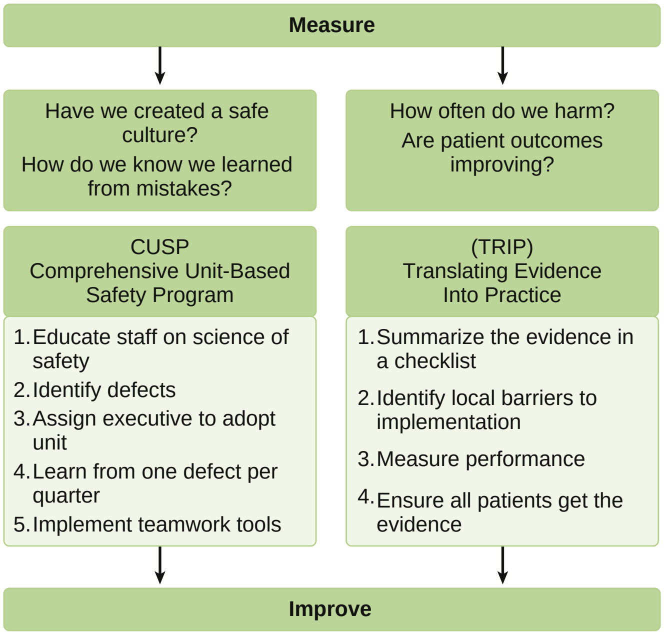


**Fig. 5.9** Comprehensive unit-based safety program *(CUSP)* and translating evidence into practice *(TRIP)*: basic steps to ensure patients receive evidence-based care. (Reproduced with permission from Sawyer M. Using evidence, rigorous measurement, and collaboration to eliminate central catheter-associated bloodstream infections. *Crit Care Med.* 2010;38:S292–S298.)

**TABLE 5.4** Four Steps That Ensure Patients Receive Evidence-Based Interventions Through a Collaborative Using the Example of Catheter-Related Bloodstream Infections

| Step | Action | Example |
|---|---|---|
| Engage | Make the problem real | Share information of local CRBSI rate vs. national rate |
| Educate | Develop an educational plan to reach ALL members of the caregiver team | Present evidence-based practices at grand rounds and multidisciplinary team meetings<br>Present plans to improve care and measure outcome |
| Execute | Develop a safety culture<br>Reduce complexity of the processes<br>Introduce redundancy in processes<br>Hold regular team meetings | Develop a culture of intolerance for CRBSI<br>Ensure that all equipment and supplies for sterile CVC insertion are in one place and easily available<br>Use checklists that identify key steps to reduce CRBSI<br>Focus on one to two tasks per week and identify team member responsible for task |
| Evaluate | Measure and provide feedback | Develop data collection plan and database to track progress<br>Give staff real-time feedback; post progress in highly visible location<br>Identify causes of defects |

*CRBSI,* Catheter-related bloodstream infections; *CVC,* central venous catheter.

## COMPREHENSIVE UNIT-BASED PROGRAM

Sawyer and associates reported the success of a collaborative that incorporates a "mechanism to move evidence to the bedside and foster a culture where the focus is the patient."[76] The collaborative includes an emphasis on translating evidence into practice (TRIP) and the Comprehensive Unit-Based Safety Program (CUSP). This methodology has been reproduced and validated in several large collaborative efforts (Fig. 5.9).[76-78]

The TRIP model incorporates the following key steps and emphasizes the importance of measurement and feedback of data to teams.

1. Identify evidence-based interventions associated with an improved outcome through review of peer-reviewed publications.
2. Select goal-oriented interventions that have the most impact on outcomes and transform them into behaviors. In selecting behaviors, focus on interventions with the strongest treatment effect (smallest number needed to treat) and the lowest barrier to use.
3. Develop and implement measures that evaluate either the interventions (processes) or the outcomes.
4. Measure baseline performance and establish databases to facilitate accurate data management and timely feedback to teams.
5. Ensure that patients receive evidence-based interventions through four basic steps: engagement, education, execution, and evaluation (Table 5.4).

The format for the collaborative also includes annual face-to-face meetings with the participating teams and periodic conference calls, which focus on education about the actual processes being implemented, the evidence base to support these processes, and the sharing of experiences. First, weekly immersion calls provide an initial overview of the program, describe the roles and responsibilities of each of the individuals, and introduce the tools that are to be used. Once the collaborative is introduced, monthly content calls are held throughout the program and are typified by a slide presentation of the evidence base for the intervention or of other components of the program to be implemented. The monthly coaching calls offer an opportunity for teams to share how well or how poorly they are implementing the interventions and share ideas for overcoming barriers.

Inclusion of the CUSP program in the collaborative provides a structured approach to improve safety culture and identify and mitigate hazards (i.e., learn from mistakes).[38,47] CUSP is a five-step program that has been tested and used successfully to improve quality and safety in ICUs (Table 5.5).[79,80] CUSP programs have been used in many different environments including inpatient units, primary care practices,[81] and in the perioperative period[82] to enhance the safety culture and improve the patient experience.[83]

Safety culture is assessed before the implementation of CUSP and reassessed after 1 year to evaluate the impact of the program. Multiple culture assessment tools are available.[64,65] The AHRQ offers a free survey online (www.ahrq.gov). The initial measure provides a baseline assessment of staff perceptions of safety culture in their clinical areas and their perceptions of the organization's commitment to patient safety.

Education is a crucial aspect of CUSP; it provides staff with a new set of lenses through which to identify hazards and

**TABLE 5.5** Five-Step Comprehensive Unit-Based Safety Program

| | Step | Description |
|---|---|---|
| 1 | Present educational material | Educate staff on science of safety though lectures and other educational materials |
| 2 | Complete forms that identify patient safety issues | Ask the following questions:<br>▪ How will the next patient be harmed?<br>▪ How can this harm be prevented?<br>▪ Establish voluntary incident reporting |
| 3 | Assign senior executive responsible for specific area | Senior executive meets with all staff of the clinical area to:<br>▪ Help prioritize safety efforts<br>▪ Remove barriers for system changes<br>▪ Provide resources<br>▪ Demonstrate hospital commitment to patient safety<br>▪ Foster relationship between senior leadership and staff |
| 4 | Learn from defects | Implement projects focused on two to three safety issues<br>Keep goals simple:<br>▪ Reduce complexity in the process<br>▪ Create independent redundancies to ensure critical steps are accomplished |
| 5 | Implement teamwork tools | Implement programs such as checklists, training, and daily goals targeted at improving teamwork and communication |

recommend system changes to improve care. The objectives of these educational efforts are to ensure that staff: (1) understand that safety is a system property, (2) learn concepts for reliable healthcare design, and (3) understand the basics of change management. After an educational lecture on the science of safety, staff members are requested to identify patient safety hazards in their clinical areas and suggest improvement interventions. For this process, staff members review incident reports, liability claims, and sentinel events from their unit. In addition, two questions are asked: "How do you think the next patient will be harmed?" and "How can we prevent it from happening?"

After the completion of the survey and educational component, a senior leader of the institution (e.g., hospital president, vice president, director) is partnered with a unit or clinical area. This leader attends rounds on the unit monthly to help staff members prioritize safety efforts, to ensure that they have the resources to implement improvements, and to hold them accountable for evaluating whether safety has improved. Staff members are asked to learn from one defect per month and to implement one tool per quarter designed to improve care delivery.[38,47]

CUSP was pilot-tested in ICUs and subsequently implemented throughout Johns Hopkins Hospital and in the Michigan Keystone project.[77] In the pilot, a patient-safety team that consisted of staff from the clinical area was responsible for oversight of the program. To be most effective, this team included the ICU director as the ICU physician safety champion, the nurse manager, another ICU physician and nurse, a risk manager or patient-safety officer, and a senior executive from the institution. The program worked best if the physician and nurse who led the program dedicated at least 20% of their time to improving quality and patient safety. The first unit was the beta site; subsequent teams from other clinical areas would learn from its successes and failures. The ultimate goal was to have every area in the hospital organizing and managing safety through CUSP.

CUSP has been associated with significant improvements in safety culture. The percentage of staff reporting a positive safety climate increased from 35% before CUSP to 60% after CUSP.[80,84] In addition, teams identified and mitigated several specific hazards through CUSP. As a result of asking staff members to speculate on how the next patient might be harmed, the ICU created a dedicated ICU transport team, implemented point-of-care pharmacists, implemented the daily goals sheet, clearly labeled epidural catheters to prevent inadvertent intravenous connection, and standardized the equipment in transvenous pacing kits.[85] Moreover, the use of CUSP decreased the length of stay and nurse turnover.

In summary, CUSP provides several benefits for improving safety culture and is a primer for staff compliance in implementing any safety or QI intervention or project. It provides enough structure to convert the often-vague goals of improving safety into a focused strategy; yet it is flexible enough to allow units to work on issues most important to them. CUSP provides a venue to introduce rigorous research methods, acts as a learning laboratory to identify and mitigate hazards, and has the potential to improve patient outcomes.

## CHALLENGES AND BARRIERS TO QUALITY IMPROVEMENT PROJECTS

Multicentered and/or single-hospital projects can fail because of inadequate resources, lack of leadership support, vague expectations and objectives for team members, poor communication, complex study plans, inadequate management of data collection, and wasted efforts to "reinvent the wheel" rather than adopting practices proven to be effective. Successful collaboratives require a local culture (the set of values, attitudes, and beliefs of the group) that is ready for change and participants who have a shared view of safety and who understand the science of patient quality and safety (i.e., the technical components of how care is organized and delivered).

## RELATED CONCEPTS: IMPROVEMENT SCIENCE AND IMPLEMENTATION SCIENCE

The focus of this chapter has been QI operations, or the efforts concerned with the measurement and timely improvement of quality in a given setting. QI operations is related to improvement science and implementation science, both of which aim to create generalizable knowledge that has the potential to improve care quality and patient outcomes across settings. These three fields are often confused because they share tools and are all interested in improving patient outcomes, but may use different terms to refer to similar concepts. To provide clarity about the similarities and differences between these fields, Koczwara and colleagues conceptualized a spectrum with QI operations at one end, implementation science at the other, and improvement science in the middle.[86] Understanding the roles for these fields may prove useful to those interested in anesthesia QI.

*QI operations.* As described at length in this chapter, QI is the systematic approach to improving problems in healthcare delivery that compromise care quality and outcomes. It is a timely, context-dependent team endeavor that has the potential to improve local care in the short, medium, and long term.

*Improvement science.* A common criticism of QI is that it is "unscientific" and more concerned with action than with understanding the mechanisms through which improvement occurs (or the reasons underlying the failure of improvement efforts). Improvement science draws from QI principles, aiming to "create practical learning that can make a timely difference to patient care."[87] But improvement science is also concerned with the creation of generalizable knowledge. Hence, close attention is paid to both internal and external validity in the design of improvement studies. Rigorously designed improvement science projects may sacrifice some of the timeliness of QI projects, but balance this downside with greater potential utility of the findings outside of a local setting.

*Implementation science.* Implementation science (known as knowledge translation in Canada) aims to narrow the evidence-to-practice gap evident when proven-effective interventions do not translate into improved care and outcomes.[88] Although the field is characterized as a new one, it draws from psychology, education, management, and related sciences. Two features clearly distinguish implementation science from QI and improvement science: the reliance on evidence-based practices and the use of explicit frameworks, theories, and models. Implementation science is a major focus for research funding agencies in the United States and Canada, as it is seen as one approach to maximize the return on grant dollars allocated to scientific discovery in health care. As with QI and improvement science, the adequate characterization of "real world" contexts is paramount. In contrast, there tends to be greater emphasis on generalizability in implementation science as compared to improvement science.

A key distinction between these three fields is their relationship to evidence. Implementation science relies on evidence-based interventions. However, there is not always evidence to guide our practice in situations with clearly suboptimal quality. In these situations, QI approaches can be useful, as rapid-cycle small-scale tests of change can minimize harm and mitigate risk at the same time as quality is addressed.

## The Future: Research, Education, and Ethics

Much remains to be accomplished in QI. The opportunity to improve patient care is substantial, and the pressure to improve the quality of perioperative care continues to increase. Improving quality of care requires the ability to measure and improve performance. Research is needed to develop measures of quality that clinicians believe are valid and to learn how to ensure that all patients reliably receive recommended interventions. Innovation is needed to develop information systems that can be used by multiple disciplines. Anesthesiologists and professional societies may need to partner with experts in quality measurement to develop and implement quality measures. Future efforts should balance the feasibility and validity of quality measures and develop integrated approaches to improving quality, including strategies to develop care bundles, decrease complexity, and create independent redundancies.

**TABLE 5.6** Accreditation Council of Graduate Medical Education (ACGME) Six Core Competencies and Institute of Medicine (IOM) Six Aims for Improvement

| | ACGME Core Competencies | IOM Aims for Improvement |
|---|---|---|
| 1 | Patient care | Safe |
| 2 | Medical knowledge | Timely |
| 3 | Interpersonal and communication skills | Effective |
| 4 | Professionalism | Efficient |
| 5 | System-based practice | Equitable |
| 6 | Practice-based learning and improvement | Patient-centered |

Clinicians now need the skills necessary to improve quality. Health care will cross the quality chasm only when all view quality and safety as their primary job, rather than as an added activity, and healthcare organizations provide the infrastructure to monitor and improve performance. Frontline healthcare providers must understand the science of quality and safety and evaluate safety risks as hazardous systems, not incompetent people. Integral to this is the education of our trainees. CQI in anesthesia residency training programs has been touted for more than 25 years.[89] In the United States, residents in training are expected to master six core competencies, as mandated by the Accreditation Council of Graduate Medical Education,[90] competencies that are linked to the NAM's six Aims for Improvement (Table 5.6).[3] In an effort to link these two sets of goals and apply them to the clinical setting for training purposes, Bingham and colleagues[91] developed a framework called the Healthcare Matrix that can be used as both an educational tool and a research tool for improvement.

With the increasing amount of intellectual focus and healthcare resources being directed toward QI programs, the ethics of QI have come to light. QI projects have generally been exempt from the rigorous review of human-subjects research. However, a Hastings Center Report on the ethics of using QI methods to improve health quality and safety suggests that some QI projects may involve risk to patients and should undergo a formal review.[92] This report lists QI initiatives that may trigger the need for a review as those that have a randomized design, use novel treatments, involve researchers, have delayed feedback of monitoring, or are funded by external sources. The reporting of QI activities should be encouraged, as should requiring approval by an internal review board and following a standardized format for reporting the results. All of these practices support the premise that delivery of quality care is a science as well as an art.

## Summary

Healthcare organizations need a systematic approach to three areas of patient safety: (1) TRIP, (2) identifying and mitigating hazards, and (3) improving culture and communication. The underlying principle for all of the approaches discussed in this chapter is that improvement of the quality of care dictates that practitioners must be able to measure their performance. Healthcare practitioners traditionally have had limited ability to obtain feedback regarding performance in their daily work, in part because of the absence of information systems and a lack of agreement on how to measure quality of care.[44] As a result, many in health care do not have access to performance data and consequently do not know what results they achieve (or fail to achieve). As consumers, payors, regulators, and accreditors increasingly require evidence regarding quality of care, the demand for quality measures will grow. To meet these demands, anesthesiologists must be prepared to use valid measures to evaluate the quality of care that they provide and to implement evidence-based best practices in the perioperative care of patients.

## Acknowledgments

The editors and the publisher would like to acknowledge Dr. Elizabeth Martinez (b. 1966–d. 2013) for her contributions to previous editions of this chapter. Her work served as the foundation for the current chapter.

This chapter greatly benefited from the thoughtful editing of Claire Levine.

**Complete references available online at expertconsult.com.**

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# 6 Avoiding Patient Harm in Anesthesia: Human Performance and Patient Safety

STEPHANIE MARIA OBERFRANK, MARCUS RALL, PETER DIECKMANN, MICHAELA KOLBE, and DAVID M. GABA

**KEY POINTS**

- Excellent clinical performance is not achieved by the use of sound medical knowledge alone, as clinicians have to face multifaceted challenges not just medical issues. There is an increased awareness that human factors—both on the individual and the team level—as well as organizational factors in the health care system play major roles in providing excellent medical care. Therefore, for anesthesia professionals (1) the study of human performance is fundamental, (2) the knowledge and successful application of efficient safety strategies are highly relevant, and (3) understanding of the pertinent organizational matters is very important.
- The health care system in general, individual clinical institutions, and work units in particular must provide the appropriate organizational characteristics to facilitate safe patient care including: promoting a culture of safety, effective incident reporting and analysis systems, continuous training for professionals, and optimized structures and processes.
- Organizations that provide such characteristics are referred to as high-reliability organizations (HRO). HRO theory describes the key features of systems that conduct complex and hazardous work, but do so with extremely low failure rates and complications. The credo of HROs is not to erase all errors but rather to identify human error mechanisms and make systems more impervious to errors and their sequelae (resilience).
- Several mechanisms of optimal versus poor performance have been demonstrated through human performance research. A particular technique of human performance research called task analysis has been useful in understanding the work of anesthesia professionals. Observing them during routine operations or in the handling of (simulated) adverse events has improved our knowledge on human performance. The findings include the impact of critical and continuous situation awareness and decision making (i.e., core cognitive process model), effective teamwork, leadership, and communication, as well as task management and the use of cognitive aids (e.g., checklists or emergency manuals).
- Organizations and individuals need to fully recognize that the performance of individual anesthesia professionals can—as for all human beings—be adversely influenced by performance-shaping factors, including noise, illness, aging, boredom, distraction, sleep deprivation, and fatigue, as well as by social dynamics within and between crews and teams.
- It is necessary to have a clear understanding of known human performance pitfalls such as fixation errors, ineffective team communication, misunderstandings, medication errors, unclear task management, and erroneous assumptions. While anesthesia professionals' knowledge and skill are key strengths needed for safe patient care, addressing the limitations will help them to actively avoid or mitigate the risk of adverse events.
- One approach to understanding and intervening in human performance issues for anesthesia care, especially focused on challenging situations, is that of crisis resource management (CRM). CRM (as in "cockpit [then crew] resource management") was developed in aviation first but then adapted to health care, initially for anesthesia care, in the early 1990s. There are many formulations of CRM but they typically highlight situation awareness, dynamic decision making, task management, communication, and teamwork. The introduction of CRM in anesthesiology and its spread into many other health care disciplines and domains have typically been associated with the use of realistic simulation-based training of anesthesia professionals in single-discipline or combined team training. It also has helped focus attention on systems' issues that relate to key aspects of human performance highlighted in CRM-oriented training.

- "First do no harm": Every avoidable harm or death to a patient is one tragic event too many. Anesthesia professionals must strive to avoid all harm that they may potentially impose, knowingly or not, on patients. Future progress on patient safety and human performance in anesthesia will require interdisciplinary research and training, improvements in systems thinking and systems safety, organizational learning, and the involvement of all levels of the health care industry.

## What this Chapter is About: An Overview

This chapter provides the reader with an overview of key human performance and safety issues concerning anesthesiology and demonstrates the relevance of those topics to the clinical performance of anesthesia professionals. Applying the knowledge of this chapter to patient care can help to avoid unnecessary harm to patients and also prevent psychological harm to the anesthesia professional (as the "second victim"). Hence, this chapter is not only about patient safety, but also about the anesthesia professional's safety and well-being as care provider. The authors provide a set of practical safety concepts and strategies to guide the reader in improving or refreshing case management-related skills and to sensitize the reader to safety-related core issues and competencies in anesthesia.

Because most of the work on human performance has focused on anesthesiology in the operating room (OR), this chapter deals primarily with aspects of performance and safety in that setting. Nevertheless, most of the same principles and issues are relevant to other perioperative settings, to critical care, and to a lesser degree, in pain medicine. They will also largely apply to emergency medicine and other health care domains sharing similar cognitive profiles. For readers with a special interest in intensive care, a selection of references is given as a starting point.[1-8]

The chapter contains references ranging from several decades old to quite recent. The authors have tried to balance retention of classic references, where the intellectual content has only changed slightly over the years, with the introduction of current literature that reflects changes in thinking or evidence, or newer syntheses of knowledge and experience.

In this chapter, the authors use "anesthesia professional" to refer to any anesthesia clinician taking care of a patient, whether a physician, certified registered nurse anesthetist (CRNA), or anesthesia assistant (or to similar positions in other countries).

### READERS WILL LEARN

- … safety relevant aspects of a dynamic and complex work environment and the resulting consequences for clinicians. Several sections highlight the nature of anesthesia as a highly complex and dynamic working environment and the difficulties that arise for human performance and patient safety.
- … characteristics and risks of different tasks performed by anesthesia professionals and countermeasures to mitigate their potential risks.
- … the issues of human performance, human limitations, and various relevant safety strategies that address them for both individuals and teams.
- … aspects of system safety concerning high-reliability organizations (HROs).

### WHAT THIS CHAPTER IS NOT ABOUT

The literature related to human performance and patient safety is vast. Standard reference works are available[9-14] as well as several Internet sources (Appendix 6.1). This chapter samples only a portion of this literature as it most closely relates to the work of anesthesia professionals. This chapter does not address in detail human-machine interactions and the physical design of the work environment. These aspects of human factors, or ergonomics, in anesthesiology are important in their own right. The reader is referred to several publications that review these issues in detail.[15-20] Also not part of this chapter are most issues of infection control and medication safety, even as they pertain to the perioperative arena. Here, too, the reader is referred to several publications that review these issues in detail[21-36] and also to other chapters in this book.

## Human Performance and Patient Safety in Anesthesia: Why is this Important?

Even though provision of anesthesia has become a "safe" discipline over the last decades through many scientific and technical improvements, anesthesia per se is an intrinsically hazardous undertaking. Many aspects of anesthetic drugs and care can affect vital human functions and are potentially lethal while they are not therapeutic in themselves. Evolution did not intend for human beings to be rendered temporarily insensitive to pain, unconscious, amnestic, and in many cases paralyzed. The surgical procedure itself may cause or trigger a variety of physiologic derangements and some patients needing anesthesia are already severely ill. Thus, in anesthesiology a stable situation can turn into a life-threatening situation in seconds, minutes, or hours, whereas in many arenas of health care changes happen in days, months, or years.

**Medical and technical skills alone are not sufficient for excellent medical care.** Historically, an adequately trained anesthesia professional was automatically assumed to always perform appropriately. Deviations from optimal outcomes were understood to result from imperfections in the art and science of anesthesiology. This perception led to heavy emphasis on the scientific and technical aspects of anesthesia training and care. Adverse outcomes were mostly ascribed to unavoidable side effects of a medication, underlying patient disease, negligence, or incompetence on the part of the anesthesia professional.

Interestingly, research shows that the etiology of most adverse events is generally not related to intrinsic problems associated with equipment, drugs, or diseases, but rather that 80% of the avoidable events are caused by so-called human factors (HF)—similar to the statistics emanating from the aviation industry. For instance, a review of critical anesthesia incidents by Cooper and associates revealed that human factors were contributory in 82% of the 359 incidents reported.[37] These incidents ranged from simple equipment malfunction in some cases, to death in others, indicating the seriousness and importance of the problems. Data from an earlier evaluation of 2000 incident reports support these findings with 83% of incidents occurring due to human error.[38] The term HF describes the physical and psychological behavior of humans in relation to specific environments, jobs, organizational patterns, machines, products, and individual challenges.

The performance of human beings is incredibly flexible, powerful, and robust in some aspects but limited and vulnerable in others. Today we have a more complete understanding of the human performance of anesthesia professionals than existed decades ago. For example, we know that the successful conduct of an anesthetic depends on having the requisite technical skills and relevant pathophysiologic knowledge. But it has also become clear that the effective real-time implementation of such expertise to a large extent depends on several nonmedical and nontechnical elements of performance. Among HF issues are those that are termed human performance-shaping factors like fatigue, boredom, and distraction.

**Human factor-related safety strategies for the individual and the team are indispensable.** Lapses, mistakes, and errors have the potential to harm a patient ("first victim"), but can also harm professionals themselves ("second victim"). Professionals suffer as second victims largely from the perceived guilt about an error that led to actual harm.[39] The clinical institution involved may also suffer financially or in reputation from such events, although often the occurrence of these events are not known to the public, and unlike in other industries (e.g., aviation, chemical manufacturing) there is no direct harm to the physical means of production. Nonetheless, the best way to avoid harm to the professional or the organization is to prevent adverse events or mitigate harm to patients.

**Organizational safety attitudes are essential to support high individual human performance.** More attention should be devoted to training anesthesia professionals in human performance issues so that they can develop and apply core competencies for achieving human performance on a daily basis. Moreover, departmental and organizational leadership must understand the enormous impact their attitudes and behavior have in shaping human performance, safety culture, outcomes, and ultimately (in all likelihood), the level of patient safety.

**Even in anesthesiology, still a long way to go.** Historically, anesthesiology was the first medical specialty to specifically focus on the promotion of patient safety. As a consequence, anesthesiology is widely recognized as the pioneering leader in patient safety efforts. Compared to other medical disciplines, the track record of anesthesiology is indeed a model of patient safety for the rest of health care.[40] However, safety science teaches us that patient safety and quality improvement are never-ending processes and complacency is dangerous. In addition, the increasing "production pressure" in anesthesia practice from expanding clinical demands in the face of constant or diminishing resources may threaten previously won gains. Any patient harmed by an anesthetic is one patient too many. This approach is aligned with the zero vision statement of the U.S. Anesthesia Patient Safety Foundation (APSF): *"That no one shall be harmed by anesthesia care."* In this regard Cooper and Gaba wrote that anesthesia professionals "… should remain aware of the hazards they still face, take pride in having been the leaders in patient safety efforts, and stay motivated to continue the pursuit of 'no harm from anesthesia' with the passion it still demands" (p. 1336).[40]

**Saving hearts, brains, and lives.** Several recently published studies demonstrate the benefits of implementing various patient safety strategies.[5,41-44] The authors have experienced the benefit of a more safety- and human performance-focused approach in their own work, as have their colleagues who also work in this field or in other fields that are endeavoring to create a safer health care system. Although it may be challenging to produce undisputable evidence that patient outcomes are improved by addressing the issues and implementing the strategies presented in this chapter, there is strong reason and ongoing research to support the belief that hearts, brains, and lives have indeed been saved by applying them. That belief is reward enough for the efforts of the authors as they share with the reader what is known about human performance and patient safety.

## Nature of the Anesthesia Professional's Operational Domain: A Dynamic and Complex Environment

The practice of anesthesiology can be characterized as a dynamic and complex environment that presents the anesthesia professional with challenges that may jeopardize human performance and patient safety.

To better understand these patient safety challenges that are related to human performance, the authors first describe the key characteristics of anesthesia work. In what follows they address (1) critical factors that categorize anesthesiology as a complex and dynamic working environment; (2) the safety challenge of inherent asymmetry between safety and production, and the effects of production pressure; and (3) the safety challenge of complexity and tight coupling in the anesthesia domain.

### ANESTHESIOLOGY BY ITS NATURE INVOLVES CRISES

What makes anesthesiology and a few other medical domains (such as intensive care medicine, emergency medicine, obstetrics, neonatology, and surgery, to name a few) different from most other medical fields? The answer is that the clinical environment of anesthesiology is both complex and dynamic which, when combined with the inherent risks of surgery and anesthesia, makes crisis situations frequent and challenging to deal with. These moments of terror necessitate that anesthesia professionals be expert in crisis management.

## CRITERIA DEFINING A COMPLEX AND DYNAMIC WORLD

Based on the work of Orasanu and colleagues,[45] the following text describes some of the characteristics of anesthesia that make it a complex and dynamic world.

1. **Ill-structured problems.** In contrast to well-structured problems, the nature and the goal of ill-structured problems are often vague or unclear, and many problem elements remain unknown or ambiguous. In anesthesiology, the patient's physiologic behavior is not an independent random variable but is causally linked to previous decisions and actions. There often is not just a single problem with a single decision to be made, but rather a variety of interrelated problems. Interdependent decisions must be made and actions taken by the anesthesia professional, surgeon, and other perioperative personnel.
2. **Uncertain system.** The patient is the main "system" of immediate interest to the anesthesia professional, just as the aircraft is of immediate interest to the pilot.[46] Patients are intrinsically very complex, and they contain many components with underlying functions that are imperfectly understood. The medical world knows very little about the underlying causes of specific physiologic events, although the general principles involved can be described. Unlike industrial or aviation systems, patients are not designed, built, or tested by humans, nor do they come with an operator's manual. The true state of the patient cannot usually be measured directly. It must be inferred from ambiguous patterns of clinical observations and data from electronic monitors. These data are imperfect because, unlike industrial systems that are designed and built with sensors in key areas to measure the most important variables, patients are typically instrumented to measure the variables that are easiest to monitor, predominantly with the use of noninvasive methods. Most physiologic functions are observed indirectly through weak signals available at the body surface that are prone to various types of electrical and mechanical interference. Invasive measurements are also vulnerable to artifacts and uncertainties of interpretation. Even if the anesthesia professional knew the exact state of the patient, the patient's response to interventions would be unpredictable, as normal patients show genetic or acquired differences in reflex sensitivity, pharmacokinetics, or pharmacodynamics that can yield a wide range of responses to a given dose of a drug or to a routine action (e.g., laryngoscopy). In diseased or traumatized patients, or in the presence of acute abnormalities, these responses may be markedly abnormal, and patients may overreact or underreact to otherwise appropriate actions. Thus, the patient as a system has substantially greater uncertainty than do engineered systems.
3. **Dynamic environment.** Dynamism stems from the frequency of routine and anomalous changes or events, the rapidity with which they evolve, and the unpredictability of the patient's physiology and response to interventions. An anesthetized patient is in a constant state of change during surgery, with many events outside the anesthesia professional's control, such as when the surgeon inadvertently transects a major vessel or when a patient with a previously unknown allergy suffers anaphylaxis. Although preventive measures can reduce the likelihood of some events, other events cannot be totally avoided because they are inevitable side effects of medically necessary procedures (e.g., surgical blood loss). Unpredictable and dynamic occurrences compete with the preplanned aspects of the case and together they drive the anesthesia professional's actions.
4. **Time stress.** Because the OR is a scarce resource, an incessant overall time pressure exists to use the OR efficiently (see section "Production Pressure"). Surgeons or OR managers pressing to start a case may affect the anesthesia professional's decisions and actions that could jeopardize safety standards. Over the long run this can cause a systematic "normalization of deviance" [47-50] (see section "Normalization of Deviance and Flirting with the Margin"), meaning the emergence of new, less stringent standard behaviors that are seen as normal judgments that previously would have been viewed as aberrant. An even more intense time stress occurs within a case when dynamic situations evolve rapidly and become time critical.
5. **Shifting, ill-defined, or competing goals.** Multiple goals of case management may compete with each other. (e.g., hemodynamic stability vs. good operating conditions for the surgeon vs. rapid emergence from anesthesia). The OR manager's administrative goals (high throughput, low cost) may sometimes compete with those of the anesthesia professional. All these goals shift as the patient's situation changes dynamically throughout a procedure and the flow of cases changes throughout the work day. For example, decisions on surgical operation planning are heavily influenced and manipulated by micropolitics and power, as investigated by Engelmann and colleagues.[51] Nurok and colleagues[52] portray this aspect in their survey: *"Are surgeons and anesthesiologists lying to each other or gaming the system?"*
6. **Short action feedback loops.** The time constants of actions and their effects are very short, on the order of seconds to minutes. Complete intermixing of decision making and action occurs; these functions are not performed in separate cycles. Most decisions and actions are implemented incrementally, constantly evaluating the relative success or failure of actions-to-date to determine how best to proceed. Anesthesia professionals often do not jump to conclusions or implement a whole set of actions all at once but try one or two approaches and see how they work, constantly reassessing rather than jumping ahead too far at once.
7. **High stakes.** The decisions and actions taken by anesthesia professionals can determine the outcome for the patient. The stakes are high because even for elective surgery in healthy patients, the risk of catastrophe is ever-present. Death, brain damage, or other permanent injury may be the end result of many pathways that can begin with seemingly innocuous triggering events. Each intervention, even if appropriate, is associated with side effects, some of which are themselves serious. Some risks cannot be anticipated or avoided. Unlike an event such as a commercial flight, which can be delayed or aborted if a problem occurs or if the weather is bad, these options are not always possible in health care. Sometimes immediate surgery (and anesthesia) may be necessary to treat

a medical problem that is itself life threatening. Balancing the risks of anesthesia and surgery against the risk of the patient's underlying diseases can be extremely difficult.

8. **Multiple players.** Perioperative domains involve multiple players from different professional backgrounds. Each profession has its own characteristics. On the one hand, surgeons, anesthesia professionals and OR nurses all want safety and a good outcome for the patient. On the other hand, each discipline and profession has other inherent goals. For example, surgeons may usually seem eager to perform the surgery and may seem to be more willing to take risks and to view the probability of a good outcome with optimism. In contrast, anesthesiologists may tend to be rather risk averse. Also, for a variety of reasons, it seems that surgeons tend to put production pressure on anesthesia professionals and nurses more than the other way around. The idiosyncrasies of interaction among various individual OR team members sometimes dominate the work environment. The OR sometimes offers a unique team structure of action teams, where the members may vary greatly from one day to the next (see later section "Teamwork"). Furthermore, there is a certain individual variation in the performance of each member; on any given day even usually "good" people may not be at their best.
9. **Organizational goals and norms.** The anesthesia professional works within the formal and informal norms of the OR suite, the anesthesia department, the institution, and the professional culture as a whole. Sometimes anesthesia professionals feel pressured to make decisions that they do not believe are best for the patient in order to comply with these norms. Therefore, it is important to face human performance and patient safety pitfalls not only on the individual and team level, but also on a larger departmental and organizational level (see later section "Patient Safety on the Organizational Level: Issues and Strategies").

Although some of these aforementioned characteristics apply to other domains of medicine, anesthesiology is unique in that many of the characteristics are prominent. In particular, what sets anesthesia apart from clinic-based or ward-based medicine is the intensity of the dynamics, time pressure, uncertainty, and extreme variation within the complexity, with danger lurking just below the surface, as well as the unique team constellation of so-called action teams (see section "Human Factors on the Team Level").

**Other factors influencing complexity in anesthesia: device variety and tight coupling.** The complexity in anesthesia also stems from the variety of devices in use and their interconnections. The challenge is that the equipment often consists of a proliferation of independent devices with multiple, nonstandardized interconnections. Devices seem often to be designed by engineers in isolation. As a consequence, interactions between devices, or among the equipment, the patient, and the human operator, may not be adequately addressed in the design phase.

Furthermore, complexity in anesthesia derives from complex interactions which are highly interdependent (tightly coupled). Coupling describes the notion of relations between parts of a system, which either can be tightly or loosely coupled.[46] Because many body systems affect each other, the patient is a major site of tight coupling. The anesthetic state tends to erode the protective and compensatory physiologic buffers among some of these interconnected systems, thereby forcing the patient's system to become even more connected and strengthening the coupling between them and between the patient and external technologic supports (e.g., ventilator or infusions of hemodynamically active drugs).

## PRODUCTION PRESSURE RESULTING IN ASYMMETRY BETWEEN SAFETY AND PRODUCTION

The current trend of increasing production pressure in perioperative care can further strain the working conditions in this demanding work environment.[53] Social and organizational environments may act as a source of production pressure on anesthesia professionals.

**Safety attitudes compete against economic thinking.** Production pressure encompasses the economic and social pressures placed on workers to consider production, not safety, their primary priority.[54] In anesthesiology, this typically means starting cases early, keeping the OR schedule moving speedily, with few cancellations and minimum time between cases. In principle, safety and efficiency can go hand in hand. Many aspects of high reliability, such as standard operating procedures, preprocedure briefings, and flattening the hierarchy, may smooth operation of the system, as well as make it safer. However, the pressure for throughput as well as the wish to please the surgeon or the OR manager, or the attempt to make up time by skipping essential procedures can erode safety and lead to a normalization of deviance (the new normal, see sections "Normalization of Deviance" and & "Flirting with the Margin").[55] For example, when anesthesia professionals succumb to production pressures, they may skip appropriate preoperative evaluation and planning, or they may not perform adequate pre-use checkout of equipment. Even when preoperative evaluation does take place, overt or covert pressure from surgeons (or others) can cause anesthesia professionals to proceed with elective cases despite the existence of serious or uncontrolled medical problems.

**Production pressure as a trigger to depart inappropriately from standard operating procedures and standards.** Production pressure can cause anesthesia professionals to choose techniques that they would otherwise believe to be inadvisable. Gaba and associates reported on a survey of a large random sample of California anesthesiologists concerning their experience with production pressure.[56] A nontrivial minority of respondents (20% to 40%) reported meaningful levels of pressure to conform to such pressures, to make decisions against their judgment of optimal safety, and to risk economic consequences if they act as they see appropriate. Generally, the pressures were already internalized after prior unpleasant experiences rather than stemming from blatant external attacks. Although there are anecdotal reports of increasing production pressure, as well as organizational practices that increase it (e.g., scheduling elective cases to start late at night or after midnight without separate shifts of anesthesia professionals), there has been no comparable repeated survey of such pressures in recent years. Fully investigating these aspects of the work environment is difficult because such relationships are driven by economic considerations, as well as by the complex organizational and interpersonal networks linking the different medical cultures. Changing the environment will be equally challenging and calls for organizational action (see section "Patient Safety Strategies on the Individual and Team Level: Crisis Resource Management [CRM] and Other Training Curricula").[57]

**The efficiency-thoroughness trade-off (ETTO).** Given the limited resources in the health care system, professionals constantly need to prioritize and make trade-offs, the most common being the efficiency-thoroughness trade-off (ETTO) described in detail by Eric Hollnagel in his book *The ETTO Principle: Efficiency-Thoroughness Trade-Off: Why Things that Go Right Sometimes Go Wrong*.[58] One example of a tradeoff is reducing the amount of information sought about individual preoperative patients in order to more efficiently process large numbers of them. Since it rarely is possible to be both effective and thorough at the same time, the balance of the trade-off can get into an unnoticed disequilibrium threatening human performance and patient safety.

**Inherent imbalance between signals of safety and signals of production.** One of the challenges in achieving optimal safety is the asymmetry of the signals of safety and the signals of production[59]: (1) Investments for production are easy to plan for and measure. Feedback about production is easy to obtain (revenue, earnings, expenses) and to interpret (success, no success). Success is indicated positively (more production, more earnings) and reinforcing. The relationship between the application of resources (money, effort, time) and production goals is relatively certain. (2) On the contrary, investments for safety are more difficult to plan for and the costs and benefits can only be measured indirectly and without continuity, making them difficult to interpret or even deceptive. Feedback about safety is inherently weak and ambiguous. Success is less reinforcing because if indicated negatively (fewer accidents or incidents)—how can one measure the accidents that could have occurred but did not? The relationship between the application of resources (money, effort, time) and safety goals is equally uncertain. There have been many occasions when only after a catastrophe takes place are the signals concerning a safety hazard understood, and often there is evidence that some personnel did recognize the hazards but either did not sufficiently press the issue or else they were systematically ignored or repressed.

# Nature of the Anesthesia Professional's Work: Task Variation and Workload Management

As previously described, the operational domain of anesthesia can be considered as a complex and dynamic world, managing different challenges with uncertain systems, competing goals, time pressure, and multiple players with special team constellations. All of these can affect human performance and patient safety. There also exist the challenges of the different specific tasks of conducting an anesthetic, whether manual (i.e., insertion of cannula, intubation), behavioral (i.e., leadership behaviors, communication patterns), or cognitive (i.e., attention, preparedness, dynamic decision making). Safe and efficient performance requires both medical and non-medical skills.[11,60]

Human failure or equipment failure can have disastrous consequences. Errors in cognitive tasks as well as cognitive biases are common in anesthesiology and pose a threat to patient safety.[61,62] In the following section the authors provide insights into the nature of the anesthesiaology professional's many tasks and their various vulnerabilities. This is important not only for individual and team improvements but also for improvements concerning clinical education, training, organizational structures, and equipment design. The focus of the upcoming section is on manual and cognitive tasks. The behavioral non-medical are discussed later (see section "Patient Safety on the Individal and Team Level").

This section briefly highlights the different phases of an anesthetic regimen and summarizes findings of task analysis and task performance studies, provides facts about the anesthesia machine checkout protocol as a safety relevant task, and introduces nonobservable cognitive tasks of administering anesthesia, in particular dynamic decision making. In addition, this section provides an introduction to workload measurement methodologies, gives study results concerning the performance of anesthesia professionals summarizes the benefits and obstacles of human performance measures, and highlights results from task analysis studies.

## PROCEDURAL TASKS OF ANESTHESIA PROFESSIONALS AND RELATED VULNERABILITIES

Multiple task analysis studies have investigated what actions and thought processes an anesthesiologist is required to perform to achieve good anesthetic care. Since the 1970s, numerous studies have been done either by direct observation during real cases[63-67] or by indirect observation during cases captured on videotape.[64,68-74] In addition, an increasing number of studies have been performed in realistic simulation environments.[8,64,75-79] Of note, many of the studies cited are pioneering ones that remain valid today.

The early studies of the work of anesthesiologists drew attention to the wide spectrum of tasks in the trajectory of perioperative care. They highlighted that many tasks must be done in close parallel with others (approximating multitasking, see section Task Management), showing not only the different tasks and their substeps that can be prone to error, but also different phases of task intensity during an anesthetic. Subsequent task analysis studies focused on the workload and the performance of the anesthesiologist, at a later time expanding to performance measures based on teamwork,[80-82] communication,[83] and leadership.[82,84,85] More recently, task analysis studies have been performed with respect to ergonomic equipment design questions. Certain very complex issues concerning human-machine interactions and the ways in which technology affects behavior in complex patient-care environments are beyond the scope of this chapter; however a number of publications address these issues.[16,86,87]

The different phases for an anesthetic regimen are commonly classified into (1) preoperative planning, (2) induction, (3) maintenance of, and (4) emergence from anesthesia. [63] Every phase is characterized by manual and cognitive tasks, each of which consists of further subordinated steps and each of which presents with a variable density of tasks and human error pitfalls. For a comprehensive review, the reader is directed to the publication of Phipps and colleagues [63] for detailed information.

## Preoperative Planning

The anesthesia professional needs to be prepared for active intervention during the whole anesthetic regimen. Part of this preparedness involves obtaining the necessary equipment and supplies, preparing medications, and conducting pre-use checkouts of life-support equipment and the anesthesia machine before induction (See section "Pre-use Checkout of Equipment/Anesthesia Machine Checkout").

However, with 44 task steps as identified in the task analysis study by Phipps and associates, the equipment check is a lengthy and detailed process, and it is possible that steps may be omitted, either intentionally or unintentionally.

## Induction

Task analysis studies demonstrated increased anesthesiologist workload during induction, emergence, and emergency surgery.[63,67,88-94] Phipps and associates identified 73 task steps between the preparation of drugs and transferring the anesthetized patient to the operating room (induction phase), including cognitive and communicative tasks, machine checkouts, as well as a considerable number of manual task steps, such as the insertion of the cannula and airway devices. Pape and Dingman examined the number of unrelated distractions during the induction process (i.e., unrelated questions of other personnel, OR doors opening and closing, noise, answering incoming telephone calls, unrelated communication), discovering an average of 7.5 total interruptions per 9 minutes.[95] They argued that interruptions and distractions can lead to loss of focus and result in errors, and requested further research to determine whether silence during induction is needed as a safety measure. Another study concluded that on average during cases one distractive event occurs every 4 minutes 23 seconds, with approximately 3.4 distractions during induction and 3.0 distractions when moving from the induction room to the OR.[96] In this study while most distracting events had no negative consequences for the patient, 22% had negative consequences (suboptimal management). Interestingly 3% were actually not distractions because they had positive consequences for the patient. In another study, 20% of visual attention during induction was directed to the patient monitor, increasing up to 30% during simulated critical incident induction scenarios.[97] During the observation of real cases, yet another study group found that drug/fluid tasks comprised 20 ± 6% of induction, 15 ± 8% of maintenance, and 12 ± 7% of emergence during routine cases.[91]

## Maintenance Phase of Anesthesia

Betza and colleagues found in an observational study that anesthesia providers spent 71% of their time during maintenance doing patient or display monitoring tasks.[98] Transitions between the task categories occurred approximately once every 9 seconds. It appeared that regardless of the task, there was a high frequency of task transitions to look at the visual displays and then from the visual displays toward the patient. Compared with the induction phase, there are fewer (16) task steps during the maintenance phase. [63] However, there is evidence that a relatively high proportion of critical incidents occur during the maintenance phase (59% of incidents during maintenance, 26% during induction).[37] Patients' conditions may vary in an overt or subtle way. Therefore, anesthesia professionals need to continuously monitor several parameters. Their attention may be distracted or misbalanced, as not all parameters need the same level of attention all the time. Sometimes other tasks, such as telephone calls, auscultation, insertion of an arterial cannula, use of transesophageal echocardiography (TEE), and "problem solving," may divert the attention of the anesthesia professional. As attention is a limited resource and susceptible to distractions, it is important to learn how to best allocate one's attention in continuously changing and complex environments like anesthesia (see later section, "Situation Awareness").

Very detailed task analyses took place in a series of studies carried out by the University of California, San Diego (UCSD), Stanford University, the San Diego and Stanford Veterans Administration Medical Centers.[66,67] Generally, studies of workload indicate that induction and, to a lesser degree, emergence are the most intensive. However, it is also argued that many of those tasks performed are part of a routine, which tends to reduce the effort required. Maintenance, in contrast, is typically less physically "action dense" but mental activity continues as a wide range of information is used and processed.[99]

## Emergence

With 40 task steps to carry out in a relatively short period of time, the discontinuation of anesthesia and subsequent transfer of the patient to recovery is fairly busy.[63] A study from Broom and associates suggests that emergence is the most distractive period compared with induction and maintenance, finding noise during emergence at 58 decibels (dB) (compared to induction at 46 dB and maintenance at 52 dB), with sudden loud noise (>70 dB) occurring more frequently during emergence than at induction or maintenance.[100] The range of staff entrances and exits were also highest during emergence (10), compared to induction (0) and maintenance (6). Conversations unrelated to the procedure occurred in 93% of emergences. Emergence also was found to be the period of most frequent distractions, occurring on average every 2 minutes.[96] Those findings are acknowledged by the following quotations retrieved from subjective study interviews:

*"I don't think people quite appreciate that emergence is as important as induction really and sometimes they're just glad to have finished off their case. They're crashing and banging and moving on and fail to realize." and "(…) [B]asically as far as they're concerned the job's finished. They're there moaning, yelling, or talking about the next case. I do find that distracting because I think: 'we haven't actually finished this case yet'." (p. 711)*[96]

**PATIENT SAFETY ACTION BOX**

The period of the patient's emergence from anesthesia is high risk and a high workload for the anesthesia professional while low stress for other OR personnel. Often they forget and the noise level may rise considerably. If so the anesthesia professional should politely demand thoughtfulness and quiet from the other OR team members. This would also be a possible setting to invoke the auditory "sterile cockpit" protocol (see later section "Distractions and Interruptions in the Operating Room").

## PRE-USE CHECKOUT OF EQUIPMENT/ ANESTHESIA MACHINE CHECKOUT

A pre-use check to ensure the correct functioning of anesthetic equipment is essential to patient safety. Failure to check anesthesia equipment prior to use can lead to patient injury or "near misses."[101,102] Based on a retrospective incident analysis of 668 reported incidents, Marcus reported a total of nearly 18% of in-theater incidents in pediatric anesthesia resulted from the failure to check.[102] More recent generations of anesthesia machines have internal computers that can conduct checks of many aspects of machine functioning and alert the anesthesia professional to problems. However, the authors have observed in simulations of embedded machine problems or external equipment faults (e.g., nitrous oxide vs. oxygen swap) that anesthesia professionals may lack a complete understanding of these systems.

In the United States an updated machine checklist was released by the American Society of Anesthesiologists (ASA) in 2008.[103] Because no specific checkout recommendation could be applicable to all modern anesthesia delivery systems and to all anesthetizing locations, the latest recommendation is based on a set of design guidelines for the pre-anesthetic checkout and provides samples of checkout procedures (available at: www.asahq.org/resources/clinical-information/2008-asa-recommendations-for-pre-anesthesia-checkout). The 2008 pre-use anesthesia apparatus checkout recommendation (AACR) contains a list of 15 separate items that should be checked at the beginning of each day (preoperative check) or whenever a machine is moved, serviced, or the vaporizers changed. Eight of these items should be checked prior to each procedure (preinduction check). Some of the steps may be already part of an automated manufacturer's checkout process in the anesthesia machine; others need to be performed individually. Feldman and associates state:

*"Following these checklists will typically require <5 minutes at the beginning of the day, and <2 minutes between cases, but will provide you with the confidence that the machine will be able to provide all essential life support functions before you begin a case." (p. 6)*[104]

In 2012, the Association of Anaesthetists of Great Britain and Ireland (AAGBI) released a new safety guideline on checking anesthesia equipment that also includes, but is not limited to, the pre-use checkout of the anesthetic machine (available at: https://www.aagbi.org/sites/default/files/checking_anaesthetic_equipment_2012.pdf).[105] Rather recently revised guidelines on pre-use checking of the anesthetic equipment including the anesthesia workstation have been published by the Australian and New Zealand College of Anaesthetists (ANZCA)[106] in 2014 and by the Canadian Anesthesiologists' Society (CAS)[107] in 2016.

**PATIENT SAFETY ACTION BOX**

There are numerous checkout checklists available. A serious patient safety issue is the non-adherence to standard protocols. The anesthetic checkout of equipment is a method of systematically ensuring the anesthetic professional executes a thorough check of the anesthetic equipment. All professionals should therefore use it as a standard practice for checking the anesthetic machine to provide the best and safest patient care. The implementation of a checklist is an organizational process that needs systematic implementation and, optimally, user training.

## COGNITIVE TASKS OF ADMINISTERING ANESTHESIA AND RELATED VULNERABILITIES

The observable tasks do not tell the whole story of what the anesthesia professional is doing. Even when the anesthesia professional appears idle, most of the time mental activity is ongoing. Several investigators have written about the cognitive elements in anesthesiology.[91,108-111] Of those errors made, cognitive errors and cognitive biases in anesthesiology are common and pose a threat to patient safety.[61,62,102] In the following section, (1) the cognitive tasks of dynamic decision making and situation awareness are described and summarized in the anesthesia professional's core cognitive process model; (2) subsequently, the management and coordination of the core cognitive process model are discussed in this section; and (3) several methodologies to measure cognitive workload are touched on.

### Introduction of the Anesthesia Professional's Core Cognitive Process Model

Besides the constant check whether anticipated milestones of the anesthetic regimen are achieved and the constant check of incoming data streams, the anesthesia professional must also react to a large number of contingencies, some of which can be predicted in advance based on the patient's history and the type of surgery, whereas others cannot. If so, the existing plan may have to be reactively modified.

Different aspects of decision making and situation awareness are summarized in the anesthesia professional's core cognitive process model. The model was developed by David Gaba and draws heavily on the work of a number of other investigators who studied human performance in a variety of complex, dynamic worlds.[91,112-114] It is described in detail as a framework for understanding the empiric data, and provides a vocabulary for discussing the elements of both successful and unsuccessful performance by anesthesia professionals.

The entire core process model, shown in Fig. 6.1, depicts the anesthesia professional as working at five different interacting cognitive levels (resource management level,

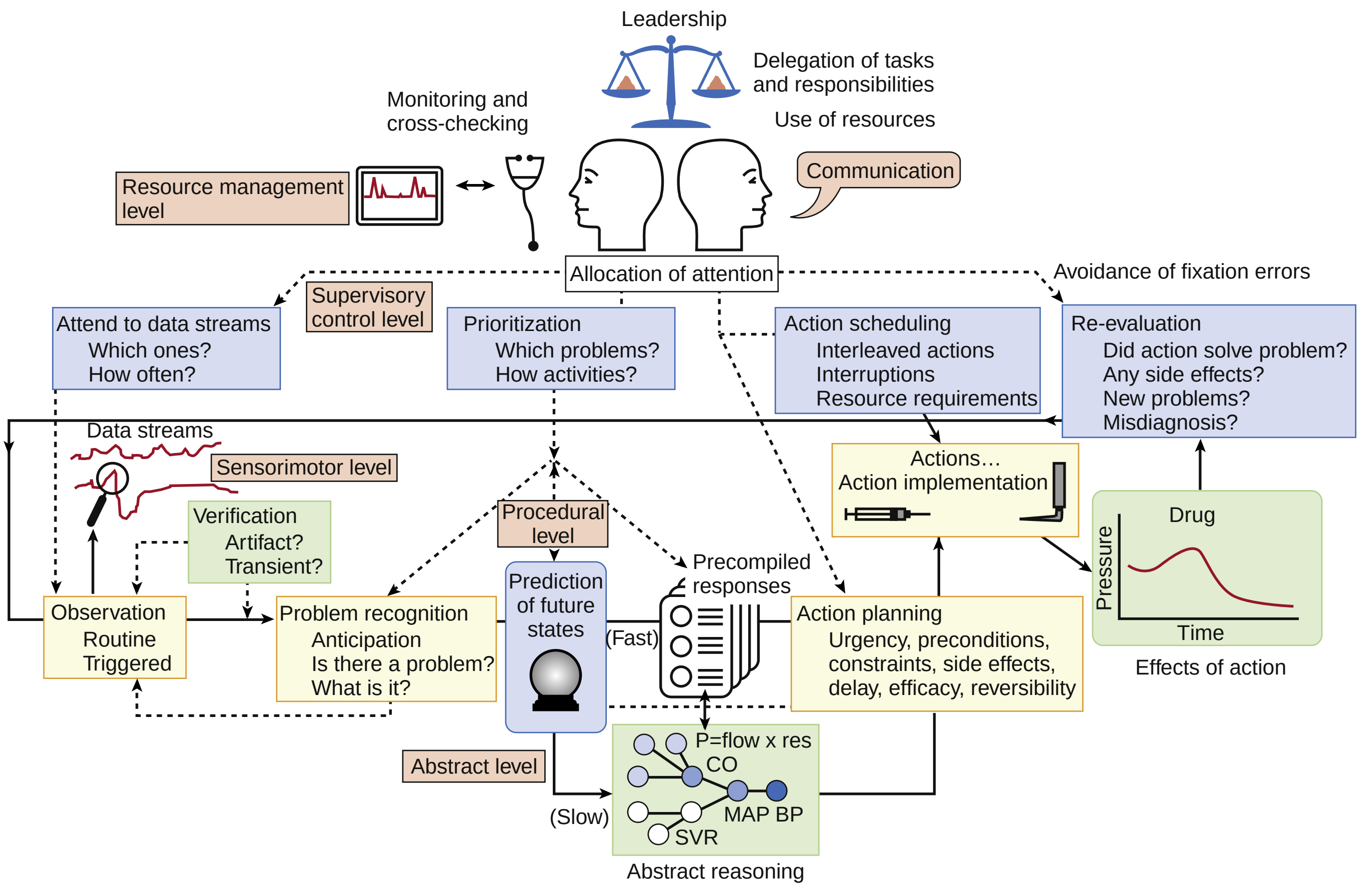


**Fig. 6.1 Core cognitive process model of the anesthetist's complex real-time problem-solving behavior** (see text for detailed description). Five levels of cognition operate in parallel. The core process involves a main loop (solid arrows) of observation, decision, action, and reevaluation. The core process is managed by two levels of metacognition that involve a second, higher-level loop (both above the core process): supervisor control (allocation of attention) and resource management. Each component of the model requires different cognitive skills. Each component is vulnerable to a different set of performance failures or errors. *BP*, Blood pressure; *CO*, cardiac output; *MAP*, mean arterial pressure; *SVR*, systematic vascular resistance. (From Gaba DM, Fish KJ, Howard SK. *Crisis Management in Anesthesiology*. New York: Churchill Livingstone; 1994.)

### BOX 6.1 Elements of the Core Cognitive Process of an Anesthesiologist

1. Observation
2. Verification
3. Problem recognition
4. Prediction of future states
5. Decision making
   a. Application of precompiled responses (recognition-primed decision making)
   b. Decision making using heuristics and probability
   c. Decision making including abstract reasoning
6. Action implementation
7. Reevaluation (avoiding fixation errors)
8. Start again with 1 (loop continues)

procedural level, communication level, abstract reasoning level, supervisory control level) to implement and control a core process of observation, verification, problem recognition, prediction of future states, decision making, action, and reevaluation (Box 6.1). The core process must then be integrated with the behavior of other team members and with the constraints of the work environment. Expert performance in anesthesia involves these features in a repeated loop of the different steps. Errors can occur at each step in this process.

The division of mental activities into levels follows the work of Rasmussen and Reason et al..[113,115] Having multiple levels supports the concepts of parallel processing (performing more than one task at a time but working on different levels of mental activity) and multitasking/multiplexing (performing only one task at a time but switching very rapidly from one task to another), as shown in several task analysis studies.[64,67,89] Table 6.1 gives an overview and a brief explanation of the different mental activity levels.

At the sensorimotor level, activities involving sensory perception or motor actions take place with minimal conscious control; they are smooth, practiced, and highly integrated patterns of behavior. At the procedural level, the anesthesia professional performs regular routines in a familiar work situation. These routines have been derived and internalized from training and from previous work episodes. A level of abstract reasoning is used during preoperative planning, and intraoperatively it is used in unfamiliar situations for which no well-practiced expertise or routine is available from previous encounters. Rasmussen's model[113] was extended by the explicit addition of two additional levels of mental activity—the supervisory and the resource management level—that provide for dynamic adaptation of the anesthesia professional's own thought processes. Supervisory control is concerned with dynamically allocating finite

**TABLE 6.1** Levels of Mental Activity

| Level of Control | Explanation | Comments |
|---|---|---|
| Resource management level | Command and control of all resources, including teamwork and communication | Incident analysis shows a huge contribution of lack of resource management and communication skills to the development of incidents and accidents; the importance of these factors is reflected in the ACRM principles and simulation training courses (see Chapter 7) |
| Supervisory control level | Metacognition: thinking about thinking | Dynamic adaptation of the thought process, decision making (e.g., avoiding fixation errors), scheduling, and remembering actions (e.g., prospective memory tasks) |
| Abstract reasoning level | Use of fundamental medical knowledge, search for high-level analogies, deductive reasoning | Often in parallel with other levels; in emergency situations often too slow and too sensitive to distractions in high-workload situations |
| Procedural level | Precompiled responses, following algorithms, heuristics, "reflexes" | Recognition-primed decision making—experts are more often on this level; special errors may occur as a result of not checking for the appropriateness of the "procedure"; less experienced personnel may misuse this level for ill-considered, unadapted "cookbook medicine" |
| Sensorimotor level | Use of all senses and manual actions; "feeling, doing, hearing"; sometimes subconscious control of actions | Experts perform smooth action sequences and control their actions by direct feedback from their senses (e.g., action sequences of placing an intravenous line or endotracheal intubation; skill-based errors such as slips and lapses may occur) |

*ACRM,* Anesthesia crisis resource management.

attention between routine and non-routine actions, among multiple problems or themes, and among the five cognitive levels. Attention is such a scarce resource, therefore its allocation is extremely important in every aspect of dynamic decision making. Resource management deals with the command and control of available resources, including teamwork and communication. Expert performance in anesthesia involves these features in a repeated loop. An overview of the core cognitive process and its elements is given in Box 6.1. The elements are explained in detail in the following text sections and include (1) observation; (2) verification; (3) problem recognition; (4) prediction of future states; (5) precompiled responses; (6) action taking/action implementation; and (7) reevaluation.

**Observation.** Anesthesia professionals use observations to decide whether the patient's course is on track or whether a problem is occurring; this is the first step of the decision making cycle. Data are observed and transformed by interpretation into information, followed by further interpretation into meaning. Data streams typically involve direct visual, auditory, or tactile contact with the patient, the surgical field, routine electronic monitoring, special (sometimes invasive) monitoring systems, contents of suction canisters and sponges, reading of reports of laboratory test results, and communications from other personnel. Loeb showed that anesthesiologists typically observe monitors for approximately 1 to 2 seconds every 10 to 20 seconds and that it usually took several observing cycles before they detected a subtle cue on the monitor.[88] Management of rapidly changing situations requires the anesthesia professional to assess a wide variety of information sources. Because the human mind can attend closely to only one or two items at a time, the anesthesia professional's supervisory control level must decide what information to attend to and how frequently to observe it (as later shown at CRM key point 14 "Allocate attention wisely"). Constant observation and interpretation of the different information systems is executed repeatedly throughout the course of an anesthetic regimen. The plethora of simultaneous data streams in even the most routine cases is a challenge. Vigilance, defined as the capacity to *sustain* attention, plays a crucial role in the observation and detection of problems and is a necessary prerequisite for meaningful care. Vigilance can be degraded by performance-shaping factors (see later section "Performance Shaping Factors") and it can be overwhelmed by the sheer amount of information and the rapidity with which it is changing.

**Verification.** In the working environment of an anesthesia professional, the available, observed information is not always reliable. Most monitoring is noninvasive and indirect and is susceptible to *artifacts* (false data). Even direct clinical observations such as vision or auscultation can be ambiguous. Brief *transients* (true data of short duration) can occur that quickly correct themselves. To prevent them from skewing the decision making process and triggering precipitous actions that may have significant side effects, critical observations must be verified before the clinician can act on them. This requires the use of all available data and information and cross-checking different related data streams rather than depending solely on any single datum without sensible interpretation (as later shown in CRM key point 8 "Use all available information" and CRM key point 10 "Cross check and double check; never assume anything"). Verification uses a variety of methods, shown in Table 6.2.

**PATIENT SAFETY ACTION BOX**

Try to be sensitive to changes and do not just explain them away as normal without double-checking or using other information to determine if everything really is okay. Assume there is a big problem unless you can prove otherwise. If in doubt, it should always be assumed that the patient is at risk and that the parameter in question is real (rule out the worst case). The burden of proof is on you. Beware of too easily assuming that it is just a technical artifact.

**TABLE 6.2** Methods for Verification of Critical Observations

| Method | Explanation and Example |
|---|---|
| Repeating | The observation or measurement is repeated to rule out a temporary wrong value (e.g., motion artifacts during noninvasive blood pressure measurement) |
| Checking trend information | The short-term trend is observed for plausibility of the actual value. Trends of physiologic parameters almost always follow curves, not steps |
| Observing a redundant channel | An existing redundant channel is checked (e.g., invasive arterial pressure and cuff pressure are redundant, or heart rate from an ECG and pulse oximeter) |
| Correlating | Multiple related (but not redundant) variables are correlated to determine the plausibility of the parameter in question (e.g., if the ECG monitor shows a flat line and "asystole" but the invasive blood pressure curve shows waves) |
| Activating a new monitoring device | A new monitoring modality is installed (e.g., placing a pulmonary artery catheter). This also adds another parameter for the method of "correlating" |
| Recalibrating an instrument or testing its function | The quality and reliability of a measurement are checked, and its function is tested (e.g., if the $CO_2$ detector shows no values, the anesthetist can exhale through it to see whether the device works). Observation of redundant channels can also help verify a value (see above) |
| Replacing an instrument | If doubt exists about the function of a device, an entirely new instrument or an alternative backup device may be installed |
| Asking for help | If the decision on the values remains unclear, help should be sought early to obtain a second opinion from other trained personnel |

*ECG*, Electrocardiogram.

**Problem Recognition.** Having recognized a problem, how does the expert anesthesia professional respond? The classical paradigm of decision making involves a careful comparison of the evidence with various causal hypotheses that could explain the problem. This is followed by a careful analysis of all possible actions and solutions. This approach, although powerful, is relatively slow and does not work well with ambiguous or scanty evidence. Many perioperative problems faced by anesthesia professionals require quick action under uncertainty[116,117] to prevent a rapid cascade to a catastrophic adverse outcome, and solution of these problems through formal deductive reasoning from first principles is just too slow. The process of problem recognition is a central feature of several theories of cognition in complex, dynamic worlds.[110,118,119] Problem recognition involves matching sets of environmental cues to patterns that are known to represent specific types of problems. Given the high uncertainty seen in anesthesia, the available information sources cannot always disclose the existence of a problem, and even if they do, they may not specify its identity or origin. Anesthesia professionals use approximation strategies to handle these ambiguous situations; psychologists term such strategies *heuristics*.[120] Stiegler and Tung give a detailed review of heuristics and other biases that affect problem recognition.[121] One heuristic is to categorize what is happening as one of several generic problems, each of which encompasses many different underlying conditions (similarity/pattern matching). Another is to gamble on a single diagnosis (frequency gambling[115]) by initially choosing the single most frequent candidate event. During preoperative planning, the anesthesia professional may adjust a mental "index of suspicion" for recognizing certain specific problems anticipated for that particular patient or surgical procedure. The anesthesia professional must also decide whether a single underlying diagnosis explains all the data or whether they could come from multiple causes. This decision is important because excessive attempts to refine the diagnosis can be very costly in terms of allocation of attention. By contrast, a premature diagnosis can lead to inadequate or erroneous treatment. The use of heuristics is typical of expert anesthesia professionals and often results in considerable time savings in dealing with problems. However, it is a double-edged sword. Both frequency gambling and inappropriate allocation of attention solely to expected problems can seriously undermine problem solving when these gambles do not pay off or are not corrected in the reevaluation process.

Many of the issues that are related to problem recognition and cognition in general are discussed in more detail in the section on decision making further below, especially when dealing with the models of System I thinking and System II thinking and of recognition-primed decision making.

**Prediction of Future States.** Problems must be assessed in terms of their significance for the future states of the patient.[110,118] Predicting future states based on the occurrence of seemingly trivial problems is a major part of the anticipatory behaviors that characterize expert crisis managers. Problems that are already critical or that can be predicted to evolve into critical incidents receive the highest priority (as later shown in CRM key point 15 "Set priorities dynamically"). Prediction of future states also influences action planning by defining the timeframe available for required actions. Cook and colleagues described *"going sour"* incidents in which the future state of the patient was not adequately taken into account when early manifestations of problems were apparent.[122] One of the challenges known from research in psychology is that the human mind is not very well suited to predict future states, when things are changing in a nonlinear fashion. Under such circumstances, which are common for natural systems such as the human body, the rate of change is almost invariably underestimated, and people are surprised at the outcome.[123]

**PATIENT SAFETY ACTION BOX**

Slow but steady and sustained blood loss in a child during surgery might result in few or subtle changes in hemodynamics for some time until rapid decompensation occurs. If the weak signs of the developing problem were not detected or misjudged the ensuing catastrophe may seem to have occurred suddenly. The use of a visible trend monitoring of heart rate or blood pressure over a longer period of time can help the anesthesia professional to be better aware of changes that are not readily apparent if only the last few measurements are compared.

**Precompiled Responses.** Once a critical event has been observed and verified the anesthesia professional needs to respond. In complex, dynamic domains, the initial responses of experts to the majority of events stem from *precompiled* rules or response plans for dealing with a recognized event.[115] This method is referred to as recognition-primed decision making,[114,124] because once the event is identified, the response is well known (see later section "Decision Making"). In the anesthesia domain, these responses are usually acquired through personal experience alone, although there is a growing realization that critical response protocols must be codified explicitly and taught systematically. Experienced anesthesia professionals have been observed to rearrange, recompile, and rehearse these responses mentally based on the patient's condition, the surgical procedure, and the problems to be expected.[125] Ideally, precompiled responses to common problems are retrieved appropriately and executed rapidly. When the exact nature of the problem is not apparent, a set of *generic* responses appropriate to the overall situation may be invoked. For example, if a problem with ventilation is detected, the anesthesia professional may switch to manual ventilation at a higher fraction of inspired oxygen ($FiO_2$) while considering further diagnostic actions. However, experiments involving simulation have demonstrated that even experienced anesthesia professionals show great variability in their use of response procedures to critical situations.[75,125-127] This finding led these investigators to target simulator-based training in the systematic training of responses to critical events.[108,128]

Even the ideal use of precompiled responses is destined to fail when the problem does not have the suspected cause or when it does not respond to the usual actions. Anesthesia cannot be administered purely by precompiled "cookbook" procedures. Abstract reasoning about the problem through the use of fundamental medical knowledge still takes place in parallel with precompiled responses, even when quick action must be taken. This seems to involve a search for high-level analogies[115] or true deductive reasoning using deep medical and technical knowledge and a thorough analysis of all possible solutions. Anesthesia professionals managing simulated crises have linked their precompiled actions to abstract medical concepts.[125]

**Taking Action/Action Implementation.** Anesthesiologists need to share their attention among different cognitive levels, among tasks, and often among problems. The intensive demands on the anesthesia professional's attention could easily swamp the available mental resources. Therefore, the anesthesia professional must strike a balance between acting quickly on every small perturbation (which requires a lot of attention) and adopting a more conservative "wait-and-see" attitude. This balance must be constantly shifted between these extremes as the situation changes. However, during simulated crisis situations, some practitioners showed great reluctance to switch from business as usual to emergency mode even when serious problems were detected. [75] Erring too far in the direction of wait and see is an error that can be particularly catastrophic. Preparedness for active intervention in case of dynamically changing events is a key element of an anesthesiologist's work. But how frequent is this requirement? According to the review of Wacker and Staender, adverse events in the perioperative period continue to be frequent, occur in about 30% of hospital admissions, and may be preventable in more than 50%.[129]

**PATIENT SAFETY ACTION BOX**

Once you are sure there is a big problem, it is important for the entire team to transition into emergency mode efficiently. One way of doing so is to declare the emergency out loud with appropriate force, such as: *"Ok, everybody, there's a very serious problem with the patient—probably anaphylaxis—this is a major emergency."*

At any time during an anesthetic regimen there may be multiple things to do, each of which is intrinsically appropriate, yet they cannot all be done at once. Simulation experiments have shown that anesthesia professionals sometimes have difficulty selecting, planning, and scheduling actions optimally. [75]

**PATIENT SAFETY ACTION BOX**

It helps if team members know the actions planned and the schedule of actions preferred (referred to as shared mental models). If the anesthesia professional does not provide the information, team members should check with the anesthesiologist. It also is helpful to distribute actions with clear communicated priorities and/or timeframes (CRM principle 7: "Effective Communication", e.g., *"[Name of receiver of message], prepare xxx first, then I need xxx, and after that bring me xxx,"* or *"After you have done xxx, let's start xxx together"*, or *"In 30 minutes, please check the blood gases/blood sugar level/ etc. again…"*)

A particular hallmark of anesthesiology is that the decision maker does not just decide what action is required but is often involved directly in the implementation of actions. Executing these actions requires substantial attention and may in fact impair the anesthesia professional's mental and physical ability to perform other activities (e.g., when an action requires a sterile procedure). This is particularly an issue when other tasks have been interrupted or temporarily suspended. *Prospective memory,*[130-134] one's ability to remember in the future to perform an action (i.e., to complete a task) can be easily disrupted. In addition, anesthesia professionals engaged in a manual procedure are strongly constrained from performing other manual tasks or from maintaining awareness of incoming information.

**Reevaluation.** In order to successfully solve dynamic problems and to cope with the rapid changes and profound diagnostic and therapeutic uncertainties seen during anesthesia, the core process must include repetitive reevaluation of the situation. Thus, the reevaluation step, initiated by the supervisory control level, returns the anesthesia professional to the observation phase, but with specific assessments in mind (see also CRM key point 12, "Reevaluate repeatedly"). Only by frequently reassessing the situation can the anesthesia professional adapt to dynamic processes, since the initial diagnosis and situation assessment can be incorrect. Even actions that are appropriate to the problem are not always successful.

BOX 6.2 **Reevaluation Questions—Maintaining Situation Awareness**

- Did the actions have any effect (e.g., did the drug reach the patient?)?
- Is the problem getting better, or is it getting worse?
- Are there any side effects resulting from previous actions?
- Are there any other problems or new problems that were missed before?
- Was the initial situation assessment/diagnosis correct?
- What further developments can be expected in the (near) future?

The process of continually updating the assessment of the situation and monitoring the efficacy of chosen actions is termed *situation awareness*.[118,119] Situation awareness is a very interesting and important topic in analyzing performance and reasons for errors[110,135,136] and is discussed in detail in a later section. Box 6.2 gives examples of reevaluation questions in order to maintain situation awareness.

Faulty reevaluation, inadequate adaptation of the plan, or loss of situation awareness can result in a type of human error termed *fixation error*.[137,138] Fixation errors have been described in responses of professionals to abnormal situations.[125,126,137-139] Avoiding and recognizing fixation errors in the field of anesthesia is covered more in detail in section "Introduction of the 15 Crisis Resource Management Key Principles."

### Management and Coordination of the Core Cognitive Process: Supervisory Control and Resource Management

Anesthesia professionals' abilities to adapt their own thinking (metacognition—thinking about thinking) through supervisory control and resource management are key components of dynamic decision making and therefore of crisis management.

**Supervisory Control.** The supervisory control allocates the scarce resource of attention during multitasking, and oversees and modulates the core process. For example, determining the frequency of observation of different data streams, prioritizing diagnostic and therapeutic alternatives, actively managing workload, prioritizing and scheduling actions. Supervisory control actively manages the workload by (1) avoiding high-workload situations by anticipation and planning, (2) distributing workload over time or (3) over personnel, (4) changing the nature of the task to reduce work, or (5) minimizing distraction. More details regarding the active management of workload are touched on in the later section on CRM key point 5 "Distribute the Workload."

**Resource Management.** The highest layer of metacognition and control is known as resource management—the ability to command and control all the resources at hand to care for the patient and to respond to problems. This involves translating the knowledge of what needs to be done into effective team activity by taking into account the limitations of the complex and often ill-structured perioperative domain. Resources include personnel, equipment, and supplies, both in the immediate vicinity and, when necessary, throughout the various levels of the organization. Resource management explicitly demands teamwork and crew coordination. It is not enough for the anesthesia professional to know what to do or even to be able to do each task alone. Only so much can be accomplished in a given time, and some tasks can be performed only by other skilled personnel (e.g., catheterization lab). A key responsibility of the anesthesia professional is to mobilize needed resources and to distribute the relevant goals and tasks among those available. The details of this critical function are described in the section on "Crisis Resource Management."

## ANESTHESIA PROFESSIONAL'S WORKLOAD AND METHODOLOGIES TO MEASURE IT

Most anesthesia professionals have significant other responsibilities in addition to the manual, cognitive, and behavioral duties described above, for example in administration, supervision, or teaching. Depending on the task, the task density, the individual's experience and skill, the patient's state, and the given circumstances (production pressure, staff availability, noise, light, space, team, etc.), the workload of the anesthesia professional can change at any time during an anesthetic regimen. Cognitive resources are diminished when the workload is heavy (i.e., during task dense phases like induction, emergence, or during an emergency), leading to lower levels of performance,[76,127] increased response time, [93] decreased vigilance,[90,92] and greater risk of errors.

The concept of workload is tricky to define. Hart and Staveland[140] describe it as follows: *"Workload is not an inherent property, but rather emerges from the interaction between the requirements of a task, the circumstances under which it is performed, and the skills, behaviors, and perceptions of the operator"* (p. 140). Psychology literature suggests that emotions during highly demanding activities impair cognitive processing efficiency.[141] Task analysis studies as described earlier and task (action) density studies (see later) give insights into several aspects of workload, especially facilitating workload measurements by identifying the individual work components or subtasks to be measured. However, those kind of studies do not necessarily give insight into the performance shaping aspects of workload.

Methods to measure workload include task performance via observation, subjective assessments, and physiological measures. They are described below. For a more comprehensive review, see, for example, Leedal and Smith, [142] and Byrne.[143]

**Primary Task Performance.** The primary task performance measure assesses the subject's performance on standard work tasks (e.g., cases seen, knots tied, etc.) as they are made progressively more difficult by increasing the number of tasks, task density, or task complexity. At first, the subject is able to keep up with the increasing task load, but at some point, the workload exceeds the ability to manage it, and performance on the standard tasks decreases.

**Secondary Task Probing.** Secondary task probing tests the subject with a minimally intrusive secondary task that is added to the primary work tasks. The secondary task is a simple one for which performance can be objectively measured. Reaction time, finger tapping, mental arithmetic and a vibrotactile device have for example been used for this technique as a secondary task. The anesthesia professional is instructed that the primary tasks of patient care take absolute precedence over the secondary task. Therefore, assuming that the secondary task requires some of the same mental resources as the primary task, the performance of the anesthesiologist on the secondary task is an indirect reflection of the spare capacity available to deal with it: the greater the spare capacity, the lower the primary workload. Depending on the secondary task response channels (manual, voice, gesture, multiple ways) there can exist channel interference. Controversy exists about whether these probes measure "vigilance" or "workload," although the same techniques probably measure both aspects of performance. When probes occur infrequently, are subtle, have multiple response channels, and are performed with a low level of existing workload, they are more likely to measure vigilance; when they are frequent, readily detectable, require a manual response, and are performed during a high-workload period, they probably are more indicative of spare capacity and workload.

**Subjective Measures.** In subjective measures, individuals are asked, most commonly in retrospect but sometimes in real time, how much load they were or are under during actual work situations. A common and validated form to assess subjective workload is the NASA TLX form.[140] Subjective measures usually complement objective measurements of external observations, since an anesthesia professional may subjectively underestimate the workload in settings in which objective measurements demonstrate a marked reduction in spare capacity.

**Physiologic Measures.** The final set of techniques for assessing workload consists of physiologic measures. Visual or auditory evoked potentials have been used successfully to assess mental workload, but this technique can be used only in a static laboratory environment. Heart rate (especially certain aspects of heart rate variability) and blood pressure are other physiologic measures that have been used, but there are challenges in reliable interpretation.

## ASSESSING THE PERFORMANCE OF ANESTHESIA PROFESSIONALS

Over the years several study designs investigating manual (i.e., technical aspects of a procedure), cognitive (i.e., dynamic decision making, situation awareness, vigilance) and behavioral/nontechnical (i.e., communication, teamwork, leadership) tasks were used to assess the performance of anesthesiologists. In this section, studies with special focus on anesthesia professional's performance about action density, work experience, teaching/delegation/supervision activity, and critical incidents/emergency treatment are presented. Most of the studies were performed in a simulated medical environment.

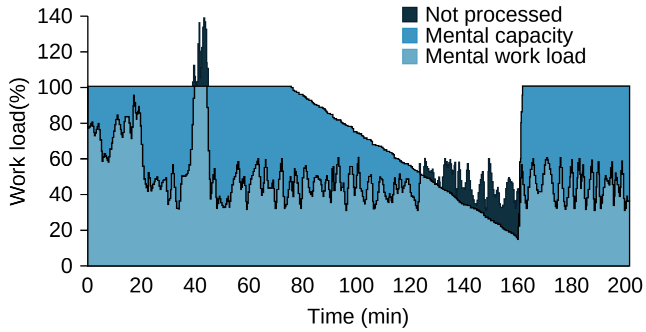


**Fig. 6.2 Illustration of how mental workload for the individual and the team may vary during anesthesia.** Time is shown on the x-axis. Total workload is shown on the y-axis. During the first 20 minutes of anesthesia induction the workload is high, but does not exceed mental capacity. Then, during the first minutes of maintenance the workload drops. At 35 minutes a crisis leads to a sudden increase in workload, which exceeds mental capacity. As shown, during this time certain information is not processed. Such a sudden overload is a typical feature of critical incidents, known in aviation as "maxing out." Thereafter, the workload of the maintenance phase drops again. But at the same time, after around 80 minutes in the case, the anesthesia professional becomes progressively more tired, resulting in less mental capacity available. So between 120 and 160 minutes workload again exceeds mental capacity and information is not processed. Finally, the anesthesiologist is roused after 160 minutes and workload again lies within capacity until the end of the case. (Figure based on the publication of Byrne A. Measurement of mental workload in clinical medicine: a review study. *Anesth Pain Med*. 2011;1(2):90–94.)

Because much of the more recent literature recapitulates findings of the pioneering studies, in this chapter those initial studies are used but the reader also is referred to newer, selected studies, without providing an exhaustive list.[6-8,68,73,74,76,144-149] The latest, large-scale study concerning the performance of anesthesiologists was published by Weinger and co-workers in 2017, examining the performance of board-certified anesthesiologists during four emergency cases.[75] The study is also presented in detail below.

A broader view on general human performance aspects related to anesthesia can be found in the next sections on "human performance, human factors and nontechnical skills" and "system thinking."

### Performance as a function of task density

It is generally accepted that there are limits on human ability to process information, and that information overload can lead to poor performance.[150] For example, many people will have experienced the difficulties of simultaneously trying to drive, navigate, read road signs, and listen to passengers. However, the work domain of anesthesia oftentimes seems to require exactly this kind of task density (Fig. 6.2). An interdisciplinary research group performed several task analysis studies, which allowed the analysis of multiple parallel and overlapping actions (action/task density).[89] Figs. 6.3 and 6.4 show examples of observations of 24 real OR studies. The observation data contain many short-term fluctuations *(dots)*; the moving average of action density of the previous 5 minutes was charted as well *(line)*. Fig. 6.3 shows a complete anesthesia procedure with increases in action density during induction and emergence from anesthesia. Fig. 6.4 shows two final phases of cardiac cases

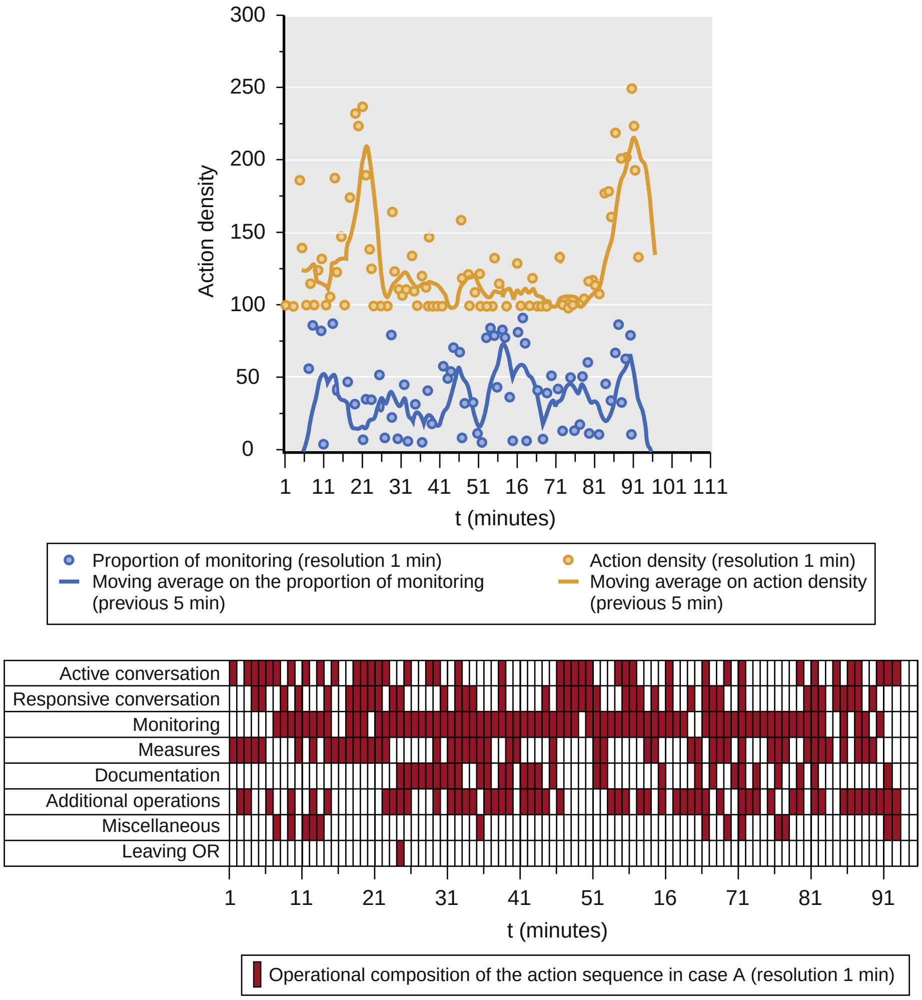


**Fig. 6.3 Action density diagram illustrating the derived parameter "action density" from induction of anesthesia to emergence in a real anesthetic case.** The *yellow line* in the graph shows the overall action density and the *dots* show the moving average of the density. The *blue line* shows the contribution of one task group, "monitoring," as an example. The table in the lower graph shows the composition of the data for all eight task groups from the same case. *OR,* Operating room.

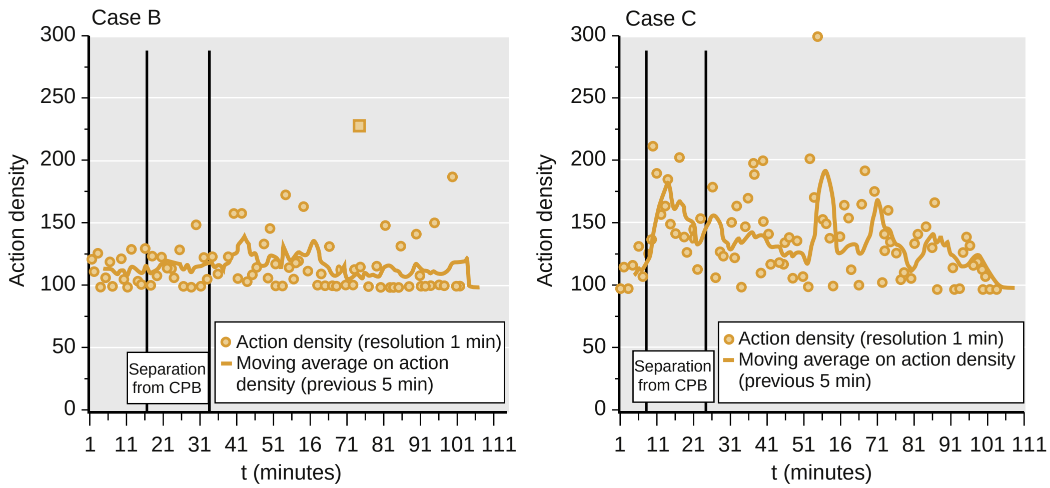


**Fig. 6.4 Action density during separation from cardiopulmonary bypass without and with complications.** The graph on the *left* is the density diagram of an uncomplicated case (case B) with a "flat" action density diagram during (between the two *vertical lines)* and after separation from cardiopulmonary bypass (CPB). In contrast, case C, shown in the graph on the *right,* had a complicated weaning from CPB; a very high action density is followed by an elevated density with further peaks after separation.

involving cardiopulmonary bypass. The described task analysis technique was also used to study action sequences in simulated cases and compare them with findings in the real OR to demonstrate and evaluate the ecologic validity of simulators (see Chapter 7).[64,89] Findings indicated that as the density of tasks per unit time increased, the dwell time on each task decreased, and vice versa. This finding has important implications for how anesthesia professionals allocate their attention.

Another interesting aspect in this respect is the hypothesis that the mental workload of novices may be lower than that of more experienced staff because they have yet to appreciate the difficulties facing them; this is termed unconscious incompetence.[151]

Xiao and colleagues[70] used simulations to investigate the dimensions of task complexity and their impact on crisis activities and team processes in the trauma room. They identified four components of complexity that affected team coordination in different ways. Multiple concurrent tasks led to goal conflict, task interference, and competition for access to the patient. Uncertainty regarding the case led to differences in opinion when interpreting information and difficulties when trying to anticipate the actions of other team members. The use of contingency plans caused difficulty in knowing when to switch tasks and how then to reallocate activities. Finally, a high workload caused procedures to be compressed and this deviation from normal work further increased the complexity of the situation. They suggested training in explicit communication to meet the challenges of task complexity.

### Performance as a Function of Teaching, Delegation, and Supervision

**Teaching.** Close interaction of experienced anesthesia professionals with inexperienced clinical trainees during actual surgical procedures is a standard approach to training. It can be hypothesized that teaching adds to the workload of the more experienced care provider who is simultaneously responsible for safe and efficient anesthesia care during the procedure. Weinger and co-workers[92] found that teaching teams, involving one-to-one supervision of fourth-year medical students or first-month anesthesia residents by an attending anesthesiologist, had significantly slower response times to a warning light than non-teaching teams of attending(s) of similar experience. Response latency was highest during induction and emergence. This vigilance test was also a procedural (performance) workload assessment measure indicating increased workload and reduced spare capacity. They also found that workload density was significantly increased for teaching as opposed to non-teaching teams. In sum, intraoperative teaching increased workload and decreased vigilance, suggesting the need for caution when educating during patient care.

**Delegation and Supervision.** Experience suggests that the effect of delegation on workload varies depending on the nature of the task and how confident the delegating anesthesia professional feels about the capability of the person to whom the task is assigned. Delegation must be guided by the supervisor's situation awareness and overall ability to process information on the patients' condition. Several further aspects are presented in the work of Leedal and Smith.[142]

### Performance as a Function of Experience

**Routine Events.** Novice trainee anesthesia professionals were found to perform many of the same tasks as do more experienced personnel at specific phases of an anesthetic regimen, but take longer over tasks, show longer latency of response, and greater task workload than third-year trainees and experienced nurse anesthetists.[90] While task density was generally highest for both subject groups in the period up to, during, and immediately after intubation, the more experienced trainees had higher task densities than the novices, suggesting greater competence among the former in carrying out multiple tasks in a short period of time. Those findings are in line with other studies, including the study of Weinger and associates[67] that evaluated the mean response time of pressing a buzzer at the flashing of a red light (secondary task). The response time was markedly less than 60 seconds for experienced subjects in both the induction and post induction (maintenance) phases, but it was much higher for novice residents during the induction phase. One explanation for those findings may be that the reduction of workload depends partly on the degree to which tasks can become routine, thus freeing mental resources for other tasks. Leedal and Smith conclude concerning this matter in their review: *"Experienced staff appear to show 'spare capacity' in performance during routine cases, which we suggest allows them an attentional 'safety margin' should adverse events occur"* (p. 708) [142]

In contrast, a more recent study presented by Byrne and co-workers found there was limited evidence of a relationship between workload and experience.[152]

Another recent finding indicates that more experienced anesthesia teams may be more likely to attempt to coordinate implicitly, without much overt communication, which makes them more reliant on accurate and shared understandings of the task and their teamwork.[153]

Novice residents also spent more time speaking to their attending staff (11% of preintubation time) than did experienced residents or CRNAs.[90] Experienced personnel observed the surgical field more than did the novices. Novices did take longer to complete patient preparation and induction of anesthesia, but it appeared that some of the extra time taken by novices working under supervision was offset by the efficiency of offloading other concurrent tasks to the attending anesthesiologist such that preintubation time was increased by only 6 minutes for novices.

**Critical Events/Emergencies.** Schulz and colleagues[97] presented data where more experienced anesthetists (>2 years work experience) increased the amount of time dedicated to manual tasks from 21% to 25% during critical incidents, whereas the less experienced decreased from 20% to 14%. The less experienced anesthesia providers spend more time on monitoring tasks.

A study by Byrne and Jones [76] looked at differences in the performance of experienced and less experienced anesthesia professionals during 180 simulated anesthesia emergency scenarios. The results showed significant differences only between the first and second year. As seen in other studies, significant errors occurred at all levels of experience,[75,76,125,126] and most of the anesthesia professionals deviated from established guidelines.[75,76,154]

A classic simulation study by DeAnda and Gaba investigated the response of anesthesia trainees and experienced anesthesia faculty and private practitioners to six preplanned critical incidents of differing type and severity.[126,155] The incidents included (1) endobronchial intubation (EI) resulting from surgical manipulation of the tube; (2) occlusion of intravenous (IV) tubing; (3) atrial fibrillation (AF) with a rapid ventricular response and hypotension; (4) airway disconnection between the endotracheal tube and the breathing circuit; (5) breathing hoses too short to turn the table 180 degrees, as requested by the surgeon; and (6) ventricular tachycardia or fibrillation. For each incident, considerable interindividual variability was found in detection and correction times, in information sources used, and in actions taken. The average performance of the anesthesia professionals tended to improve with experience, although this varied by incident. The performance of the experienced groups was not better than that of the second-year residents (who were in their final year of training at that time). Many (but not all) novice residents performed indistinguishably from more experienced subjects. Each experience group contained some who required excessive time to solve the problem or who never solved it. In each experience group at least one individual made major errors that could have had a substantial negative impact on a patient's clinical outcome. For example, one faculty member never used electrical countershock to treat ventricular fibrillation. One private practitioner treated the EI as though it were "bronchospasm" and never assessed the symmetry of ventilation. One resident never found the airway disconnection. The elements of suboptimal performance were both technical and cognitive. Technical problems included choosing defibrillation energies appropriate for internal paddles when using external paddles, ampule swap, and failure to inflate the endotracheal tube cuff that resulted in a leak. Cognitive problems included failure to allocate attention to the most critical problems and fixation errors.

Schwid and O'Donnell[125] performed an experiment similar to those of DeAnda and Gaba and received similar results. After working on several practice cases without critical incidents, each subject was asked to manage 3 or 4 cases involving a total of 4 serious critical events (esophageal intubation, myocardial ischemia, anaphylaxis, and cardiac arrest). The anesthesiologists studied had varying experience levels. Significant errors in diagnosis or treatment were made in every experience group. The errors occurred in both diagnosis of problems and in deciding on and implementing appropriate treatment. For example, 60% of subjects did not make the diagnosis of anaphylaxis despite available information on heart rate, blood pressure, wheezing, increased peak inspiratory pressure, and the presence of a rash. In managing myocardial ischemia, multiple failures occurred. 30% of subjects did not compensate for severe abnormalities while considering diagnostic maneuvers. Fixation errors in which initial diagnoses and plans were never revised were frequent, even when they were clearly wrong.

Independent from professionals' experience, Howard and colleagues[127] found a substantial incidence of difficulties during simulated emergencies: managing multiple problems simultaneously, applying attention to the most critical needs, acting as team leader, communicating with personnel, and using all available OR resources to best advantage. Analysis of videotaped trauma and resuscitation cases has revealed inadequacies in the availability and arrangement of monitoring equipment, as well as nonexistent or ambiguous communication.[69] Byrne and Jones [76] evaluated the performance of anesthetists during nine emergency cases, showing that serious errors in both diagnosis and treatment were made and accepted treatment guidelines were not followed. Diagnosis of several common critical incidents, for example, anaphylaxis, was hard to name.[74,125] As described earlier, once diagnosed, no structured plans or algorithms were used.[73,74]

These classic studies date back 25 years or more, yet the most recent studies [75,156] remain completely consistent with older studies. In the 2017 Weinger and colleagues publication, a total of 263 consenting U.S. board-certified anesthesiologists (BCAs—i.e., physicians) participated in two, 20-minute, standardized, high-fidelity simulation scenarios of unanticipated acute events during existing Maintenance of Certification in Anesthesiology simulation courses. The scenarios were from among the following: (1) local anesthetic systemic toxicity with hemodynamic collapse; (2) hemorrhagic shock due to hidden retroperitoneal bleeding during laparoscopy; (3) malignant hyperthermia presenting in the postanesthesia care unit; and (4) acute onset of AF with hemodynamic instability during laparotomy followed by ST elevation myocardial infarction. Performance measurement rubrics were established in advance: a scoresheet of critical clinical performance elements, behavioral anchored ordinal scales of four nontechnical skills, ordinal scales for overall individual and team technical performance and nontechnical performance, and a binary rating as to whether performance met or exceeded that expected of a BCA. The results showed that critical clinical performance elements were commonly omitted, roughly in four broad areas of crisis management, failures to: (1) escalate therapy where first-line options did not work (e.g., using epinephrine or vasopressin when phenylephrine, ephedrine, or fluids did not sufficiently correct hypotension); (2) use available resources (e.g., calling for help when conditions have deteriorated appreciably); (3) speak up and engage other team members, especially when action by them was required (e.g., asking the surgeon to change the surgical approach when it is essential to effective treatment); and (4) follow evidence-based guidelines (e.g., giving dantrolene to a patient with obvious MH). The performance of approximately 25% of subjects was rated in the low portion of the various technical and nontechnical 9-point ordinal scales. In about 30% of encounters, performance was rated as "below the level expected of a BCA."

**PATIENT SAFETY ACTION BOX**

Experienced anesthetists are not immune to error. Studies show that significant errors can occur at all levels of experience. *Experience is not a substitute for excellence or expertise*, making recurrent training and continuous awareness of possible safety pitfalls important, independent of the experience level.

**PATIENT SAFETY ACTION BOX**

Do not think this cannot happen to you… In her paper, "Lake Wobegon for anesthesia...where everyone is above average except those who aren't: variability in the management of simulated intraoperative critical incidents," McIntosh[157] discusses the applicability to anesthesiology of the pervasive human tendency to overestimate one's achievements and capabilities in relation to others. Such effects have been documented for drivers, CEOs, stock market analysts, college students, parents, and state education officials, among others.[158] Indeed we may all be living in Lake Wobegon in terms of evaluating our own abilities to manage critical events.

### What are the practical implications of performance assessment in Anesthesia?

In summary, simulation studies on performance all showed appreciable performance gaps of anesthesia professionals managing critical incidents and emergencies. The results expand on the few comparable data on real cases.[159-163] Overall, the surprisingly high frequency of mediocre performance represents a patient safety concern for the field of anesthesiology, emphasizing the need for anesthesia professionals and their organizations to:

- be aware of performance shortcomings and pitfalls in everyday work
- regard the knowledge and training of performance-enhancing strategies as one of the core competencies
- focus on the application of and adherence to evidence-based practice guidelines
- focus on the efficient management of the environment (team, resources, equipment, etc.)
- implement case management skills in the education, training, and re-certification, that go beyond only medical/technical knowledge and skill

## BENEFITS AND CHALLENGES OF ASSESSING PERFORMANCE

### Benefits of the Scientific Study of Tasks and Performance in Anesthesia

The generation of an improved understanding of the human performance of anesthesia professionals can help them to provide patient care more safely, in a wider variety of clinical situations, with greater efficiency, and with increased satisfaction to both patients and practitioners. The possible benefits of studying human performance include, but are not limited to, the following:

1. Improved clinical performance: Behavior observation helps to identify which processes and behaviors are associated with effective and safe performance.[63,83,164] Thus, it provides us with new knowledge on what effective teams do differently compared with ineffective teams and how they do it.[165] Compared with self-reports, behavior observation allows for measuring actual team-level phenomena and dynamics that teams may not even be aware of and that may unfold over time.[166]
2. Improved operational protocols: The way in which individuals conduct anesthesia is based, in part, on knowing the limits of their performance envelope. Anesthetic techniques and OR practices should draw on anesthesia professionals' abilities and should mitigate their weaknesses.
3. Enhanced clinical education and training of anesthesia professionals: Understanding the required performance characteristics and inherent human limitations will lead to improved training, which will most fully develop the strengths and counter the existing vulnerabilities of the anesthesia professional. Identification of performance gaps informs opportunities for improvement.[75] Identification of expert knowledge through elicitation of unaware expertise behavior creates educational gain.[167] Taking this knowledge into action should make patient care safer, less stressful, and more efficient.
4. A more effective work environment: Anesthesia professionals now perform their tasks by using an array of technologies, many of which have not been designed to support the anesthesia professional's work optimally. By understanding the relevant tasks and performance requirements, the workspace and tools could be improved for better support of the most difficult tasks. This, too, can lead to greater safety and to greater efficiency and work satisfaction.
5. A more efficient organizational system: Anesthesiology is embedded within a larger system of organized medical care that involves interactions among numerous people, institutions, organizations, and professional domains. Understanding how the anesthesia professional's work relates to the larger system may enable the development of more rational and efficient flow of information and organizational control.
6. A more rational view of professional work and legal responsibility: Modern health care, especially in the United States, is strongly influenced by medicolegal concerns. The litigation system has a major selection bias in that every case that comes before it involves an adverse outcome for a patient. The duty of the practitioner is to render care as a reasonable and prudent specialist in the area of anesthesia. What is reasonable and prudent? What type of performance is to be expected from appropriately trained human beings in a complex and dynamic environment? By understanding human performance, it may be possible to generate a more rational view of what is and is not within the standard of care.

### Challenges of the Scientific Study of Tasks and Performance in Anesthesia

Study of human performance involves research paradigms different from those typically used in the science of anesthesia. Many obstacles exist to obtaining valid data on human performance. There are no animal models for expert human performance and no Sprague-Dawley anesthesia professionals to be studied in detail. Recruiting experienced personnel to be the subjects of study is difficult and raises issues of selection bias concerning those who do volunteer. Especially if conducted during actual patient care, investigations of human performance are strongly influenced by concerns about litigation, credentialing, and confidentiality, thus making it difficult to execute optimal studies. Furthermore, variability among individual anesthesia professionals is quite striking because different anesthesia professionals respond to the same situation in different ways, and each individual may act differently on different days or at different times of the same day. The magnitude of this intraindividual variability is often nearly the same as the interindividual variability. Another challenge is that the performance measures may not be sensitive to an increase or decrease in workload if the subject compensates through increased, or reduced, effort respectively.

Performance itself is an intuitively meaningful concept that is difficult to define precisely. No universal standards are available for the clinical decisions and actions of anesthesia professionals. They depend heavily on the context of specific situations. In addition, determining how anesthesia professionals perform their jobs, whether successfully or unsuccessfully, means delving into their mental processes. This cannot be measured easily. Experimental designs can involve artificial laboratory tasks for which performance can be objectively measured, but these tasks will then be far removed from the real world of administering anesthesia. Conversely, investigating the actual performance of trained practitioners in the real world yields primarily subjective and indirect data. Understanding the anesthesia professional's performance must be seen as analogous to solving a jigsaw puzzle, an analogy introduced by Gaba[128] and extended by McIntosh.[157] Pieces of the puzzle probably come from a variety of sources, none of which by itself captures the entire picture.

Problems faced by all investigators are the lack of an accepted standard for objective or subjective evaluation of anesthesia professional performance and the absence of an agreed-on methodology for analyzing and describing anesthesia professional performance. As one result of the divergent research landscape in human performance, the number, scope, and variety of applied behavior observation taxonomies are growing, making comparison and convergent integration of research findings difficult. Several groups were working on methodologies for evaluating technical and behavioral aspects of performance.[75,89,166,168-170]

Kolbe and colleagues[166] pointed out four methodological challenges when rating behavior. First is identifying the optimal balance between specificity versus generalizability. Researchers must decide whether to investigate processes from a general perspective using methods that capture all teamwork behaviors simultaneously or whether to focus on one single process (e.g., closed-loop communication) to explore it in detail. Second is deciding whether to rate the quality or describe the occurrence of teamwork behavior. Quality of behavior can be measured with an anchored ordinal rating scale (e.g., from excellent to poor). Or alternatively, the occurrences of particular behaviors can be measured such as when?—by whom?—to whom?, etc., delivering different results. Third is linking research findings with team training content, when no common language and no common behavioral codes, respectively, are used in research. Fourth is applying different rating systems (in different studies) without respect to the usability and the different requirements for research, training, and examination purposes.

## Patient Safety on the Individual and Team Level

In earlier sections the characteristics of the complex and dynamic working environment in anesthesia were described in detail, as well as the multiple manual, behavioral, and cognitive tasks and related performance assessment studies of the anesthesia professional. Both sections illustrated several human performance and patient safety challenges that personnel face regularly. The knowledge and management of the complex work environment and the various tasks, workload, and performance pitfalls can determine the ultimate success of professionals' intervention. These human factors comprise issues related to perception, memory, problem solving, physiological rhythm, and more. This section focusses on the so-called nontechnical skills and performance-shaping factors [37,38,136,171-174] as they have the most direct practical impact for the work of anesthesia professionals.

The importance of nontechnical skills and performance-shaping factors is also in line with the performance studies of anesthesiologists mentioned earlier in this chapter.[69,70,73-76,125,127] They revealed room for improvement at any level of experience, especially in non-routine and emergency situations. Recent views on nontechnical skills emphasize their relevance also in routine situations to prevent those from becoming critical.[175] Nontechnical skills explain difficulties in applying knowledge and skills that team members possess in stressful moments in a dynamic, complex, and high-workload environment. They are related to challenges in managing and coordinating oneself (e.g., remembering to do tasks, monitoring one's own actions, acting as a team leader), the team (e.g., distributing tasks, managing conflict, sharing mental models), and the equipment (e.g., knowing the application of the equipment, understanding different use modes, troubleshooting).

Therefore, in the upcoming sections the following topics are addressed: (1) General concepts of human factors (HF) and nontechnical skills (NTS) are introduced and discussed in the larger context of human performance. Subsequently, several examples of the impact of HF/NTS are given, indicating that from a safety point of view, HFs and NTS deserve as much attention as medical knowledge [patho-] physiology, diagnosis, treatment) and practical skills, which by tradition have dominated training programs for anesthesia professionals. (2) Two sets of key elements of patient safety: first relating to individual performance (situation awareness and decision making), and second relating to team performance (communication, teamwork, and task management). (3) Additionally, individual performance-shaping factors are discussed, in particular fatigue, interruptions, distractions, and ambient noise.

### HUMAN PERFORMANCE, HUMAN FACTORS, AND NONTECHNICAL SKILLS

In the literature, the interrelated terms human performance, human factors, and nontechnical skills are used in a variety of ways and sometimes even synonymously, making it difficult to classify them. They are interconnected and while several models and taxonomies exist there is not always a clear distinction between these terms and concepts. In the upcoming section the authors explain the general underlying principles and give a simplified overview of their interrelationships in order to generate a more systematic understanding of key concepts. The term human error, also used in this context occasionally, is itself a different term, almost the flipside of human factors. One might say that challenges in human factors (and other aspects) can result in human error. For the definition and classification of human error see later section on "System Thinking."

## HUMAN PERFORMANCE AND HUMAN FACTORS

**What are Human Factors?** Human performance is shaped, positively or negatively, by different levels of so-called human factors (HF). Good HF increases and poor HF decreases human performance. The term ergonomics is also used in some contexts. A broad variety of disciplines are involved and many different topics are embraced by both terms; hence, several definitions exist. The Human Factors and Ergonomics Society defines HF as follows: *"Human factors is concerned with the application of what we know about people, their abilities, characteristics, and limitations to the design of equipment they use, environments in which they function, and jobs they perform."*[176] Catchpole and McCulloch define human factors in the medical context as: *"Enhancing clinical performance through an understanding of the effects of teamwork, tasks, equipment, workspace, culture, and organization on human behavior and abilities and application of that knowledge in clinical settings."*[177]

**Different Components of Human Factors.** Derived from the SEIPS model[178,179] and adapted by the authors, different components of HF are:

- the behavior of individuals and their behavior/knowledge in regard to tasks (individual level)
- the interactions with each other (team level)
- the interactions of professionals with the organizational/sociocultural conditions (organizational level)
- the interactions of professionals with the environment/workspace (environmental level) and
- the interactions of professionals with technology/equipment (technology/engineering/design level)

Those five human factor components are necessary and sufficient to describe and understand the anesthesia professional's entire work system from a HF perspective. The components interact with and influence each other, resulting in a large number of relationships between different levels. At times the components compensate each other (e.g., when professionals work faster to compensate for time pressure or when people collaborate to solve problems that are beyond an individual's abilities). Other times the components resonate with each other and amplify their effects—for the good (e.g., having the right equipment for the task at hand) or the bad (e.g., lacking resources to solve a problem). Given that this chapter cannot deal with human factors in a comprehensive way, many topics can be touched on only briefly. Although the environmental and technology levels can be important—cognition is challenged when there is a power failure or a breakdown of key clinical equipment—in this chapter the focus lies on the most important aspects of human factors directly relevant to anesthesia professionals: the individual level, team level, and organizational level.

## HUMAN FACTORS AND NONTECHNICAL SKILLS

**What are NonTechnical skills in comparison to Human Factors?** When talking specifically about HF that are directly related to actions of a single individual and/or of a team, often this is referred to as the concept of nontechnical skills (NTS). NTS are defined as *"the cognitive, social, and personal resource skills that complement technical skills (which encompass the technical knowledge of health care and its various procedures), and contribute to safe and efficient task performance"*[11] or alternatively as *"attitudes and behaviors not directly related to the use of medical expertise, drugs, or equipment."*[171]

While some authors object to the term nontechnical skills—using a negative to describe something—others have pointed out that not only is this term in wide use already, but that actually a variety of terms involving negation are in common use in science, mathematics, and medicine. One main paper and an editorial discuss this issue.[180,181] For health care, instead of nontechnical skills, the term could also be non-medical skills. However, because of the extensive use of nontechnical skills in the literature of other industries and in health care, this chapter uses that terminology.

**Different Ways to Categorize NonTechnical Skills.** In general, NTS can be categorized into two broad areas: (1) *cognitive and mental skills* on the individual level, including decision making and situation awareness; and (2) *social and interpersonal skills* on the team level, including teamwork, communication, and leadership. Commercial aviation incorporated such nontechnical skills in the cockpit (later crew) resource management paradigm (CRM, 1980s and continuous later evolution) and the "NOTECHS" paradigm in the late 1990s. In anesthesiology, the anesthesia crisis resource management (ACRM) framework was introduced by Howard and co-workers in 1990[127] as an adaptation of aviation's CRM. The ACRM approach categorizes NTS based on the five key elements of communication, situation awareness, decision making, teamwork (implicitly including leadership), and task management (Fig. 6.5). The anesthesia nontechnical skills (ANTS) framework by Fletcher and colleagues was introduced in 2003; Flin and colleagues give an overview of its history, development, application, use, and emerging is issues.[182,183] The ANTS approach typically includes the four categories of situation awareness, decision making, teamwork (explicitly including leadership), and task management. Neither of these frameworks, and indeed no usable paradigm, can capture explicitly every important aspect of HF applied to anesthesiology. For example the management of the performance-shaping factors stress and fatigue are also part of the ANTS framework, but are implicit in ACRM. Communication itself is not an explicit skill element of the ANTS framework (which assumes that communication pervades each element), whereas in ACRM it is a specific skill that needs explicit mention and training.[184] Of note, from their start in anesthesiology, nontechnical skills frameworks have been further adapted to several other medical fields, such as for surgeons and intensive care specialists.[8,11,168,169,185-188]

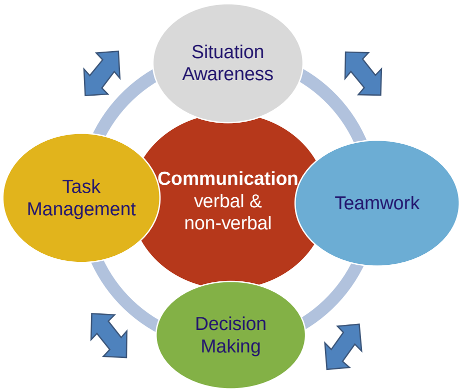


**Fig. 6.5 The five main elements of Crisis Resource Management (CRM).** The main elements include: Communication, situation awareness, decision making, task management, and teamwork. In this approach, effective communication is like the glue that holds all the other components together. Besides, all the components are intertwined with and related to each other, indicated by the arrows between the elements.

**Assessment of NonTechnical Skills.** In response to the growing acceptance of human factors and nontechnical skills influencing medical performance, several rubrics to measure NTS have been developed. Gaba and colleagues in 1998 described the direct adaptation for assessment of NTS of a set of CRM-anchored ordinal scale markers from Helmreich et al. concerning aviation.[169,189] In 2004 the ANTS framework was complemented by a behaviorally anchored rating scale in 2004.[182,183] A new set of assessment scales for four markers of NTS was introduced by Weinger and colleagues [75] in 2017 based on the fusion of aspects of a number of prior approaches.

A further, rather new approach for the assessment of nontechnical skills is the Co-ACT framework described by Kolbe and co-workers.[166] The framework serves observing coordination behavior, especially in acute care teams like anesthesia, and consists of four categories, each category obtaining three further subelements that more specifically describe the NTS: (1) *explicit action coordination* with the elements *instruction*, *speaking up*, and *planning*; (2) *implicit action coordination* with the elements *monitoring*, *talking to the room* (action-related), and *providing assistance*; (3) *explicit information coordination* with the elements *information request*, *information evaluation*, and *information upon request*; and (4) *implicit information coordination* with the elements *gathering information*, *talking to the room (information-related)*, and *information without request*.

**Challenges of the Assessment of NonTechnical Skills.** The psychometric qualities of measuring NTS have been assessed by the developers of the ANTS system and were considered to be of acceptable level,[182] whereas another study[190] assessed the reliability after a 1-day training for raters and concluded that reliability was poor. A study from Denmark showed good psychometric qualities.[185] Originally developed for educational purposes and used to discuss the NTS of anesthesiologists after training sessions in order to improve in NTS, Zwaan and colleagues assessed the usability and reliability for ANTS in research, finding that the ANTS system was reliable for the total score and usable to measure physicians' NTS in a research setting.[191] However, the investigators found a variation between the reliability of the different elements and recommend excluding elements in advance that are not applicable or observable in the situation of interest. It might not always be easy, however, to identify those elements that should be excluded. On the whole, the ANTS system appears to be a useful tool to enhance assessment of nontechnical skills in anesthesia and other medical fields further, and its careful derivation from an established system of nontechnical assessment in aviation (NOTECHS) may even allow some interdomain comparisons. However, more recently Watkins and colleagues directly compared ANTS with the system used in the Weinger and colleagues 2017 paper [75] and showed that ANTS was more difficult to use but that the two systems otherwise achieved equivalent assessment results.[192]

**NonTechnical Skills: The Bad - The Good - The Variable.** Good nontechnical skills (i.e., vigilance, efficient communication, team coordination, etc.) reduce the likelihood of active and passive errors and adverse events, and also increase human performance, whereas suboptimal NTS are expected to do the reverse. These effects are variable; for example, a person may communicate very effectively in one instance and fail to do so in the next challenging communication role.

A study from Denmark investigated the relationship between technical and nontechnical skills.[193] Twenty-five video recordings of second-year anesthesiologists managing a simulated difficult airway management scenario were rated with the ANTS instrument[185] and a score for the technical aspect for the procedure. In addition, written descriptions of the NTS performance were collected and content analyzed. The correlation between the two scores was not significant, but the content analysis comparing the NTS description in the best and poorest three scenarios identified what contributed most to good NTS. These were systematically collecting information, thinking ahead, communicating and justifying of decisions, delegating tasks, and vigilantly responding to the evolving situation. Poor NTS were related to: lack of structured approach, lack of articulating plans and decisions, poor resource and task management, lack of considering consequences of treatment, poor response to the evolving situation, and lack of leadership.

**What is the Impact of Non-Technical Skills and Human Factors on Poor Performance in Medicine?** The impact of poor NTS on poor human performance in the medical field cannot be overestimated. Depending on the literature, it is estimated that up to 80% of all errors in medicine can be attributed to problems with NTS and human factors.[37,38,171-174]

Even though one can argue on the one hand that due to progress in technology the findings and estimates of the pioneer study of Cooper and colleagues[37] performed in 1978 (results relating up to 80% of incidents to human factors) have been outdated for a long time, on the other hand those figures are (1) comparable to findings in other dynamic and complex work environments[171] and (2) newer studies as recent as 2015 still reconfirm those findings (references see below). In the following some illustrative studies are mentioned that link HF and safety challenges.

In 1993 an analysis of 2000 incident reports from the Australian Incident Reporting Study took place, investigating the incidents for relations to human factors and NTS.[38] In 83% of incidents, human factor elements were scored by the reporters. Even though scoring by the incident reporters might not produce results as accurate as those of a systematic scoring by human factor experts and such text descriptions are of limited value for this type of data collection, it still shows the scope of the problem—having also in mind that voluntarily reported incidents only represent the peak of an iceberg, with many incidents not reported at all.

Fletcher and colleagues published a review of studies describing the influence of nontechnical skills in anesthesia in 2002, summarizing that it is clear "*that nontechnical skills play a central role in good anesthesia practice and that a wide range of behaviors are important [...] [including] monitoring, allocation of attention, planning and preparation, situation awareness, prioritization, applying predefined strategies/protocols, flexibility in decision-making, communication, and teamworking*" [p.426].[171]

As increasing evidence suggested that human factors like communication, leadership, and team interaction influence the performance of cardiopulmonary resuscitation (CPR), Hunziker and colleagues[6] presented a study in 2010 reviewing the impact of human factors during simulation-based resuscitation scenarios. Similar to studies in real patients, simulated cardiac arrest scenarios revealed many unnecessary interruptions of CPR as well as significant delays in defibrillation—two outcome-relevant parameters. The studies showed that human factors played a major role in these shortcomings and that medical performance, at least in non-routine situations, depends among others on the quality of leadership and team-structuring.

Jones and co-workers[194] only recently systematically reviewed the literature on the impact of HFs in preventing complications in anesthesia due to poor airway management and highlighted recent national reports and guidelines, including the 4th National Audit Project (NAP4). NAP4 (2011) was the first prospective study of all major airway events occurring throughout the UK, reviewing any complications resulting from airway management that led to either death, brain damage, the need for an emergency surgical airway, unanticipated ICU admission, or prolongation of ICU stay.[173] 184 reports were reviewed. Subsequent in-depth analysis identified HFs as having been a relevant influence in every case, with a median range of 4.5 contributing HFs per case.[195] HFs in the report included for example[173]: casual attitude toward risk/overconfidence, peer tolerance of poor standards, lack of clarity in team structures, poor or dysfunctional communication including incomplete or inadequate handovers, inadequate checking procedures, failure to formulate back-up plans and discuss them with team members, failure to use available equipment, attempts to use unknown equipment in an emergency situation, heavy personal workload, lack of time to undertake thorough assessment, equipment shortage, inexperienced personnel working unsupervised, organizational cultures which induce or tolerate unsafe practices, no formalized requirement to undertake checking procedures, incompatible goals, and reluctance to analyze adverse events and learn from errors.

The Sentinel Event Report of the Joint Commission analyzed the root causes of 764 sentinel events (patient's death, loss in function, unexpected additional care and/or psychological impact) reported voluntarily in 2014.[172] Human-factor-related root causes, including among others communication and leadership, were the leading root causes of sentinel events and made up 65% of root causes. Even though the data are not specifically linked to anesthesia practice, it is very likely that there exist strong parallels.

One of the latest simulation-based studies, performed by Weinger and colleagues [75] in 2017 and explained in detail earlier (section on assessing performance, "Performance as a Function of Experience"), also shows a broad variety of human-factor-related hurdles for anesthesiologists when handling emergencies.

**What are the implications of the Impact of Humand Factors and NonTechnical Skills on Human Performance?**

- Balancing the importance of technical and non *technical skills during medical education and training.* While technical skills and medical knowledge have always been at the core of medical education and training, the importance of NTS has—despite long growing evidence—only recently been recognized.
- *Acknowledgement of the importance of human factors as individual and team.* One of the first steps for individuals and teams in minimizing and mitigating human frailties and strengthening human strengths—and in consequence reducing medical error and its consequences—is by acknowledging human factors as a part of human performance and thus acknowledging human limitation. The World Health Organization (WHO) states:

*"A failure to apply human factors principles is a key aspect of most adverse events in health care. Therefore, all health-care workers need to have a basic understanding of human factors principles. Health-care workers who do not understand the basics of human factors are like infection control professionals not knowing about microbiology." (p. 111)*[196]

## HUMAN FACTORS ON THE INDIVIDUAL LEVEL

This section will introduce three levels of human factors in more detail: (1) understanding the behavior of individuals (individual level), (2) the interactions between individuals (team level), and (3) their interactions with the organization (organizational level). This first section on the individual level addresses five interrelated elements: (1a) task management, (1b) situation awareness, (1c) decision making, (1d) general individual performance-shaping factors (e.g., fatigue, distractions and noise), and (1e) personal (safety) attitudes.

### Task Management

According to the ANTS framework, task management is defined as (p. 8) "*skills for organizing resources and required activities to achieve goals, be they individual case plans or longer-term scheduling issues. It has four skill elements: planning and preparing; prioritizing; providing and maintaining standards; identifying and utilizing resources.*"[170]

Anesthesia professionals are often—within the operating room setting—their own phlebotomist, IV inserter, echocardiographer, pharmacist, technician, cleaner, data recorder, patient transporter, as well as performer of activities on behalf of the surgeon (e.g., manipulate the OR table, answer telephone calls, etc.) all while maintaining situation awareness, engaging in decision making, doing administrative tasks, and managing the anesthetic itself. That's a lot of activities! Task management in a team might include the delegation of tasks to appropriate personnel, using effective communication, and closing the loop, both to verify the request was received and understood and then to inform the leader that the task is done, or that there are problems.

Task density can become so high that (1) errors in tasks or their subtasks are more likely; (2) no single person can manage all the tasks alone[89] so that help from team members is needed (teamwork); and (3) tasks may be delayed by interruptions or competing demands, which then require prospective memory[130-134,197] to remember what to do in the future or to correctly resume interrupted actions.

**Multitasking and Multiplexing.** Sometimes multitasking—doing several things at a time—can be successful, depending on the situation and the tasks at hand. Yet professionals need to be aware that it can be unsuccessful when the situation or the tasks change. When task density becomes high, simple linear performance of tasks becomes impossible; instead more complicated processes of both multitasking and multiplexing are needed. Multitasking—trying to perform two (or more) tasks simultaneously—is frequent in hospital settings,[198] but is virtually impossible to execute if the same cognitive resources are involved. Conducting two or more relatively simple tasks is often possible, such as observing the surgical field while asking the surgeon a straightforward question. Even then there is a risk that one task will be dropped or degraded. However, adjusting an infusion pump while calculating the upcoming dose of antibiotic for an infant would be difficult to do in parallel.

In common use, the term multitasking sometimes refers specifically to media multitasking—everyday attempts to simultaneously work, listen to music, check email and text messages, and search the web. Studies[199,200] have shown that frequent media multitaskers perform worse on psychology laboratory probes of actual multitasking than those who are infrequent media multitaskers. Many suggest that true multitasking is impossible and that almost always there is a decrement of performance on some or all tasks when multitasking is attempted.

The degree to which media multitasking, or laboratory tests, relate to the kinds of multitasking performed by personnel in professional settings of many data streams and many tasks is as yet uncertain; it seems likely that in anesthesia care there are limits to what individuals can safely do on their own.

While simple multitasking in perioperative settings may work, when tasks are complex it may in fact be inefficient. Rather than conducting two (or more) activities in parallel, humans often do things sequentially but shift rapidly between items or back and forth across many simultaneous threads. If the tasks use different cognitive resources, this is referred to as multiplexing.[201] Multiplexing brings the challenges that people (1) have to refocus their concentration each time they switch and (2) are more susceptible to distractions and errors. This is especially true if the tasks at hand involve intensive real-time control as opposed to being cognitively automatic.[201] There is evidence that health care personnel are not aware of the risks of decreased performance when attempting to multitask.[202]

Douglas and co-authors recently reviewed the current literature concerning multitasking in the health care setting.[198] They suggest that multitasking typically results in increased time of task completion, increased stress, risk of memory lapses, and subsequent errors and accidents. Those performance limitations occur more often if one is forced to multitask by the environment and/or if the different tasks compete for the same local cognitive resource. Their review located only two studies on the association between multitasking and errors in the health care setting although nothing definitive was found. Executing two tasks at the same time was found to carry the risk of decreased accuracy and efficiency[203] and to have an increased reaction time to environmental stimuli.[204]

**PATIENT SAFETY ACTION BOX**

Keep focused. Instead of trying to do several things at once—and maybe none of them well—shift your attention consciously and completely from one task to the next and organize the tasks at hand according to priority. Giving your full attention to what you are doing will help you do it better, with fewer mistakes and less load on your prospective memory. Prevent or modulate avoidable distractions whenever possible.

**Multitasking During Handovers?.** One study observed different modes of patient handover from the OR to the postanesthesia recovery unit in six hospitals.[205] The researchers compared handovers of (1) *simultaneous* transfer of equipment and information (i.e., a nurse connecting the monitor while at the same time receiving verbal information) to (2) *sequential* transfer (equipment is first connected and lines sorted, then verbal information follows). The findings from 101 observed handovers showed that 65% of them took place simultaneously. Interestingly, simultaneous handovers were not significantly faster than sequential ones (1.8 vs. 2.0 min). In review of postoperative handovers Segall and colleagues[206] recommended: (1) standardize/structure processes (e.g., through the use of checklists and protocols); (2) complete urgent clinical tasks before the information transfer; (3) allow only patient-specific discussions during verbal handovers; (4) require that all relevant team members be present; and (5) provide training in team skills and communication. More information on handoffs is given in the later section on "Communication."

**PATIENT SAFETY ACTION BOX**

The recommendations given above are helpful for safe postoperative handovers. Another handover type occurs when one anesthesia professional replaces another, temporarily or permanently. And yet another handover is when you have called someone for help or when you are the one coming to help. For this last situation often the person arriving to help concentrates immediately on performing tasks without really listening to the briefing from the original anesthesia professional. Unless the task is critical (e.g., CPR) it is better to wait, assess the situation and the observable information, and then pay full attention to the briefing. For further information on handoffs see section "Effective Communication and Delegation of Tasks."

## Situation Awareness

In anesthesia many sources of information need to be scanned in order to get the overview of the situation. These include, but are not limited to: the patient (clinical impression and history), various monitoring equipment, the patient chart, explicit and implicit information by colleagues and OR team members, and workday characteristics (i.e., staff composition, staff shortage, available equipment/time, etc.). Gaba, Howard, and Small introduced the concept of SA in the context of anesthesia in 1995.[110] Schulz and colleagues wrote a review article in 2013 especially on SA in anesthesia. [135]

Situation awareness (SA) describes *"the ability of an individual to maintain an adequate internal representation of the status of the environment in complex and dynamic domains where time constants are short and conditions may change within seconds and minutes"* (p. 729). [135]

SA is a concept drawn from military aviation concerning a variety of aspects of cognition in complex real-time environments. While important itself, situation awareness is influenced by previous decisions, communication patterns, and team dynamics; the level of SA in turn influences team communication and coordination. Situation awareness incorporates the circumstances of the patient at hand (e.g., "Is all required expertise represented?"), the state of the treatment team (e.g., "Is a team member task-overloaded?," "Do team members trust each other?"); and the state of the environment including the rest of the facility (e.g., "Is the problem I'm having also happening elsewhere in my OR suite?").

One of the primary experts on SA, Mica Endsley,[207-209] postulates three different components of individual SA: (1) *Perception* of the elements of a situation/environment within a volume of time and space (= gathering information, detection of cues); (2) *comprehension* of elements and their meaning (= interpretation of information/cues, diagnosis); and (3) *projection* of their status in the near future (= anticipation, prediction). Dekker and Hollnagel challenge this model.[210,211]

Success or failure of SA can occur at each component: gathering, comprehension, and projecting. Some readily available information can be missed, or perceived incorrectly; on the other hand experience makes them sensitive to barely perceptible cues. They also often, but not always, comprehend the meaning of what is perceived by everyone even when others miss its significance.[212] Experts also are usually able to assess the situation not only as it stands but also to project where things are headed, but of course their future projection can be inaccurate or disregarded (including the "everything is OK fixation error").

Schulz and colleagues reviewed 200 incidents in anesthesia and critical care in an in-hospital setting and determined the frequency of situation awareness errors for an individual patient.[136] Admittedly there could be some degree of hindsight bias; nonetheless, situation awareness errors were identified in 81.5% of cases—predominantly in perception (38.0%) and comprehension (31.5%).

**Shared Situation Awareness.** SA is a concept that can be applied to the individual (personal SA, see above), but also the team (shared SA). Team SA is defined as *"the degree to which every team member possesses the SA required for his or her responsibilities"* (p. 39).[207] Within different professions and different physical positions in the room, the situational awareness and interpretation of the same case can differ substantially within a team, due to variation in experience, involvement, focus point, interest, knowledge, or information. Of course, not every bit of information can be shared with the whole team; doing so would overwhelm everyone. Yet, creating and maintaining an overall shared mental model of the situation across all team members is critical for determining the best plan of action for patient care. Some team communication in the operating room that seemingly does not serve an obvious purpose, might, in fact, be a gauging of shared mental models and therefore shared SA.[213,214] Anesthesia professionals, for example, routinely assess the progress and possible complications of the operation by perceiving nuances in the conversation of the surgeons.[213]

Shared mental models predict good team performance[215] and were, for example, shown to be related to positive performance in trauma teams, with team leaders and followers actively working toward an information exchange.[216] Adapted from psychology and management literature, Schmutz and Eppich[217] introduced the conceptual framework of team reflexivity to health care. They propose that shared SA is fostered by components of team reflexivity, namely (1) pre-action briefing, (2) in-action deliberation, and (3) post-action debriefing. Fioratou and colleagues[218] challenge the common model of individual and team SA and instead introduced the model of distributed situation awareness (DSA) to anesthesia, arguing that cognition actually involves elements of the (physical) environment, for example, the values on a monitor.

A multicenter study from Denmark explored shared mental models of surgical teams during 64 video-assisted thoracoscopic surgery lobectomies to explore familiarity of the people involved in the operation with each other; mutual assessment of technical and nontechnical skills in the other persons present during the operation; assessment of the perceived risk for the patient from the procedure and from the anesthetic; and noting of problems in the present co-works task management. There was poor agreement between team members' risk ratings showing limitations in how much the members of the surgical team share a mental model about the patient and the related risks. A follow-up study demonstrated the connection between relevant clinical markers and shared mental models.

Other aspects of situation awareness have already been introduced within the "core cognitive process model" in an earlier section. Box 6.2 gives examples of reevaluation questions in order to maintain situation awareness.

## Decision Making

Decision making is the generic term for the cognitive and emotional processes of determining appropriate information seeking and actions in a changing environment. It involves "*skills for reaching a judgement to select a course of* *action or make a diagnosis about a situation, in both normal conditions and in time-pressured crisis situations. It … [includes]: identifying options; balancing risks and selecting options [and] re-evaluating"* (p. 13).[170] Many aspects of the anesthesia professional's decision making have already been addressed in the earlier section where the "core cognitive process model" was introduced, so for more information the reader is referred back to that section.

Although decision making in anesthesiology involves many sorts of perioperative decisions, this chapter is particularly interested in the processes used for the non-routine decisions made during the management of problems or crises. This is a very complex process. Although information is sometimes used in what seems to be a purely rational manner,[219,220] decision making is affected strongly by a number of non-rational elements such as group pressure, ingrained habits, cognitive biases, and perceptual illusions. When determining the alternatives and their various pros and cons the set of options available or their perceived value will also vary.

Traditional concepts of decision making in much of medicine (not anesthesiology) have concentrated on relatively static, well-structured decisions. For example, should patient A with an elevated blood pressure be treated for hypertension with drug X, or should no treatment be started? Other studies have looked at diagnosis as an isolated task (specifically, diagnostic explanation) both in internal medicine and in radiology. These approaches to decision making have not captured the unique aspects of dynamism, time pressure, and uncertainty seen in anesthesiology. Since the 1980s, several paradigms have emerged regarding decision making and action in complex real-world situations.

On the one hand there are models that have their basis largely in research done in the psychology laboratory investigating the limits and pitfalls of decision making under controlled conditions, especially delineating cognitive biases. Daniel Kahneman and his colleague Amos Tversky won a Nobel Prize in Economics in 2002 for this kind of research. While Tversky passed away in 1999 Kahneman continued to work on decision making, and he recently synthesized and summarized the topic in the popular book *Thinking Fast and Slow*.[212] Two cognitive systems are described. System I is intuitive (heuristic), very fast, less concerned with the precision of the information processing and decision (as long as it is approximately correct) and more concerned with reducing cognitive load. Research about heuristic decision making shows that reducing the amount of information considered can still lead to equally good or superior decisions.[221] System II is analytical, slow but able to consider in detail the sources of information and the fine points of a decision. Especially in time-critical situations humans tend to run on System I as long as possible, sometimes too long—accepting imprecise results when precision is actually needed. Understanding the pitfalls of System I thinking can help professionals to lower the bar for their activation of System II. Another approach to studying and describing decision making, based on observational research on professionals engaged in doing complex decision-making work in real-world settings (or simulations thereof) is known as naturalistic decision making (NDM), with Gary Klein, Judith Orasanu, and others as the pioneers.[45,114,118] Models in NDM-oriented work also invoke the idea of parallel systems of decision making, one heuristic and fast, the other systematic, precise, and slow, as well as a number of other aspects of iterative consideration of useful actions.

The core cognitive process model including dynamic decision making (see earlier section on "Core Cognitive Process Model of the Anesthesia Professional") is based largely on the NDM model, but is consistent with Kahneman's description of System I and System II. In fact, Klein and Kahnemann have co-written a paper that outlines how their two approaches are in many ways similar, while in a few ways somewhat different. [222] A common (if incomplete) way to describe this is that the work of Kahneman and Tversky emphasizes the pitfalls and errors of decision making, NDM emphasizes how it is often successful despite these risks.

Stiegler and Tung—representing views influenced by the Kahneman-Tversky research—(1) identified current theories of human decision behavior in the context of anesthesia, which are: expected utility, Bayesian probability, formalized pattern matching, heuristics, dual process reasoning, and sensemaking; (2) identified common effects of non-rational cognitive processes on decision making; and (3) suggested strategies to improve anesthesia decision making.[121]

In another publication, Stiegler and co-workers summarized the most common cognitive/non-rational errors detected specific to anesthesiology practice; the leading 10 errors were anchoring, availability bias, premature closure, feedback bias, framing effect, confirmation bias, omission bias, commission bias, overconfidence, and sunk costs.[61] In a simulated emergency setting, the frequency of seven of those errors was over 50%, with premature closure (accepting a diagnosis prematurely, failure to consider reasonable differential of possibilities) and confirmation bias (seeking or acknowledging only information that confirms the desired or suspected diagnosis) being the most common cognitive errors with a frequency of nearly 80% each. In 2016 the Joint Commission also published a paper on the safety issues of cognitive errors and factors that can predispose or increase the likelihood of cognitive biases.[62]

Gigerenzer frames the view on the characteristics of human decision making differently.[223,224] What is called biases in other frameworks is seen as relevant features of human cognition and decision making that allow for functional perception and action in a very complicated world. Perhaps like NDM, this view suggests that theories of decision making do not really describe decision making in the real world. For example, in many situations it will not be possible to collect all relevant decision alternatives, to assess them fully, and to select the best option. There might not be enough data available about the alternatives and/or the evaluation might take too long. The "take-the-best" (also termed "satisficing") heuristic suggests that decision makers consider what they see as a key feature for the decision and only compare any alternatives along this criterion. Further criteria are only considered if the first ones do not identify an acceptable option.

## PERFORMANCE-SHAPING FACTORS ON THE INDIVIDUAL LEVEL

The previous discussion about the performance of skilled anesthesia professionals has mostly assumed that they are normally fit, rested, and acting in a standard working environment. However, human performance on the individual level also depends on so-called performance-shaping factors such as interruptions, distractions, fatigue, and stress. Performance-shaping factors can predispose a person to error. Experience in human performance in the laboratory and other domains suggests that internal and external performance-shaping factors exert profound effects on the ability of even highly trained personnel. The degree to which this occurs and to which it affects patient outcome is highly uncertain. In extreme cases, such as profound fatigue, it is obvious these factors result in severe degradation of the anesthesia professional's performance or even complete incapacitation. However, these extreme conditions are quite unusual, and it is still unclear whether the levels of performance decrement most frequently seen in typical work situations have any significant effects.

Several performance-shaping factors are potentially of sufficient magnitude to be of concern. Those include ambient noise, music, distraction by personal electronic devices, distraction by other personnel, fatigue and sleep deprivation, aging, illness, drug use, and relatively fixed hazardous attitudes. These are discussed in the course of this section. A variety of other performance-shaping issues such as the level of illumination and environmental temperature are not dealt with in this chapter.

Currently, the responsibility for ensuring fitness for duty rests solely with the individual clinician. In high-reliability organizations (see later), where the maintenance of organizational safety is one of the key elements, the institution implements measures to mitigate decrements due to performance-shaping factors. As health care systems address issues of human performance and patient safety more seriously, these aspects of work will need to be dealt with.

### Distractions and Interruptions in the Operating Room

Several recent publications deal with distractions and interruptions in the OR. For detailed information the reader is referred to further literature,[68,95,96,225-234] as the upcoming section can only give a brief overview on the topic.

**Ambient Noise and Music.** The workplace of anesthesia professionals—predominantly, but not exclusively, the operating room—is a very complex physical and cognitive setting. Unless there is an unusual effort to reduce sound levels the routine noises of the suction, surgical equipment (electrocautery, pneumatic or electric power tools), and monitoring equipment yield levels considerably higher than in most offices or control rooms. Other sound sources such as conversation and music are controllable. The potential interference of noise with communication and situation awareness[235] among personnel in the OR is particularly worrisome to those concerned with optimizing teamwork in this complex work environment.[68,236]

The use of music in the OR is now widespread. Many health care professionals believe that music enlivens the workday and can build team cohesiveness when all team members enjoy the music. Others note that in some cases the volume level of music makes it harder to hear the rhythm and tone of the pulse oximeter and alarms as well as work-related conversation between team members. A laboratory study by Stevenson and colleagues determined that visual attentional loads and auditory distractions additively reduced anesthesiology residents' ability to detect changes in pulse oximeter tone.[235]

A controversial study by two social psychologists, Allen and Blascovich, suggested that surgeon-selected music improved surgeons' performance on a serial subtraction task and reduced their autonomic reactivity (i.e., "relaxed" them) when compared with control conditions consisting of experimenter-selected music or no music at all.[237] The methodology of this study has been criticized.[238] In response to Allen and Blascovich, several anesthesiologists challenged the notion that the surgeon's preference for the type or volume of music can or should override the needs of other members of the team.[238]

Murthy and colleagues[239] studied the effect of OR noise (80 to 85 dB) and music on knot-tying ability in a laparoscopic skill simulator. They found no difference in time or knot quality in the conditions tested and concluded that surgeons can effectively block out noise and music. The invited commentary that accompanied the article brings up important issues: What impact does noise have on other members of the surgical team? How does noise affect communication between team members? Does noise affect judgment? The question of the proper role of music in the OR has no simple answer. Clearly, optimal patient care is the primary goal. Some surgical or anesthesia personnel explicitly forbid any type of music in the OR. A more common approach of many OR teams is to allow any team member to veto the choice or volume of music if they believe that it interferes with their work.

**PATIENT SAFETY ACTION BOX**

Distractions include music, social conversation, and jokes. Each of these activities is appropriate under the right circumstances. They can make the work environment more pleasant and promote the development of team spirit, but they can also seriously lessen your ability to detect and correct problems. This issue can be raised during the presurgical time-out to ensure that all personnel agree. During patient care you must take charge of modulating these activities so that they do not become distracting. If the music is too loud, one must insist that the volume be reduced or that it be turned off (a rule of thumb is that the pulse oximeter volume should always be louder than the music or conversation). When a crisis occurs, all distractions should be eliminated or reduced as much as possible.

**Reading and Use of Mobile Electronic Devices.** The observation that some anesthesia professionals have been seen to read journals or books casually during patient care led to a vigorous debate of the appropriateness of such activity.[240] Although it is indisputable that reading could distract attention from patient care, a study by Slagle and Weinger in 2009 suggested that when the practice of reading is confined to low-workload portions of a case, it has no effect on vigilance.[65] Many comments about the issue were related not to the actual decrement in vigilance induced by reading but rather to the impact of the negative perception of the practice and of those who do it by surgeons and by patients, if they were aware of it.

This issue has been greatly magnified by now-ubiquitous smartphones and social media. Nearly all clinical personnel (other than those scrubbed into surgery) have a smartphone immediately at hand. These provide great temptation for both pull activities—reading email, websites, or social media sites—and push activities, notification of new text messages, mail, or social media posts. The wide variety of channels of information makes it far more likely for people to spend time interacting with their phones than with newspapers, journals, or books. The content available is never ending. In their survey, Soto and colleagues give a current update of the usage patterns, risks, and benefits of personal electronic device use in the operating room.[241]

**Distractions Caused by Work Itself.** An important source of distraction is actually the work itself. That is, engaging in one task can distract attention from other important tasks. Repositioning the patient on the operating table (or rotating the table itself) can take a surprising amount of time and physical and mental effort. During these tasks it can be difficult, and in some cases impossible, to maintain all usual data streams, or to view, hear, or attend to them. Another highly distracting activity is the use of echocardiography, which requires focused attention on the image and manipulation of the probe and of the device's interface. While it may generate crucial clinical information, it can also distract attention from other important monitors or the surgical field.

**Interruptions.** Beyond distracting attention from important data streams, various stimuli can also cause "interruptions" in the sequence of conducting a task.[95] Campbell and associates[96] found that slightly more than 20% of distractions—particularly interruptions—were associated with an observable negative impact. Such events are particularly problematic when they disrupt prospective memory which is one's ability to *remember in the future* to perform an action or to resume interrupted tasks in the right spot.[132] It is particularly prone to disruption by concurrent tasks or interruptions. In anesthesia, for example, if the anesthesia professional suspends ventilation temporarily (say to allow a radiograph to be taken), the intention to restart the ventilator depends on prospective memory and can be easily forgotten.

A variety of methods may preserve prospective memory of intentions. Visual or auditory reminders can be used (physiologic monitor alarms often serve this purpose whether intended or not), although the effectiveness of such methods is variable.

**PATIENT SAFETY ACTION BOX**

Special actions—such as leaving one's finger on the ventilator switch when one has turned off the ventilator for an appropriate reason—can be used to indicate that an important intention is pending. Another strategy is putting a small sign on the ventilator to remind you that it is off. As a last resort in this example, properly set alarms should warn you of apnea should you forget to turn the ventilator back on. Depending on the requested action another strategy can be to accustom oneself to consciously finish tasks entirely before starting the next task (see also section on Task Management). If team members interrupt during a task it can be helpful to let them know that you are busy, something like "One moment please, you'll have my full attention shortly." However, asking others to help you remember ("can you please remind me"), has shown to be a less effective strategy, apparently because it diffuses the responsibility to actually remember.

**Resulting Implications.** Clearly, for all these distractions and interruptions the pros and cons of policing them need to be balanced. In our opinion—similar to those of Slagle and Weinger[65]—blanket policies against reading nonessential materials or interacting with mobile phones except for patient care needs are both doomed to failure and possibly detrimental. First, because they are hard to enforce and any intensive efforts to eradicate the use of such devices at work is likely to generate a tense work climate despite the best safety intentions of proponents. Second, because reading or phone use might actually counteract boredom in some situations and thus might increase performance. Third, these distractions are not necessarily any different from many other kinds of activities not related to patient care that are routinely accepted, such as social conversation among personnel. Of course, there are reasonable limits for such activities.

The bottom line is, to quote Slagle and Weinger: "*(1) the patient must be the foremost priority and (2) being distracted or performing noncritical tasks during critical or unstable situations is inappropriate and dangerous*" (p. 282).[65] In the end it is important for anesthesia professionals to keep in mind that there are potential pitfalls linked to distractions and that the anesthesia professional is responsible for modulating controllable distractions and for developing work processes that balance the cognitive load of tasks against their personal, clinical, or teambuilding utility. Allowing music during routine work (if all agree) and a modest amount of reading or smartphone use, but emphasizing the need to reduce or eliminate it when it is too distracting, the workload increases, or a situation becomes complex or urgent is one example. The threshold for abandoning any potential distraction to provide maximum attention to patient care should be rather low.

In response to the patient safety concerns related to distractions and interruptions in the OR and other patient care areas from the use of personal electronic devices for non-patient-related purposes, several professional societies and organizations have established position statements and guidelines to define appropriate use of those devices in the OR.[242-245] Some health care settings have implemented a "no interruption zone"[242,246] during critical phases of patient care activities, in the style of a "sterile cockpit" concept,[100] derived from aviation regulations that prohibit crewmembers from engaging in any activity except those duties required for the safe operation of the aircraft during critical phases of flight.

**Stress.** Stress is a performance-shaping factor that influences human performance. To go into detail about stress is beyond the scope of this chapter. Therefore the reader is referred to other references for more details.[11,247]

### Sleep Deprivation and Fatigue

Fatigue is common in the life of anesthesia professionals, whether due to work hours, on-call duties, or the vagaries of life with children and otherwise. Sleep can be thought of as a physiologic drive state similar to hunger or thirst and is necessary for maintenance of alertness, performance, and overall well-being. The amount of sleep required by any individual is genetically determined and is the amount that allows that individual to be awake and alert throughout the day. The average sleep time for young adults is 7 to 8 hours per 24-hour period, with an approximately 15% interindividual variation. These sleep requirements do not change with age, and humans can do little to train their physiology to function optimally on less sleep than required.

The physiology and psychology of sleep and sleep deprivation are well established, and this section can only provide a cursory summary of what is known.

**Sleep Debt.** Sleep loss is cumulative and results in what is referred to as sleep debt. An individual who has obtained an optimal amount of sleep is better prepared to perform long periods of sustained work than one who is operating from a sleep debt. Because of the additive effects of chronic partial sleep loss, even minor sleep restriction on a nightly basis can insidiously accumulate into a substantial sleep debt. The only way to pay back a sleep debt is with sleep. Sleep debts are commonplace in our culture. The National Sleep Foundation's annual survey continues to reveal that Americans chronically undersleep by 30 to 90 minutes each day.[248] Shift work, long and irregular work hours, and the demands of family and recreation lead to irregular sleep patterns and prevent restful sleep. This is particularly true for health care workers, who often work in shifts, have long duty periods, and must frequently care for patients for long periods. To some degree it seems as if sleep deprivation might have led into a situation that is more dangerous than one thinks.

**Circadian Rhythms.** Our biological clock, responsible for the human circadian system, is synchronized to the 24-hour day by external stimuli referred to as "zeitgebers," the most influential of which is the light-dark cycle of day and night. The circadian system is biphasic in that it produces a state of increased sleep tendency and decreased performance capacity during two periods throughout the 24-hour day—from 2 a.m. to 6 a.m. and from 2 p.m. to 6 p.m. These are periods when professionals are more vulnerable to incidents and accidents because the body clock is "turned off." The circadian clock is very resistant to alterations, and it does not adjust rapidly to changes such as those produced by jet lag or shift work. Disruption of the normal circadian rhythm or incomplete circadian adaptation leads to acute and chronic sleep deprivation, decreased alertness, increased subjective fatigue, and decreased physical and mental performance.[249]

**Sleepiness and Alertness.** Sleepiness and alertness are at opposite ends of a continuum. Daytime sleepiness is the most obvious effect of failing to obtain adequate sleep. Data from the U.S. Department of Transportation reveal that the greatest number of single-vehicle accidents takes place during the early morning hours when people are at a circadian lull of alertness. These accidents are thought to result from inadvertent lapses in driver attention brought about by extremes of sleepiness.[250]

Both behavioral and subjective sleepiness can be masked by a stimulating environment. When environmental stimuli wane, physiologic sleepiness manifests itself as an overwhelming propensity to fall asleep. A person who is physiologically alert does not experience sleepiness as environmental stimuli decrease. For example, without physiologic sleepiness, an individual may become bored during a lecture but does not fall asleep.

**Microsleep Events.** The most extreme cause of impaired vigilance is the occurrence of actual sleep episodes (microsleeps) encroaching into periods of wakefulness. Microsleep events typically last a few seconds to a few minutes. They are intermittent in onset, and their impending occurrence is difficult for the individual to predict. Most individuals underestimate their level of sleepiness when they can be objectively shown to be extremely sleepy, thus making this problem even more insidious. This has significant meaning in the workplace and when driving home after long work periods.

Microsleeps are a sign of extreme sleepiness and are harbingers of the onset of longer sleep periods. Typically, they occur during periods of low workload or stimulation and when an individual is maximally sleepy. In addition, an individual's performance between microsleep episodes is impaired. Frequent and longer microsleeps increase the number of errors of omission.

**Evaluation of Physiologic Sleepiness in Anesthesia Residents.** Using the Multiple Sleep Latency Test (MSLT), a sleep disorder diagnostic tool, Howard and colleagues evaluated the physiologic (objective) daytime sleepiness of anesthesia residents under three different conditions: (1) baseline (daytime shift, no on-call duty period in the previous 48 hours), (2) post-call (immediately after a 24-hour work and in-house on-call period), and (3) sleep extended.[251,252] In the sleep-extended condition, residents were told to maximize sleep and were allowed to arrive for work at 10 am (3 to 4 hours later than normal) for 4 consecutive days before testing. They were not on call during this time. The sleep-extended condition was included to provide a true control state of maximal rest and optimum alertness. In this study, for anesthesia residents the MSLT scores for baseline as well as for post-call condition revealed the nearly pathologic levels of daytime sleepiness seen in patients with narcolepsy or sleep apnea. The baseline group slept an average of 7.1 ± 1.5 hours per night, whereas the post-call group reported an average of 6.3 ± 1.9 hours of sleep during their night on call. Ironically, although the on-call periods occurred during rotations that often have very busy call nights, only a few subjects were, in fact, awake most of the night. In the sleep-extended condition, the subjects extended their sleep to an average of more than 9 hours per night, and MSLT scores were in the normal range. These results clearly demonstrate that medical personnel who have not been on call cannot be assumed to be rested when compared with fatigued post-call residents. These data also indicate that under normal working conditions, the resident physicians studied were physiologically sleepy to nearly pathologic levels. Notably, these data cast substantial doubt on previous studies of the performance of medical personnel that have relied on the assumption that individuals working under normal conditions are truly rested.

**Evaluation of Subjective Sleepiness in Anesthesia Residents.** The previously mentioned study also investigated the connection between subjective and physiologic sleepiness. In the previously discussed study, Howard and colleagues also investigated the degree of discrepancy between the residents' subjective sleepiness (how sleepy they felt) and their physiologic sleepiness (how easily they fell asleep). Subjects' self-reported sleepiness immediately before each sleep opportunity did not, in general, correlate with their measured sleepiness. The authors also found that subjects demonstrated little ability to determine whether they had actually fallen asleep. For example, in 51% of trials in which the electroencephalographic and electro-oculographic measurements showed that the subject had fallen asleep, the subjects thought they had remained awake throughout the test. These results support the contention that medical personnel are physiologically vulnerable to degraded alertness yet are unable to perceive this decrement. Thus, an anesthesia professional could, in fact, fall asleep during a case, awaken, and be totally unaware of the lapse in vigilance.

**Mood.** Long work hours, fatigue, and sleep deprivation have been shown to bring about consistent and dramatic changes in mood and emotions. Depression, anxiety, irritability, anger, and depersonalization have all been shown to increase during testing of chronically fatigued house staff. These emotions are an obvious source of stress between anesthesia professionals and their co-workers, patients, and families. The relationship of mood, performance, and patient safety has yet to be determined.

**Sleep Inertia.** Sleep inertia corresponds to the period of reduced ability to function optimally immediately on awakening. This phenomenon usually occurs when individuals are awakened out of slow-wave sleep and is manifested as grogginess and impaired performance lasting as long as 15 to 30 minutes after awakening. Sleep inertia can also occur after being awakened from normal sleep and is most common during the early morning circadian trough (2 to 6 am). Depending on the preexisting level of sleepiness, individuals who take naps longer than 40 minutes are at greater risk for sleep inertia on awakening.

**PATIENT SAFETY ACTION BOX**

Sleep inertia can be important to health care professionals who may be awakened out of deep sleep to provide emergency care to patients (e.g., emergency cesarean section or emergency intubation). If urgent work can be anticipated, the sleeping individual should be awakened with sufficient time (at least 15 minutes) to minimize the fogginess and decrement in performance associated with sleep inertia. Another option is to not sleep longer than short naps in situations where immediate performance is required. If sleep inertia is unavoidable, it would be wise for the affected person to ask for help until the grogginess dissipates.

**Effects of Fatigue on Anesthesiologists' Performance and Patient Outcome.** It is highly uncertain as to whether, how, or in what circumstances these established psychophysical changes might interact with clinical work processes to affect patient safety in anesthesiology. Various methods are used for assessing an individual's level of sleepiness, including behavioral indicators, subjective measures, and physiologic (objective) measures.

The survey by Gaba and associates revealed that more than 50% of respondents believed that they had made an error in clinical management that they thought was related to fatigue.[56] In another survey of anesthesiologists and CRNAs, 61% of respondents recalled having made an error in the administration of anesthesia that they attributed to fatigue. In a study in 2011, a large, national, random sample of CRNAs in the United States was asked to complete an anonymous survey to quantify sleep activity.[253] Findings of the almost 1300 respondents revealed that nearly 16% have experienced sleep-related behavior during a surgical case, and close to 50% have witnessed a colleague asleep during a case. A similar survey of CRNAs was conducted in 2015, where nearly 30% of the 325 respondents reported they had committed a patient care error because of fatigue.[254]

The challenge of sleep deprivation and fatigue in medical personnel was addressed by the Joint Commission on Accreditation of Healthcare Organizations in 2011 in a Sentinel Event Alert on "Health Care Worker Fatigue and Patient Safety."[255] The Sentinel Event Alert is public and can be retrieved from the homepage of the Joint Commission. Sinha and co-workers ask: *"The fatigued anesthesiologist: A threat to patient safety?"*[256] and Gregory and Edsell picked up the topic in their educational publication in 2014. [257]

Considerable research on fatigue effects has targeted the transportation industries, especially driving which needs both continuous vigilance and psychomotor skill. If a driver has microsleeps lasting many seconds a problem is likely, unless the road is quite straight or there is an autosteering/autospeed autonomy. Even in health care, studies have largely been carried out in hospital ward settings where, during night on-call shifts, they may have responsibility for many patients.[258] The anesthesiology environment is different. Each patient having anesthesia will have at least one anesthesia professional in constant attendance and that individual is not directly responsible for other patients at the same time. Moreover, although vigilance is indeed the slogan of the ASA, there are few situations that require sustained second-by-second attention. The demand for high vigilance and effort does not usually occur at random; such situations are usually present at induction, emergence, and a few key milestones during the surgical procedure. Critical events are uncommon, and even when the chain of accident evolution has begun, the clinical team will likely have multiple opportunities to detect and correct it before any substantive negative impact has occurred. Thus, while anesthesia personnel may be prone to fatigue, and complaints about sleepiness and fatigue are common, the probability of a negative patient outcome during anesthesia directly attributable to sleepiness alone is very small. In health care, there is no formal mechanism for evaluating causation in adverse events, let alone for evaluating sleep-wake issues and fatigue, so one does not know the full contribution of this factor to negative outcomes. As for many aspects of human performance, variables that can be reliably and precisely measured do not capture the complexity or the typical resilience of clinical work. Conversely, measures and techniques that do address such factors are by nature non-quantitative and invasive.

Howard and colleagues conducted a study of rested versus sleep-deprived (awake for 25 hours on a pseudo-on-call period) anesthesiology residents by collecting multiple measures of performance during a 4-hour high-fidelity simulation scenario: Mood questionnaire, PVT psychomotor reaction time, response time to secondary task probes, and response to changing clinical events.[78] Psychomotor tests revealed progressive impairment of alertness, mood, and performance over the course of the pseudo–on-call period, as well as on the experimental day, when compared with the well-rested condition. Secondary task probe response times were slower after sleep deprivation, although this reached statistical significance for just one of three probe types. No statistical difference in case management between conditions was reported—in fact, subjects in both conditions made significant errors. Sleep-deprived subjects cycled (often rapidly) in and out of sleepy behavior, and the most impaired individuals showed such behavior for more than 25% of the experiment (60 minutes).

A key thing learned about fatigue during this study[78] was that highly fatigued anesthesia personnel in simulations are not either awake all the time or asleep all the time. Rather they usually cycled frequently in and out of states of apparent wakefulness, drowsiness, and microsleeps throughout the simulated case. Typically, when awake their performance was at most mildly degraded but when they showed extreme drowsiness or were actually asleep their performance was essentially zero. Participants were observed being totally asleep at one moment but awakening just in time to happen to catch a probe stimulus or clinical event, and respond to it satisfactorily. For most subjects the fraction of time spent in highly impaired states was low as their microsleeps were brief, in part because even a quiet routine clinical setting has a variety of stimuli, including other personnel and their tasks. The intrinsic redundancies in the OR team, the potential benefits of monitor alarms, and the resilience of clinical systems and patients may explain why catastrophes during anesthesia are very rare even though many operations are conducted with personnel suffering from substantial chronic and acute fatigue.

**Fatigue Countermeasures.** Anesthesia professionals cannot prevent sleepiness by willpower alone because it is a fundamental physiologic drive. Strategies that institutions or practitioners can use to minimize the negative effects of sleepiness and fatigue on performance include: education and promotion of safety culture, improved sleep habits, rest breaks at work, strategic napping, medications and social drugs, and light therapy. Strategies that national bodies and professional societies and organizations can call for are reasonable duty hour requirements.

**Duty Hour Requirements.** One direct regulatory strategy to minimize sleep deprivation has been to limit the work hours of clinicians. For the most part this has been attempted only for those in training (who traditionally have worked very long hours both during the day and in nighttime on-call). Results of process and outcome studies have varied but there has been no proof that such regulations, by themselves, improve patient safety.[259] Changing work schedules will not eliminate chronic fatigue, and in settings where clinicians at night may cover large numbers of unfamiliar patients the probability of information loss and confusion across the handoffs may outweigh any benefits of greater alertness. Yet, these findings may not apply to the anesthesiologists' operating room environment in the same way. The previous studies provided addressed the effects of sleep deprivation and fatigue on physician performance and well-being.

Back in 2003 the Accreditation Council for Graduate Medical Education (ACGME) instituted the first set of common duty hour requirements for all accredited residency training programs in the United States. Those requirements were revised in 2011[260] in response to the 2009 Institute of Medicine (IOM) report entitled *Resident Duty Hours: Enhancing Sleep, Supervision, and Safety.* A white paper published by Blum and colleagues debates the latest information and innovative practices on the topic and discusses how to best implement the 2009 IOM recommendations.[261] Work hour regulations in the European Union and in Australia or New Zealand are much more stringent than they are for trainees in the United States. For more details on work hour regulations see also further literature.[259,262,263]

**Education and Safety Culture.** A first and relatively simple and inexpensive step in addressing sleepiness and fatigue of medical personnel is to educate practitioners and the administrators of health care institutions about the impact of sleep issues on work performance, mood, job satisfaction, and health. Educational programs covering sleep deprivation, circadian disruption and fatigue, and countermeasures have been enthusiastically adopted by an increasing fraction of the aviation community. Similar programs should be developed for the health care community. However, it is clear at both the individual and organizational level that education will not be sufficient to address this issue fully. Other competing forces, for example measures of production versus safety, are very powerful and difficult for practitioners to manage.

The organizational framework plays a major role. Only if fatigue is seen as an organizational issue affecting safety negatively and safety is made a high organizational priority with all the resulting consequences, will fatigue-related safety issues be minimized. For an organization that implies, for example, that (a) tired staff are not always implicitly expected to work under all circumstances, (b) opportunities are created for tired staff to rest and to recover (i.e., regular rest breaks, strategic napping, etc.), and (c) an organizational safety culture is fostered that allows anesthesiologists to call for the assistance of a colleague (teamwork, speak up, see next section) when they know that they are impaired (from fatigue or for any other reason), without any negative consequences (cowardice, etc.). For additional countermeasures also see the Sentinel Event Alert of the Joint Commission[255] introduced earlier.

IMPROVED SLEEP HABITS. It is important to obtain adequate sleep. Most adults need at least 8 hours and the amount you need will not change—no matter what you do. Good sleep habits include the following: regularity of bedtime and wake-up time; sufficient time for sustained and individually adequate sleep; restriction of alcohol, caffeine, and nicotine before bedtime; and use of exercise, nutrition, and environmental factors so that they enhance rather than disturb sleep. Also, mobile devices should be put aside about half an hour before sleep—not only because of their (blue) light that signals "wake-up time" to the body, but also because a lot of what you read in them might get your heart-rate up, not down.

A regular sleep schedule is an important part of optimal sleep hygiene, but it is often not possible for medical personnel, given the requirement to cover clinical needs on a 24-hour basis. It helps to maintain as constant a sleep schedule as possible and to maximize sleep opportunities before and after periods of reduced sleep. Social drug use can have profound effects on sleep (see below). Ideally, the sleep setting should be a dark, quiet room devoid of sources of interruption such as pets, telephones, pagers, and children. Psychological stressors increase baseline physiologic arousal and can impair the quality and quantity of sleep. When possible, effort should be made to separate the work of the day with a period of relaxation before attempting to initiate sleep.

Caffeine and other stronger stimulants are known to reduce nocturnal sleep if ingested close to bedtime, hence decreasing sleep quantity and quality. Potent stimulants such as amphetamines do produce increased alertness and performance, but they have significant side effects and are not an option for health care personnel (e.g., the individual must undergo a substantial amount of recovery sleep ["crash"] after their effect is gone).

### Rest Breaks, Strategic Napping at Work, and Use of Caffeine

REST BREAKS. Although other industries have openly recognized the reality of decrements in vigilance resulting from fatigue and sleepiness, the health care system has not. Rest breaks and rotation of task duties are mandatory for air traffic controllers and are part of naval ship command procedures in an attempt to prevent potential lapses in vigilance. Short breaks in surgery have been shown to increase productivity and job satisfaction, and they probably also help alleviate boredom.[264] The organizational hurdle in anesthesia: oftentimes an extra anesthesia professional would be necessary to provide these opportunities on a regular basis.

The optimal timing and length of breaks are unknown, but periodic relief from duty should be taken when possible. Cooper and co-workers studied the effects of intraoperative exchange of anesthesia personnel.[265,266] Although in some cases the process of relieving OR personnel caused a problem, it more frequently was associated with the discovery of a preexisting problem. The positive effect of relief of personnel probably depends on the quality of the handover briefing conducted by anesthesia professionals. If anesthesia professionals are unable to obtain a break during long work periods, they can take other measures to remain alert. They can engage other OR personnel in conversation (although this, too, can be distracting), thereby increasing the level of stimulation in the environment. Walking around and standing up are also techniques that decrease subjective (but not physiologic) sleepiness.

STRATEGIC NAPPING AT WORK. If adequate sleep during the night cannot be obtained, naps can be used to decrease sleepiness and improve performance. The optimal nap length for most individuals is about 45 minutes; this duration acutely improves alertness, allows improved performance, and minimizes the possibility of sleep inertia on awakening. Naps as short as 10 minutes have beneficial effects on alertness. A nap of 90 to 120 minutes allows a full sleep cycle and can additionally boost alertness and performance over that of shorter nap periods.

Health care professionals oftentimes have an individual and cultural tendency to ignore or to minimize the effect of fatigue and sleep deprivation and to view work breaks and naps as signs of weakness. The military has addressed similar attitudes with the concept of 10 minute power napping, presenting naps in a positive light as a sign of wisdom and strength rather than one of cowardice and frailty. Again, the predominant organizational safety culture is one of the key elements—how critical safety and quality issues like fatigue are judged and how those obstacles are met (see above and later sections on "Patient Safety at the Organizational Level").

Smith-Coggins and associates studied the effect of naps during the night shift on health care providers working in a busy suburban university emergency department.[267] The investigators found that a nap improved performance on some (but not all) measures. The most important result of this study may be the fact that the subjects were able to (1) use this strategy successfully in the real workplace and (2) improve alertness and performance. At some sites within the Veterans' Affairs system a strategic nap program has been successfully developed and implemented in ICU settings.[268] Components included a formal educational program, guidelines for the individual practitioner and the facility, and other guidance for implementation. No additional staff members were required for the implementation, as the program allows individuals to nap during scheduled break periods. Certain issues complicate the appropriate use of naps by medical professionals. Locating space for the nap has proven to be a major (and continuing) hurdle.

USE OF CAFFEINE. Physicians frequently use caffeine to stay awake and to increase alertness temporarily during on-call periods, but often its use could be more strategic. Strategic use of caffeine includes (1) knowledge of its onset (15 to 30 minutes) and duration of action (3 to 4 hours) and (2) use when alertness is required and the opportunity to sleep is minimal. Besides its alerting effects, caffeine produces an increase in awakenings and decreases the total nocturnal sleep time if ingested close to sleep opportunities. Long-term use of caffeine, common in our culture, produces tolerance to the alerting effect of the drug and hence should be avoided when using caffeine strategically. Nicotine is a stimulant that produces effects similar to those of caffeine.

While anesthesia professionals might get away with working when sleepy without affecting aggregate patient outcome that does not mean that issues of sleep deprivation and fatigue should be ignored. Falling asleep (a long microsleep or full sleep) while taking care of a patient is just not acceptable; it's surely not what any patient or their family has a right to expect. Thus, both the individual anesthesia professional AND the systems and institutions they work within need to address the fatigue issue systematically. It is clear that just placing limits on work hours, either for trainees alone (the current situation in many countries) or for fully certified personnel as well, cannot do so. Only an integrated approach aimed at improving individuals' sleep hygiene along with reorganizing the structure and processes of clinical work will stand any chance of ensuring that anesthesia professionals who are appropriately alert are always there vigilantly protecting their patient.

### Aging Anesthesiologists

Human abilities cannot be maintained indefinitely as humans age. On average, performance on laboratory tests of discrete sensory-motor and cognitive skills can be shown to decrease with increasing age.[269] However, large differences are noted among individuals. Again, except at extreme points of performance failure (e.g., severe impairment of vision, hearing, or cognition), the contribution of isolated changes in physiologic or cognitive performance is difficult to relate to real work situations. The work environment is often rich with redundant cues involving multiple sensory modalities, and technologic compensation for physiologic deficits is common (e.g., hearing aids or glasses). Advancing age is associated with worsening performance when tasks involve single-solution or fluency-based definitions of effectiveness.[270] However, along with possible physiologic changes of age typically comes greater experience with a variety of situations. When efficacy is defined in terms of the diversity of strategies used, as well as by the social and emotional impact of solution choice on the individual, performance is remarkably stable and sometimes even improves in the latter half of life.[270]

For many individuals, the lessons learned from experience more than offset the modest degree of physiologic impairment that they face as they grow older. Issues attributed to "age" might instead be related to a longer period away from initial or recurrent systematic training. The originally well-trained practitioner who keeps abreast of the changing standard of care and who exercises emergency skills frequently is less likely to be affected by advancing age than is a marginal practitioner whose knowledge and skills were frozen immediately after completion of initial training. For anesthesia professionals who are enrolled in mandatory maintenance of certification programs this issue might be less serious.

Patient care is a socially-organizationally constructed activity. Aging anesthesiologists may be able to modify their practice type, reducing complexity of cases or eliminating on-call and post-call patient care. Other perioperative team members may also be available to support those who while still competent may be, on any given day, not at their best.

What do other industries do about this issue? In the United States, from 1959 to 2007 there was a limit at 60 years of age for airline pilots; this has since been changed to age 65. Many countries have a higher limit and some have no limit. Moreover, regulations require airline pilots to pass a class I medical examination every 6 to 12 months, aimed at identifying individuals with chronic medical conditions that place them at risk for sudden incapacitation. Simulations show that sudden pilot incapacitation during a high-workload phase of flight (e.g., approach and landing) leads to a significant rate of crashes, even when a second pilot is at the controls. These physical examinations may also weed out pilots with severe cognitive or sensory-motor deficiencies (vision in particular), but they are not designed to assess subtle aspects of changes in performance resulting from age. Airline pilots' flying performance is also formally assessed annually throughout their career both during real flights and in simulation.

For anesthesia professionals, by contrast, there are no statutory requirements for medical examination or formal performance checking, although individual institutions or practice groups may choose to impose testing requirements or to implement age-based reductions in daytime or on-call requirements. No doubt, the issue of age-related effects on anesthesia professional performance is likely to continue to be raised periodically for the foreseeable future.

### Illness and Drug Use

Every anesthesia professional is vulnerable to transient illnesses, which in some cases probably reduce performance ability. All personnel are vulnerable to chronic medical conditions that could directly or indirectly affect their fitness and performance capability. The culture of the caring professions often leads individuals to continue to work with illnesses that would cause other professionals to stay at home or to seek medical advice. The performance-shaping effects of the illness can be exacerbated by the use of either over-the-counter or prescribed medications. The degree to which illnesses and medications affect professional performance in anesthesia is unknown.

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Pilots use a mnemonic checklist to review the effects of potential performance-shaping factors and are instructed not to fly if they are impaired for any reason. One similar safety strategy in health care is the "I'M SAFE" approach,[271] promoted by the patient safety intervention strategy "TeamSTEPPS," which is explained more in detail later. "I'M SAFE" is a simple personal checklist to determine one's ability to perform safely concerning the factors: **I**llness, **M**edication, **S**tress, **A**lcohol/Drugs, **F**atigue, **E**ating and Elimination. The difficulty in anesthesiology is that the real-world organization and incentives of many practice settings do not provide mechanisms for personnel to excuse themselves if they are temporarily impaired and that there barely exist organizational structures and departmental understanding to promote such approaches (lack of "safety culture").

A more serious problem for anesthesia professionals is that of drug and substance abuse.[272-275] Nearly 15% of all doctors will become substance-dependent over their lifetime, and the incidence in anesthetists is almost 3 times greater than other physician groups. Including alcohol, studies describe up to 3.5% of anesthesiologists being addicted; if alcohol is excluded, drug addiction occurs in about 2.5%.[276,277] The degree to which small doses of alcohol or hangovers affect performance on complex, anesthesia

**TABLE 6.3** Examples of Hazardous Attitudes and Antidote Thoughts[279]

| Hazardous Attitude | Antidote Thoughts |
|---|---|
| **Antiauthority:** *"Don't tell me what to do. The policies are for someone else."* | *"Follow the rules. They are usually right."* |
| **Impulsivity:** *"Do something quickly—anything!"* | *"Not so fast. Think first."* |
| **Invulnerability:** *"It won't happen to me. It's just a routine case."* | *"It could happen to me. Serious problems can develop even in routine cases."* |
| **Macho:** *"I'll show you I can do it. I can intubate the trachea of anyone."* | *"Taking chances is foolish. Plan for failure."* |
| **Resignation:** *"What's the use? It's out of my hands. It's up to the surgeon."* | *"I'm not helpless. I can make a difference. There is always something else to try that might help."* |

tasks is uncertain. The natural history of serious abuse of alcohol, cocaine, sedatives, or narcotics by anesthesia professionals is such that cognitive performance will at some point be seriously compromised, although addiction specialists frequently report that job performance is one of the last areas of life to become seriously impaired.[273,275,278] The period of time in which an addicted anesthesia professional's performance in the OR is significantly impaired may be a relatively small fraction of the total time during which drugs are abused. Although this in no way excuses the practice of conducting anesthesia while under the influence of drugs, it may account for the fact that reports of addicted anesthesiologists are, unfortunately, common, whereas reports of overt patient risk or harm resulting from an addicted physician's errors are unusual. A host of other threats to patient safety, including production pressure, fatigue, illness, burnout, and distraction will affect far more anesthesia professionals, occur more regularly, and pose greater safety risks to patients, but they do not carry the same level of risk to the professional's own life, nor the same social stigma, as does addiction. On the other hand, diversion of drugs from the patient who needs them to the addicted clinician for use or sale is a growing risk.

### Professionals' Attitudes as a Crucial Part of Human Performance and Patient Safety

Attitudes are important components of one's abilities. They can affect performance as strongly as physiologic and cognitive performance-shaping factors. Psychologists studying judgment in aviators have identified five types of attitude as being particularly hazardous, and they have developed specific antidote thoughts for each of these, which are supposed to be verbalized by pilots whenever they find themselves thinking in that way.[279] The authors have adapted these to anesthesiology shown in Table 6.3.

The invulnerable and macho attitudes seem particularly hazardous for anesthesia professionals. They are compounded by production pressures to handle more cases in less time with fewer cancellations and less opportunity for preoperative evaluation. The feeling that a catastrophe "cannot happen to me" and that perfect performance can always be relied on to avert a disaster can lead to cavalier behavior and poor planning. It can alter thresholds for believing that abnormal data represent a problem, thereby leading to the fixation error of "everything's OK."

Expert human performance is the anesthesia professional's most powerful tool to safeguard the patient. However, planning to avoid catastrophe is likely to be more successful than battling to avert it. The economic and social realities of practice can cause these pressures to become internalized by anesthesia professionals, who then develop hazardous attitudes they might otherwise have resisted.

Under these conditions the usual protocols for elective case management must be adapted to seek the best outcome for the patient. In the final analysis, one must ensure that the patient's benefit is the primary criterion in such decisions, and one should establish a bottom line of safe planning, pre-use equipment checks, and patient preparation beyond which one will not be pushed. Even if surgeons, nurses, colleagues, or administrators pressure one to do things that one does not think are safe, no one will thank you if the patient suffers, nor will they come to your defense should litigation arise.

To simplify these decisions, many institutions have developed multidisciplinary written consensus guidelines on the preoperative preparation of patients that address the appropriate workup for patients with various medical conditions in different surgical urgency categories.

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Sometimes it might seem appealing for a medical professional to emerge as a hero after a problem is solved or a complication is managed, but the challenge is to realize first that anesthesia professionals cannot rely primarily on heroism to achieve optimal safety, and second that in all likelihood no hero would have been needed at all if proper safety measures had been taken to begin with.

In their review *"Why hospitals don't learn from failures: organizational and psychological dynamics that inhibit system change,"* Tucker and Edmondson[280] describe a further aspect of professionals' attitudes that can have implications on safety*:* People are creative and they want to make things work for their patient. So, nearly every day they diligently work around problems and obstacles the best they can. However, the very acts of individual resourcefulness by such workarounds may mask the underlying systems issues that expose many patients to risk and thereby delay addressing successfully those very issues.

## HUMAN FACTORS AT THE TEAM LEVEL

This section focuses on the human factors at the team level, exploring the key elements (a) effective communication including handoffs and the delegation of tasks; (b) the safety enhancing strategy "speaking up"; (c) aspects of status and hierarchy effects in teams; (d) teamwork including (e) leadership aspects.

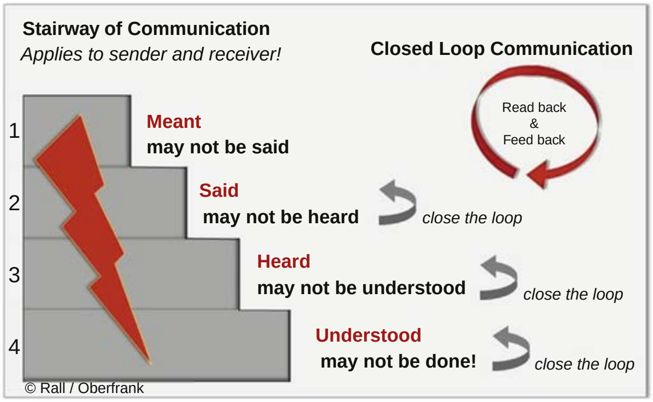


**Fig. 6.6 Stairway of Communication and Closed Loop Communication: The importance of proper communication.** (1) Especially when dealing with complex situations under time pressure, but also during routine work, people tend to "mean" or "think" a lot, but "say" little. It is important to let other team members know what one thinks in order to create shared mental models of a situation. (2) For several reasons, not everything that is said is necessarily heard by those who should hear it. The sender needs to ensure that the message was heard by the receiver and the receiver needs to confirm the message (= closed loop communication). (3) Acoustic hearing and mental understanding are not the same. "Closely monitor this patient" might be clearly heard, but what is meant is open for interpretation on a large spectrum. Misunderstanding can result, but can be smoothed out. (4) Some tasks may be forgotten, making double checking necessary. Some tasks need time to be completed, some tasks may fail. No matter what, the team needs to know (= closed loop communication).

## Effective Communication and Delegation of Tasks

The benefits of effective communication for patient care in anesthesia and the operating room have been repeatedly demonstrated.[281-284] However, the term effective communication is imprecise leaving much room for interpretation. In fact, communication is never a one-way street and effectiveness includes participation of all team members.[285] Based on research showing that teams unfortunately tend to communicate ineffectively, effective communication refers to both content and form.[286] Teams should routinely use and update information from multiple available resources, share key elements between team members, and strive to always communicate as clearly as possible.[286,287]

**Closed Loop Communication.** For example, addressing team members by name and engaging in closed loop communication (Fig. 6.6) can help avoid misunderstandings.[288-290] Closed loop communication includes (a) when the sender initiates communication, the receiver confirms that the communication has been heard by repeating the content of the communication and (b) when a delegated task is finished, the receiver gets back to the sender and the sender confirms the feedback. For instance, instead of saying *"Can someone call for help, please?"* closed loop communication presents as follows: *"Jeff, can you call for help, please."—"Yes, Megan, I will call for help immediately."—"Megan, I have called for help and they are on their way."—"Ok Jeff, thank you."* El-Shafy and colleagues evaluated the effectiveness of closed loop communication in trauma settings of a level I trauma center in the United States, analyzing all verbal orders issued by the trauma team leader for order audibility, directed responsibility, check-back, and time-to-task-completion.[291] In total, 89 trauma videos were reviewed, with 387 verbal orders identified. Of those, 126 (32.6%) were directed, 372 (96.1%) audible, and 101 (26.1%) closed loop. On average each order required 3.85 minutes to be completed. There was a significant reduction in time-to-task-completion when closed loop communication was utilized. Orders with closed loop communication were completed 3.6 times sooner compared to orders with an open loop. The authors highlighted that closed loop communication not only prevents errors, but has the potential to increase the speed and efficiency with which tasks are completed in the setting of trauma.

**ISBAR Tool.** Another effective communication tool especially useful for sharing information is the ISBAR concept (Fig. 6.7), often abridged to just SBAR. The acronym stands for **I**ntroduction, **S**ituation, **B**ackground, **A**ssessment, and **R**ecommendation. It originated in U.S. nuclear submarines and has also been used in the airline industry. ISBAR may be used variably by different members of the OR team.[292] Its use is associated with increased accuracy in communication and safety climate[293] and a decrease in communication errors[293] as well as in unexpected death.[294]

In the medical setting, ISBAR is a universally applicable communication tool that is usable in several settings, including for example face-to-face as well as telephone handovers in the OR or in the anesthesia post-anesthesia care unit. It also can be used for the briefing of new team members during emergencies and for briefing senior staff who has been asked for help. In the literature the slogan "Think—Talk—Write—ISBAR" can be found and characterizes the broad field of application of the idea. Shahid and Thomas give an up-to-date narrative review of the current literature on (I)SBAR, the challenges of communication among health care providers, and the proper use of the tool, and compares it to other communication tools that exist in order to assess their strengths and weaknesses.[295] For -detailed information the reader is referred to this review.

Because it assists the transfer of important information in limited time, ISBAR has been adopted by many health care organizations across the world. Medical associations and leading health care organizations, like the German Association of Anesthesiology and Intensive Care Medicine—Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin (DGAI), the Australian Commission for Safety and Quality in Health Care (ACSQHC), the Institute of Healthcare Improvement (IHI), and the WHO have endorsed the (I)SBAR method as a standard communication tool, when appropriate, for health care providers. The experience in the United States is that SBAR has been adopted (in principle if not always in widespread practice) for nurses but is not frequently used by physicians.

**PATIENT SAFETY ACTION BOX**

Why use ISBAR (or SBAR)? It has the potential to improve patient care by enhancing transfer of information, responsibility, and accountability. It can improve patient safety by encouraging complete communication. ISBAR is an easy-to-remember memory prompt that helps providers (a) to prioritize what needs to be said by preparing consciously for communication, and (b) to set expectations on what will be

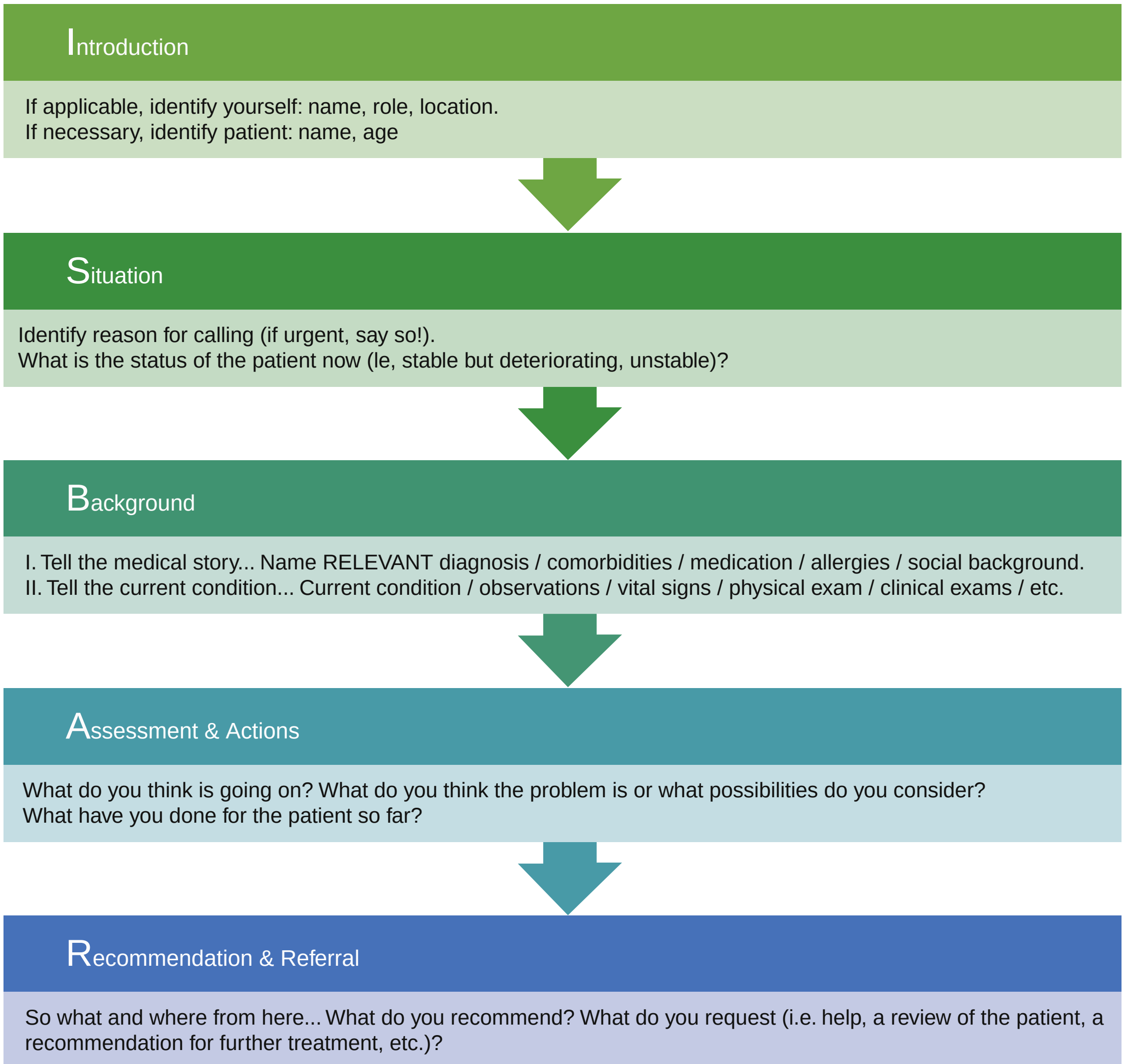


**Fig. 6.7 Example of the use of the communication tool ISBAR.**

communicated (shared mental models). ISBAR can reduce barriers to effective communication across different levels of staff, professions, and disciplines. Its application should be expected for routine cases, which will then enable its use even during stressful events.

**Handoff Protocols**[*]**.** Another aspect of safe and effective communication concerns post-intervention handoffs and intraoperative transitions of care responsibility, which are known settings of risk for critical information to be lost.[296] Intraoperative anesthesia care transitions are known to be associated with adverse postoperative outcomes, with a similar effect size for attendings, residents, and nurse anesthetists.[297] Sometimes though the new person may be able to take a fresh look at the situation, catch errors, or find opportunities to improve care.

Handoff protocols are intended to minimize patient risk by creating a designated time and framework to ensure that crucial information is not missed during care transitions. There is an increased focus on formal protocols because the number of patient care handoffs has markedly increased in some settings due to work hours limits. Protocols can be divided into conceptual models (e.g., IQ—a reminder that the caregiver should inform the receiving provider about the details of the patient and case and then allow them to ask questions before leaving) or scripted models (e.g., I-PASS[298] which stands for **I**llness severity, **P**atient summary, **A**ction list, **S**ituation awareness and contingency plans, and **S**ynthesis by receiver, or I PASS the BATON[271] which stands for Introduction, Patient, Assessment, Situation, Safety Concerns [the] Background, Actions, Timing, Ownership, Next).

Another comparison can be made between verbal and written handoffs and also supplementing a primarily verbal handoff with written information. When a patient's care is being transferred to a different care team, such as when a patient moves between the intensive care unit and the operating room, a team-to-team handoff is beneficial because the report and questions about the patient are consolidated for both teams (e.g., time out for sign out).[299] A good handoff process should be used for every transition, including intraoperative transfers for breaks,[300] dropping

*Acknowledgment: This section on handoffs was contributed by Lisa Sinz, MD (Penn State University School of Medicine).

off the patient in the PACU,[206] or changes from one anesthesiologist to another during a case. Using a checklist or structure can help prevent lapses, but regardless of the tool used, the goal is to provide clear and complete communication to protect the patient from medical errors.

**Effective Delegation of Tasks.** Delegation of tasks is sometimes ineffective leading to frustration on both sides: the person delegating and the person meant to perform the tasks. A common failing is when the delegation is incomplete and subject to assumptions, leaving too much room for interpretations.

The granularity of delegation instructions may depend on the personnel involved. For peer anesthesia professionals it may work to delegate a whole area of responsibility, such as "Sara, can you handle airway management please?," trusting that person to make the necessary decisions on their own. In other cases, especially with less experienced personnel, simply saying *"Michael, take care of the blood pressure"* may be insufficient because both the leader and the follower may have different assumptions of what that means in practical terms. With such a mismatch both parties may be unhappy. In such settings a more detailed delegation instruction may be needed, such as

*"Michael, because our patient has a known hypertension and a risk for stroke, try to keep the diastolic blood pressure at or above 80 mm Hg. If necessary, give up to 500 ml crystalloid and, if necessary, small doses of ephedrine. If that doesn't handle it let me know. Any questions?"*

**PATIENT SAFETY ACTION BOX**

Effective delegation of tasks involves sharing mental models of the situation and oftentimes also sharing concrete orders or suggestions about what one expects the other to do in order to fulfill the task to the other person's satisfaction. One reason why delegators do not use concrete delegation of tasks is because they think that it would take too much time or because they assume that the other person knows or should know what do to. Those few seconds to make it as concrete as the situation requires will probably pay off in the long run.

**Asking Open-Ended Questions.** A useful and simple means of communication, particularly in interprofessional and interdisciplinary settings, is to ask about other team members' points of view and plans using open-ended questions.[281,301]

### Status and Hierarchy: Speaking Up

Speaking up refers to "*discretionary communication of ideas, suggestions, concerns, or opinions about work-related issues with the intent to improve organizational or unit functioning*" (p. 375).[302] Often the notion of speaking up implies doing so from below to above in the authority gradient. Without speaking up, problems cannot be identified, ideas will not be shared, and potential harm will not be prevented. This is particularly important in the multidisciplinary, complex, dynamic, and yet confined environment of operating rooms.[303] Here, a team member's speaking up to raise concerns about potentially risky or inappropriate actions of other team members may often be the final barrier to an emerging adverse event.[10,304-307] Unfortunately, speaking up is rare in teams in general and in operating room crews in particular.[308-310] In a survey of 137 chiefs of medical and surgical departments, 70% said that problems were not addressed and "elephants in the room" were common.[311] Simulation-based studies in anesthesia have demonstrated that in situations that need speaking up, only 40% to 70% of the participants did so.[312,313] For example, one such study showed that faculty anesthesiologists only spoke up: (a) 73% of the time to a surgeon who demonstrated profound sleepiness; (b) 14% of the time to a nurse who put a pathologist on speakerphone while the patient was awake and could hear; and (c) only 24% of the time to an anesthesiologist colleague who ordered the wrong treatment.[303] Creating conditions that encourage speaking up is particularly useful for crews whose composition is constantly changing, so members do not have time to develop as team.[314] This instability impedes the development of both norms to speak up as well as psychological safety, that is, the perception that there is no jeopardy to one's position if they do speak up.[315]

**BOX 6.3 Raising Safety Concerns - the CUS Tool**

The CUS tool[271] is used to clearly communicate and escalate a rising level of concern for any issue and to focus a team's attention on specific key phrases that are linked to raising concerns. When a team member uses the phrase *"I am **c**oncerned…"* it is to get the team's attention and to ensure that team members are listening. In order to escalate the concern, the team member would use the phrase *"I am **u**ncomfortable because…,"* finally escalating the concern with the phrase *"This is a **s**afety issue…."* Then the current action must be stopped ("Stop the line!") and evaluated before continuing. Having a common framework, consisting of those three escalating key phrases, provides teams with a standardized, easy-to-use, attention-providing communication tool to raise concerns. At the same time, team members have a clear idea of the level of importance associated with the concern, due to the escalating concept.

Strong hierarchies, which are prevalent in many hospitals, constitute a barrier to speaking up.[303,316-318] Even formal systems designed to promote it may actually inhibit staff from speaking up.[319] Leadership is a powerful tool in facilitating it: leaders can support speaking up by providing direction and coaching,[320] by using inclusive language,[321] by implementing debriefings to reflect on speaking up, and by establishing and maintaining a norm that considers such actions as socially desirable.[322] New research shows that people who do speak up are seen as more confident, competent, and of higher social status than those who do not speak up.[323]

Two explicit safety strategies that can be used for speaking up are, for example, the CUS tool (Box 6.3) and the two-challenge rule (Box 6.4).[271] But the basic requirement for both tools, for them to work properly and beneficially, like with any tool, is the organizational integration and acceptance of the tools (see section on organizational aspects of patient safety and safety culture).

**BOX 6.4 Raising Safety Concerns - The Two Challenge Rule**

The two-challenge rule[271] is another strategy that also empowers all team members to "Stop the line!" if they sense or discover an essential safety breach.

The two-challenge rule emphasizes the following:

- It is everyone's responsibility to assertively voice concern ***at least 2 times*** to ensure that it has been heard
- The team member being challenged must acknowledge ***with an active verbal response*** that concern has been heard
- If the safety issue still hasn't been addressed: Team members should take a stronger course of action or utilize supervisor or chain of command

**PATIENT SAFETY ACTION BOX**

Speaking up is never easy. It gets even harder if there is a difference in the hierarchy and experience level or if there is little positive organizational safety culture. Nevertheless, it is important to speak up if patient safety is in danger. The key to speaking up is often how to put things and when to intervene. Speaking up can be misinterpreted as a strategy to always tell colleagues what oneself would do differently. But speaking up should be used only in the case of a patient (or a colleague, or a piece of relevant equipment) at (potential) risk. To initiate speaking up it can help to have (organizationally) standardized phrasing, like for example, *"Excuse me, I see a patient safety issue here….*" Other systematic ways of expressing concern are the use of the CUS tool and the two-challenge rule. It also helps to explain one's thoughts and state a reason for the concern or the objection. For example instead of saying *"Succinylcholine…??? Do you really want to induce with succinylcholine???"* it is more helpful to say: *"Excuse me, in my eyes there is a patient safety issue using succinylcholine for induction. The patient has a potassium of 5.3 mmol/L so I think rocuronium would be better for induction, since the patient could get serious hyperkalemia and suffer cardiac arrest…"*

## Teamwork

Teamwork can be defined as "*skills for working in a group context, in any role, to ensure effective joint task completion and team member satisfaction [.... and includes] coordinating activities with team members; exchanging information; using authority and assertiveness; assessing capabilities; supporting others.*"[170]

Unlike teams in aviation, the military, and police and fire services, the OR team is unusual in that the command structure is ambiguous. Physicians (surgeon and anesthesiologist) are nominally superior to nursing and technical staff, but the two sets of physicians are coequally responsible for the patient during the immediate perioperative period.

Although surgeons were historically considered the "captain of the ship," with even a legal doctrine giving them responsibility for the actions of all other OR team members, this has long since formally fallen by the wayside. Nonetheless remnants of this old history remain in aspects of the organizational structure and culture of OR environments. Clearly though when both anesthesiologists and surgeons are jointly caring for a patient, they are both responsible, and this situation can lead to complex issues of command authority, hierarchy, and control. Cooper recently published a paper investigating the critical role of the surgeon-anesthesiologist relationship for patient safety.[324] Even though there is little research about this relationship, Cooper argues that the relationship for each surgeon-anesthesiologist dyad is perhaps the most critical element of overall team performance. His article explores functional and dysfunctional aspects of the relationship, identifies negative stereotypes each profession has of the other, and offers some suggestions on how to improve the working relationship.

Apart from the challenge of the coequal responsibility of the patient, the composition of teams in the OR holds some further challenges. Salas and colleagues defined a team as *"a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/ objective/ mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership"* (p. 4).[325] A team is distinct from a group in that a group is an ad hoc collection of individuals without a specific mission and without specific roles. In the OR, all team members have the common goal of a good outcome for the patient. However, considerable disagreement can exist on how to achieve this goal and which elements of patient care have the highest priority. These differences are probably traceable to the fact that the OR team is itself made up of several crews (e.g., surgery, anesthesiology, nursing, as well as sometimes technical personnel from several domains) each of which has its own command hierarchy, its own global properties (professional standing, culture, traditions, and history), and its own set of local goals and objectives for management of the patient. A critical component of the success of this process comprises the establishment and maintenance of a shared mental model of the situation. The greater the overlap in mental models the more likely that team members will predict, coordinate, and adapt.[13] To the degree that these objectives can be accomplished, the different individuals will be able to tailor their efforts toward a common goal.

The quality of teamwork influences clinical performance in anesthesia.[326] Strictly speaking, teams in the operating room and resuscitation teams are not teams in the traditional sense that exist for an extended period of time with a shared goal and fixed team membership. Instead, they are considered action teams: members may be assigned together ad hoc for a rather short tenure, and team membership may change repeatedly.[81]

This has implications for teamwork and training: such teams have limited time to develop and learn as a team.[314] Instead, they must team off the cuff—an ability that has been described as teaming.[285] Teaming includes four pillars: speaking up (see earlier section), collaboration (i.e., adopting a collaborative mindset and collaborative behaviors), experimentation (i.e., working iteratively and considering uncertainty as inherent in interactions), and regular and continuous reflection about teamwork. Briefings and debriefings have been shown to offer an infrastructure for reflection in anesthesia and the OR.[314,327,328] Particularly for action teams such as in the operating room, establishing and updating shared knowledge is challenging. According to Cooke and Salas, team knowledge is more than the sum of individual team members' knowledge.[329] They distinguished between team mental model and team situation model. To judge team knowledge, information is also needed on the broader aspect of team cognition, which involves team knowledge itself, team decision making, team situation awareness, and team perception. Establishing team cognition and adapting to changing requirements requires targeted communication among team members.[215,288,290,330-332] This may be done explicitly to avoid misunderstanding and check mutual assumptions, or implicitly, for example by talking to the room.[153,290,301,333]

### Leadership

Whereas in aviation the roles of the captain and the first officer are carefully defined and involve separate but interrelated tasks, in anesthesiology the patient care roles and responsibilities of different members of the crew of anesthesia professionals—whether experienced or in training—are rarely predefined or made explicit. For example, a trainee is often expected to do all tasks with only occasional assistance from the supervisor. Leadership is pivotal in critical, non-routine, and highly complex situations in anesthesiology.[82,334,335] It includes a variety of functions such as composing team, defining mission, establishing expectations and goals, structuring and planning, training and developing, sense making, providing feedback, monitoring the team and managing its boundaries, performing team tasks, challenging the team, solving problems, providing resources, encouraging team self-management, and supporting social climate.[336] Some of these leadership functions may be shared among crew members.[335] A senior leader of a trauma team may dynamically delegate or withdraw certain active leadership roles to junior leaders.[337] While sharing leadership can be effective, it may require the team to know and discuss how to work well in this fashion[338] (see also later section on CRM, section "CRM Key Point 4"). This is important especially in highly dynamic, time-critical situations such as resuscitations in which leadership is critical for performance and has to be adapted to changing task and coordination requirements.[339,340] Behavior observation studies on leadership in acute care have shown that leadership behavior is positively associated with performance during critical and barely standardized situations, but negatively associated with performance during routine and highly standardized situations.[85] In addition, leaders should be role models of civil and respectful interaction as this is important for high and safe performance.[341,342]

**PATIENT SAFETY ACTION BOX**

There are many kinds of situations where it is not clear who is the team leader in a medical setting. For example, to nurses or even to the physicians involved, it might be unclear who is the team leader when two doctors of the same profession present during an emergency. Leadership may change as personnel of different seniority or expertise enter or exit the scene. It is helpful to clarify roles as necessary. For example: *"Thank you for the handover. Now I will take over"* or *"Thank you. You stay in charge and I will assist you,"* or if in doubt ask *"Just to double check: Am I still in charge or do you want me to assist you?"* or from the perception of a nurse *"I am sorry, but to better coordinate my work: who is in charge now?"*

A particular issue of hierarchy is known as cue giving and cue taking, in which people give off cues (often without even knowing it) that are taken up by others.[343] People lower in a hierarchy are very sensitive to cues emitted by their superiors, which can inhibit action or even questions from subordinates. Such cues may be read as *"don't bother me," "don't question me," "I know what I'm doing; you don't,"* or *"I just checked on that and it's fine,"* thus inhibiting speaking up. A qualitative, descriptive study on nontechnical skills in Sweden revealed that anesthesia nurses view anesthetists as excellent if they are calm and clear in critical situations, and able to change to a strong leading style.[344] More on leadership in anesthesia can be found later in the associated section of "CRM principle 4."

## PATIENT SAFETY STRATEGIES AT THE INDIVIDUAL AND TEAM LEVEL: CRISIS RESOURCE MANAGEMENT AND OTHER TRAINING CURRICULA

This next section is about how to minimize the negative human factors aspects of the anesthesia professional's physical, psychological, and organizational work environments and how to strengthen the positive aspects of individual and team performance. The CRM approach mentioned earlier is a useful organizing principle for tackling these issues. Below the authors (1) give a general explanation of the strategy and its history, (2) introduce the 15 key principles of CRM, (3) discuss the application of CRM in crisis as well as in routine medical situations, (4) cite evidence that CRM is beneficial in health care, and (5) briefly touch on other well-known team training curricula such as TeamSTEPPS and Medical Team Training (MTT).

### Crisis/Crew Resource Management

Crisis resource management (CRM) in medicine, sometimes also referred to as crew resource management, is an effective safety strategy concept and tool adapted from the domain of aviation and modified to the needs of health care. Gaba traditionally defines CRM: *"CRM is the ability to translate the knowledge of what needs to be done into effective team activity in the complex and ill-structured real world of medical treatment."*

In overview, CRM means to coordinate, use, and apply all available resources to optimally protect the patient—at an individual as well as at a team level. Resources include all the personnel involved, along with all their skills, abilities, and attitudes—albeit also with their human limitations. Machines, devices, and information sources, including cognitive aids, are also critical resources. In addition, CRM provides effective strategies that cover typical safety pitfalls attributed to the five main elements of human-factor-related behavior as introduced earlier. The underlying scientific basis of CRM is formatted into 15 practical CRM key principles health care professionals can apply during work (Box 6.5).

CRM was introduced in aviation by airlines working with NASA originally as cockpit resource management in the mid-1980s after some sentinel airplane crashes. It later was renamed crew resource management to acknowledge the importance of the crew, not only those in the cockpit. CRM from that time on was and still is considered to be a successful safety strategy in aviation and is also part of safety strategies in other industrial and military settings. Interestingly, even though these industries maintain CRM principles and CRM training as crucial parts of their safety processes, they do so without what evidence-based medicine would call "level 1 evidence"—sound randomized trials—to justify this.[11,345] In fact, such evidence would be impossible to collect.

A similar program for anesthesiology was first developed by Gaba, Howard, and associates at the Veterans Affairs (VA) Palo Alto Health Care System and Stanford School of

**BOX 6.5 Crisis Resource Management—Key Points in Health Care**

- Know the environment.
- Anticipate and plan.
- Call for help early.
- Establish leadership and followership with appropriate assertiveness.
- Distribute the workload. Use 10 s for 10 min concept.
- Mobilize all available resources.
- Communicate effectively—speak up.
- Use all available information.
- Prevent and manage fixation errors.
- Cross and double check. Never assume anything.
- Use cognitive aids.
- Reevaluate repeatedly. Apply 10 s for 10 min concept.
- Use good teamwork. Coordinate with and support others.
- Allocate attention wisely.
- Set priorities dynamically.

The key points are derived from the publication of Rall and Gaba in the 6th edition of Miller's Anesthesia[559] and presented here in their updated, current version.

Medicine [109,127] originally as anesthesia crisis resource management (ACRM). It was modified from the aviation-based CRM principles to better suit the medical needs. The ACRM-like curricula have since been adopted by training centers worldwide for a variety of health care domains.[346] A detailed description of the ACRM course is provided.[347] More in-depth information on CRM in anesthesiology is provided in related safety literature[11,59,123,127,348] and in both the first (1994) and second edition[14] of the pioneering *Crisis Management in Anesthesiology* textbook by Gaba, Fish, Howard, and now Burden. Note that the term crisis does not mean that these principles only apply in such dire settings; instead, they apply to everything in patient care but are most pronounced in challenging situations. In addition, the pioneers of ACRM wished to retain the CRM acronym without using terms like cockpit or crew that were not familiar in health care.

## The 15 Key Principles of Crisis Resource Management

The key points of CRM as they apply to anesthesia care have been steadily updated and expanded over time and are based on the research presented in the earlier sections. The 15 CRM key principles by Rall and Gaba (see Box 6.5) cover the content of the five main elements of human-factor-related behavior as introduced earlier: communication, teamwork, task management, decision making, and situation awareness (see Fig. 6.5). The CRM principles translate the theoretical content of those areas that are known to be important into handy and very applicable action strategies for health care professionals.

Looking closely, one can recognize that the different principles overlap in their content and aim in many cases. This way, different members and professions of a team can apply different CRM principles at different points of time during patient care, minimizing the risk of an error or harm to occur. Clinicians are not expected to memorize these principles; rather, the authors expect that they will be embedded into regular training and practice (see later section "How Can Crisis Resource Management Related Skills be Learned, Trained and Maintained").

Some of the principles may seem obvious or self-evident. However, from our experience in clinical work and simulation team training it is in fact *not* trivial to apply these principles in the real world. In the following sections the 15 CRM key points are introduced in detail.

**Know the Environment (CRM Key Point 1).** Knowing fully the environment of work is critical. Environment refers to equipment, supplies, processes, and people, as well as how they vary from case to case, or from location to location, time of day or day of the week. This knowledge reduces stress in the case of an emergency and provides more available mental capacity and prudence to deal with the case. It is important to know who can be asked for help, how to mobilize help quickly, and how long it will take help to arrive. Like pilots, anesthesia personnel can be expected to know in detail how to use all equipment and supplies, which in anesthesiology includes anesthesia machine, defibrillator, infusion and blood administration system as well as how to troubleshoot them or switch to backup devices. The experience of the authors as clinicians and teachers in real and simulated anesthetic cases suggests that many anesthesia professionals lack sufficient depth of knowledge or skill in the operation of their equipment. That these systems are not always designed optimally from a human factors standpoint only increases the need for the individual clinician to thoroughly learn about and practice with all their features and pitfalls.

**PATIENT SAFETY ACTION BOX**

**Know Your Environment**

- Know how to call for help and how to call a code in the event of a cardiac arrest or other major emergency.
- Know who to call for different kinds of problems or emergencies; learn the emergency numbers (or they may be present on available cognitive aids)—always ask for it if uncertain.
- Use any spare time at work to delve into the details and practice with devices or features that are rarely used. Some equipment (e.g., fiberoptic scopes) can be appropriately used during routine cases to stay in practice with its use.
- Be involved with organizational processes of identifying and implementing needed changes in different aspects of the environment to improve quality and safety.

**Anticipate and Plan (CRM Key Point 2).** Anticipation is key for goal-oriented behavior and it also helps avoid unpleasant surprises. Anesthesia professionals routinely consider in advance the requirements of a case and plan for its key milestones. In addition, they must imagine what could go wrong and plan ahead for possible difficulties. Savvy anesthesia professionals expect and are prepared for the unexpected. And when it does strike, they then anticipate what could happen next and prepare for the worst. In this context people often talk about "staying ahead of the game" or "not falling behind." Resources can be mobilized and used on the fly, but it is better if their possible need is anticipated and planned for.

For any case, a sound plan matches the anesthetic technique to the patient's disease state, the technical requirements of surgery (e.g., position of the patient), the anesthesia equipment available, and the skills of the anesthesia professional. It also includes specific backup procedures and contingency plans to be used if the original plan fails or needs to be changed. Often, faulty plans can result when underlying disease states are missed or ignored because of inadequate data gathering during preoperative evaluation. Poor planning may also result from the hazardous attitude of invulnerability. Note that a faulty anesthetic plan will expose the patient to risk even if it is carried out perfectly.

For anticipating and planning to be most effective, it should ensure the coordination of all members of the patient care team. One way to do so during routine cases is the use of briefings.[217,328] Over the last 10 years there has been a major movement to formalize such briefings (e.g., mandatory preoperative briefing of the WHO Surgical Safety Checklist, Patient Safety Huddles).

**PATIENT SAFETY ACTION BOX**

**Anticipate and Plan Ahead**

- In order to be prepared it is important to know what to potentially expect.
- For proper preparation it helps to imagine possible difficulties or complications before each case and mentally prepare for alternatives or actions. If in doubt it is better to err on the side of extra preparation.
- Perform anticipation and planning with your team: encourage colleagues to speak up; for challenging cases review in depth the primary plan (plan A) as well as the alternate plans B, C, D, etc.

**Call for Help Early Early Enough to Make a Difference (CRM Key Point 3).** Calling for help is associated with better individual and team performance.[75] Knowing one's own limitations and calling for help early are signs of rationality, strength, and patient-centeredness. Trying to handle everything alone or toughing out a critical situation is dangerous and unfair for everyone. The decision of when to call for help is complicated, but the key point is to do so early enough that the assistance can make a difference. A call so late that the patient is beyond rescue is futile. Knowing in advance who might be available and planning how you would use them will facilitate their utility.

Some typical triggers for calling for help that apply to any anesthesia professional at any level are (1) when there are too many tasks to do, (2) when the situation is already catastrophic (e.g., cardiac arrest, difficulty securing the airway), (3) when serious problems are becoming worse or are not responding to the usual maneuvers (or both), and (4) when you do not know what is going on.

For novice anesthesia professionals, calling for help very early is frequent as they are not expected to handle any critical aspect of a case (e.g., induction of anesthesia) without supervision or assistance. For experienced personnel it will be less frequent, as they are fully able to handle more things alone, but mobilizing help is still critically important. Many situations that would spin out of control can be readily resolved with appropriate and timely assistance.

Whereas prior research on these kinds of backing-up behavior has indicated that it is beneficial to teams, nothing is perfect. Barnes and colleagues published a critique of aspects of backing-up behavior in their article "Harmful help,"[349] citing for example decreased work on subsequent tasks after receiving high amounts of backup. A related concept is that of social shirking in which a task that is typically done separately by two people, to gain redundancy, instead is shirked (dropped) by one or both of them assuming that the other is taking care of it.[350]

**PATIENT SAFETY ACTION BOX**

**Call for Help Early Enough to Make a Difference** There are different conceptual categories of help. One can refer to them as hands help (to do things) versus head help (to assist in thinking). Providing bits of key information even during the call for help may assist incoming personnel to be thinking or planning for the possible needs. Calling for help will only succeed in sites with an organizational culture that approves and supports it (see later section on "safety culture"). If someone who calls for help appropriately but early gets criticized or even bullied by colleagues or senior leaders such pro-safety behaviors will likely be extinguished.

**Establish Leadership and Followership With Appropriate Assertiveness (CRM Key Point 4).** Leadership involves structuring the team, planning, deciding, and distributing tasks. Leadership does not imply knowing more than everyone else, doing everything alone, or putting other people down. Followership is as important as leadership. Team leaders and team followers are jointly responsible for the well-being of the patient (see earlier section on "speaking up"). Since speaking up requires the crossing of many personal and interpersonal hurdles (e.g., fear of repercussions or arising disadvantages),[307] team members may need explicit invitations to contribute and shows of appreciation by the team leader, sometimes referred to as leader inclusiveness.[351,352]

Wacker and Kolbe[82] wrote about leadership, followership, and teamwork in anesthesia:

*"Intuitively and empirically, leadership and teamwork are essential for team performance, patient safety, and patient outcomes in anesthesia and perioperative care. [...] Current research supports the concept that little explicit leadership is usually required during standardized routine work, but active and even directive leadership is important in unexpected, novel, or stressful situations."* (p. 200)

In their work they give an overview of how leadership practices in anesthesiology optimally change (implicit vs. explicit team coordination) according to clinical work phases and special situations (routine situations with low or high task load; unexpected minor or major events; initiation and maintenance phase). Rosenman and colleagues give a systematic review of leadership and leadership training for health care action teams.[353,354]

**PATIENT SAFETY ACTION BOX**

**Establish Leadership and Followership With Appropriate Assertiveness** Whenever people work together, conflict can ensue. Anyone on the team may need to diffuse conflicts to focus the team on care of the patient. One approach is to explicitly ask the team to concentrate on *what* is right (for the patient), not on *who* is right. Conflicts should be settled after the clinical event is resolved. As the leader, strive to have an open ear for the concerns of team members and actively invite them to express their opinion (for example, *"Do you have any other suggestions...?"* or *"The patient is deteriorating—I think we need to intubate him; what do* *you all think?"*). Team members need the confirmation that concerns and encouragement are appreciated. Alternate views may or may not change the leader's approach, but if they are not voiced there is little chance for a modification.

**Distribute the Workload. Use the 10-Seconds-for-10-Minutes Principle (CRM Key Point 5).** One major aspect of strategic control of attention is the active management of workload. Rather than passively dealing with rising or falling workload, the anesthesia professional actively manages it. Among others, Schneider and Detweiler[240] and Stone et al.[130] described the theoretical basis for a variety of strategies of workload management. These strategies were addressed specifically for anesthesiology by several investigators.[108,111] The anesthesia professional actively manages workload by the following five techniques:

1. *Avoiding excessive workload situations* (i.e., by anticipating and planning, CRM key point 2; calling for help early, CRM key point 3). Experts may choose techniques and plans that reduce the workload (especially when their individual and team resources are limited), even when those plans are otherwise slightly less desirable from a technical standpoint. For example, a single anesthesia professional working alone may opt not to use a high-tech, high-workload monitor (e.g., TEE) for a given case because the effort to use it might outweigh the likely information gained.
2. *Distributing workload over time* (i.e., by setting priorities dynamically, CRM key point 15). The anesthesia professional can prepare for future tasks when the current load is low (preloading) and can delay or shed low-priority tasks when the workload is high (offloading). Resources that require a significant amount of workload to prepare, such as vasopressor infusions, are often made ready before the case starts. Many tasks are made up of several subtasks, each of which has a finite duration. Because close attention may not be required during each of these subtasks, they can sometimes be interleaved with a fixed amount of attention (multitasking/multiplexing, see earlier section).
3. *Distributing workload over personnel* (i.e., by applying the actual CRM key point 5; by coordinating the team, CRM key point 13). When workload cannot be distributed over time and when additional people are available, tasks can be distributed to them with certain considerations: (a) Some resources can be handled by the individual anesthesia professional, whereas others require additional personnel; (b) Some tasks are completely incompatible, for example any activity that requires being gowned and gloved will preclude that individual from performing nearly all other tasks; (c) In very time-sensitive situations distribution over personnel may be needed whereas for more routine situations a single individual may be sufficient for the same set of tasks.
4. *Changing the nature of the task.* The nature of a task is often not fixed. They can be executed to different standards of performance; as standards are loosened, the workload required to perform them is reduced. For example, during periods of massive blood loss, the anesthesia professional focuses primarily on administering blood and fluids and on monitoring blood pressure. The acceptable limits of blood pressure may be widened to reduce the need for more frequent interventions.
5. *Modifying distractions and offloading routine activities.* In addition to the attentional demands of the anesthesia professional's core tasks, any clinical environment may be full of distractions. Expert anesthesia professionals modulate the distractions by eliminating them when the workload is high and allowing them to occur when the workload is low (to improve morale and team building). Similarly certain routine tasks (e.g., entering non-critical information into the anesthesia record) or courtesy activities (e.g., tying the gown of a surgeon or nurse) may be performed by the anesthesia professional only when workload is low, but not when it rises.

**PATIENT SAFETY ACTION BOX**

**Distribute the Workload** A team leader should try to stay free of tasks in order to observe, gather information, coordinate, distribute, and delegate tasks. This is because mental capacity of human beings is limited—multitasking leads to often unrecognized errors. Within the operating room this may not be possible until several skilled personnel arrive to help. Even then, there can be some tasks which the leader decides to perform while still being at the center of the team; for example they might choose to be the person administering IV drugs linking decision to action without a communication step. There is no single arrangement of personnel or tasks that is perfect for every situation.

Appropriate assertiveness is important. A frequent observation in simulations and real cases is that anesthesia professionals may be too quiet or too casual, even for situations that demand urgency and assertiveness. But choosing the appropriate level and style of assertiveness is also important because being excessively assertive, especially for non-critical situations, will anger or annoy co-workers and lead to suboptimal results.

Exercising effective followership (see CRM key point 4, exercise leadership and followership with appropriate assertiveness), team members should also look actively for work that needs to be done. The team leader should not have to think of and order every single task or activity. Proper communication will be needed to coordinate the work (see CRM key principle 7, Communicate effectively).

**PATIENT SAFETY ACTION BOX**

Leaders should try to sensibly prioritize tasks to single individuals or to delegate one task at a time to each person, for example, *"Mary, go and call for help. Peter, go and get the emergency cart. Michael, draw up epinephrine 100 µg per mL."* Team members should speak up if they get too much work allocated at once or when the priorities aren't clear (e.g., *"I can only do one of those things at a time, which should I do first?"*).

**We always have 10 seconds!** Patient care is very rarely a high-speed discipline where seconds matter—initiating CPR is one example. Usually patients deteriorate in minutes to hours. Despite the stress and intrinsic pressure to perform immediate actions ("do something, do something now!") there is often some time to think of a plan. Trying to be too fast may lead to avoidable errors.

To address this Rall and colleagues developed the 10-seconds-for-10-minutes principle, meaning, metaphorically,

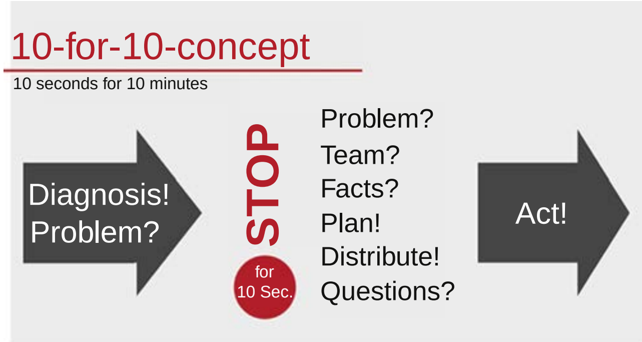


**Fig. 6.8 The "10-seconds-for-10-minutes-principle"—"10-for-10."**[563] When *making a diagnosis* or *feeling stuck,* perform the 10-seconds-for-10-minutes team timeout and check to see "what the biggest problem is right now" *(Problem)*. Clarify this with all available team members *(Opinions)*. Gather the information available *(Facts)*. Plan the treatment, including the desired sequence of actions. Distribute the workload by assigning tasks and responsibilities. *Check actively* with all team members about any further concerns of suggestions. Then act as an organized team. (Figure provided by M. Rall.)

spending 10 seconds in order to achieve a better coordinated team for the next 10 minutes. Stopping for symbolically 10 seconds in an emergency feels counterintuitive, but once used to it, it is a very effective way to improve performance and patient safety. The 10-for-10 principle has spread to many health care settings (anesthesia, ICU, prehospital, etc.).

The concept can be extended to mean that sometimes an investment of time in an activity—even many minutes—can yield big dividends in various ways (including time saved) in the future. The benefit of strategic investment of time appears to be greatest in key situations, such as (a) the making of a provisional diagnosis and the beginning of treatment, (b) planning for complex interventions, or (c) when the team feels stuck because the initial diagnosis seems incorrect, or when the usual treatment of a known problem is not working (Fig. 6.8).

Research findings show that information sharing (see also CRM key principle 8, Use all available information) can be enhanced by structuring team discussions.[355] The 10-for-10 principle offers one way to encourage and facilitate such deliberations.

**PATIENT SAFETY ACTION BOX**

When applying the 10-for-10 principle, it helps to use a key word or a key sentence for the team to pause for a moment in order to initiate the 10-for-10 break (e.g., *"Stop, everybody pause for a moment and let's summarize where we stand..."* For the 10-for-10 to work it is important for everyone to stop any non-critical action and for the leader to explicitly invite the whole team to participate (e.g., *"I want you all to stop whatever you are doing and I want to shortly summarize together where we stand. This seems to me like an anaphylactic reaction. What do you all think? Any other diagnoses in the differential?"* The 10-for-10 principle in general can be initiated by any team member, but it remains the decision of the team leader whether or when to execute it.

**Mobilize All Available Resources (CRM Key Point 6).** In case of an (imminent) emergency, everyone and everything necessary to help the patient should be mobilized, including personnel (CRM key principle 3, Call for help early), equipment, and organizational structures (radiology, other medical specialties, etc.). It is important to know which resources are available and with what delay (CRM key principles 1, Know the environment and 2, Anticipate and plan). On the human side, the anesthesia professional's knowledge and skills, constrained by human factors and one's own human deficiencies, is the most important resource, complemented by the helpers who can be brought to bear.

**PATIENT SAFETY ACTION BOX**

**Mobilize All Available Resources** When applicable think of all the team members, not just the anesthesia professionals or technicians. In a tough situation everyone should be willing to help but they do not always know how. The other professionals have many skills, some unique. Even relatively untrained personnel (housekeeping staff or orderlies, for example) may be able to help in some tasks.

**Communicate Effectively—Speak Up (CRM Key Point 7).** Good teamwork depends on everybody's being on the same page and on coordinating efforts. Communication is a very important vehicle to achieve good teamwork. It is like the glue that holds the disparate members together. Even though anesthesia professionals speak to each other all day long, effective communication is actually challenging, especially in a stressful situation. Based on research showing that teams unfortunately tend to communicate ineffectively,[356-358] effective communication refers to both content and form.[286] Many aspects make communication difficult: for example unspecified assumptions, lack of a shared mental model, hierarchy, acoustics, high mental workload, and time pressure (see earlier sections).

When dealing with complex situations under time pressure, people tend to "mean" a lot, but "say" little. Fig. 6.6 shows the closed loop communication, a systematic model of proper communication, ensuring that other team members know what one means, says, understands, and does in order to create shared mental models.

**PATIENT SAFETY ACTION BOX**

**Communicate Effectively—Speak Up** In order to communicate assertively and effectively, these approaches help:

- Do not ordinarily raise your voice, but do so if necessary to get others' attention.
- State your commands or requests as clearly and as precisely as possible. This is very difficult in a crisis, and it takes practice.
- Address people by their names if possible or search for eye contact before speaking. Despite the fact that anesthesia professionals hate to be called "anesthesia" (i.e., address people by function) routinely, there is not much choice but to do likewise to others in a crisis when you do not know their names. Avoid unclear assignments into thin air like *"Can someone monitor the saturation...," "Someone has to call for help...," "I need more propofol...," "We need more fluids..."*
- Use closed loop communication (see also earlier section):
  - Read back —If you received an assignment, repeat what you heard (i.e., Task: "Peter, I need epinephrine 10 µg per mL." Answer: "Ok Mary, I'll draw up epinephrine 10 µg per mL."

- Feedback—Give feedback when you are done with an assignment and also give feedback on what you did, even if it did not work or if it is not satisfying (i.e., "Mary, I got the defibrillator. It's right behind you. Do you want me to set it up?").
- Get back—If someone does not reply or react to you, they might not have heard it or were busy. Ask further questions, wait for acknowledgment, and wait to speak until they are ready to listen.
- Ask back—If you did not hear what the other person was saying or if you did not understand the assigned task, you should clarify matters.
- Accustom yourself to using the correct dosage indication when delegating the drawing up or the administration of medication (i.e., say *"Give 20 mg of propofol"* instead of *"Give 20 of propofol"* or say *"Draw up epinephrine 100 μg per mL"* instead of *"Draw up epinephrine."*
- Ask questions, especially if you do not know how to proceed. *"Ok, team. Right now I don't have any further ideas how to proceed. What should we do next?."*
- If you explain your thoughts or objections, this will help the team to understand better. For example, do not just say *"Get the defibrillator"* (thinking to yourself *"get the defibrillator so that we're prepared if we need it"*). Say instead what you mean: *"Get the defibrillator. We don't need it yet, but I want to be prepared in case we do…."*

**Use All Available Information (CRM Key Point 8).** Anesthesiology is particularly complex because information must be integrated from many different sources. In emergencies anesthesiologists often have only limited and indirect information on the patient, including those immediately at hand (the patient, non-invasive monitors, the anesthesia record), secondary sources such as the patient's chart, and external sources such as cognitive aids (see CRM key principle 11) or the Internet. Information provided to nurses and physicians who join an ongoing emergency can be unreliable.[355,356] The simulation study of Bogenstätter and co-workers showed that 18% of the information given to newcomers was inaccurate.[356]

Because of the various sources of unreliability of information (artifacts, transients, and miscommunications) various steps of verification and data fusion are needed to provide the best basis for problem recognition, identification, diagnosis, and management (as indicated in the cognitive process model of the anesthesiologist—see earlier section).

**PATIENT SAFETY ACTION BOX**

**Use All Available Information** Be aware of the flow of time when considering information streams. Anesthesia can be very dynamic. Vital signs that were satisfactory three minutes ago can change quickly. For periodic non-invasive monitoring—say an automatic blood pressure cuff—we are constantly trading off the rate of recurrence of the measurement against the potential complications of too frequent use. The typical 5-minute interval will leave room for hidden changes should the patient become unstable, a problem exacerbated by the higher likelihood that the next measurement will be more difficult for the device to make adding more time to obtain a reading. This of course is why we sometimes opt to invest time, effort, and a small risk to place an arterial catheter for continuous measurement.

**Prevent and Manage Fixation Errors (CRM Key Point 9).** Human decisions and actions are based on an instantaneous mental model of the current situation (see earlier section on "core cognitive process model of anesthesia professional"). If the model is erroneous, the decisions and hence the actions will probably be wrong. Faulty reevaluation, inadequate plan adaptation, and loss of situation awareness each can result in the type of human error termed fixation error.[138] A fixation error describes a mental model of a situation that is persistently faulty despite sufficient evidence to correct it. A fixation error therefore leads to a persistent failure to revise a diagnosis or plan, even though readily available evidence suggests that a revision is necessary.

Three main types of fixation errors are recognized[137-139] and described in Box 6.6. Each represents an extreme relative to another; it is usually advantageous to aim for the sweet spot between the extremes. For example, regarding "This and Only This" versus "Everything But This," usually people want to hone in on the one most likely cause of a problem in order to properly address it, while still keeping an open mind for other possibilities. Occasionally the extreme is required—if there is no pulse, initially CPR must happen with no delay (this and only this) regardless of the underlying cause. Conversely, sometimes one must delay treating a possible cause so as to find out what is really going on. And if we never act as if everything is OK every routine case would turn into chaos. One's behavior must be fluid so as to navigate optimally toward or away from the middle ground as needed.

**BOX 6.6 Fixation Errors**

Three main types of fixation errors[137-139] are recognized and should be understood:

- Fixation Error # 1: *"This and only this" or "cognitive tunnel vision."* In this type of error, attention is focused on only one possibility. Other alternatives (possibly or actually correct) are not taken into account (i.e., There is profound hypotension and tachycardia; the patient must be hypovolemic, there must be bleeding [disregarding anaphylaxis, cardiogenic shock, excessive vasodilator administration, etc.]). The available evidence is interpreted to fit the initial diagnosis or attention is allocated to a minor aspect of a major problem.
- Fixation Error # 2: "*Everything but this.*" In this type of error, attention is persistently focused on the search for further (irrelevant) information or diagnosis resulting in the failure to treat a probable cause and commit to the definitive treatment of a major problem. (i.e., Hmm… there is tachycardia, maybe it's light anesthesia, maybe it's hypovolemia, maybe it's… and there's hypercapnia maybe it's the $CO_2$ absorber, maybe it's… and there's fever, maybe the patient is septic, and… without ever committing to either definitively rule out, or else treat for—"actually all these signs point to malignant hyperthermia so I'm going to treat it as such").
- Fixation Error # 3: *"Everything is OK."* This is the persistent belief that no problem is occurring in spite of plentiful evidence that it is. In this type of error, all abnormalities may be attributed to artifact or transients. Possible (pre-) signs of a catastrophic situation are dismissed. (i.e., "The blood pressure cannot be so low. Probably the blood pressure cuff does not measure right. That is alright."). Another form of this type of fixation error is the failure to actively transition from routine mode into emergency mode when the situation demands it. A failure to declare an emergency or to accept help when facing a major crisis may stem from denial that a serious situation is actually occurring.


**Fig. 6.9 "Stop before you block" to avoid wrong site block.** Reproduced here with permission from the Safe Anaesthesia Liaison Group (SALG) and Regional Anaesthesia UK, but SALG has not reviewed this as a whole.

When working alone, an anesthesia professional can deliberately change perspectives (physically or mentally) and look for information not fitting the picture of the situation, as though freshly entering the room. Using the aforementioned 10-for-10 principle (CRM key principle 5) can be helpful by actively involving all team members and facilitating other ideas, diagnoses, and objections. Calling for head help from another anesthesia professional unaware of the previous assumptions can break fixation errors; it is best to try not to excessively bias their view of the situation during their incoming briefing. Remember that the burden of proof is on you. For every abnormality you must assume that the patient is not OK until you satisfy yourself otherwise. Similarly, you must assume that any abnormality represents the worst possible diagnosis until you can determine what is actually going on.

**Cross and Double Check—Never Assume Anything (CRM Key Point 10).** Cross checking and double checking are error-reduction strategies. Cross checking means correlating information from different sources. For example, there are often three independent sources of information on the patient's heart rate (electrocardiogram [ECG], pulse oximetry, and blood pressure monitor) and two of cardiac rhythm (ECG and pulse oximetry). Cross checking across people can be useful both for information that depends on human perception (e.g., auscultation) and for determining which actions were or were not completed. Human memory of actions delegated and performed is vulnerable, especially when interruptions have occurred.

Double checking means to verify information and/or equipment if it is very critical or if in doubt. In brief: to *never assume anything.* The more important or vital the information, the more certainty is appropriate. When chosen therapies do not seem to be working an important double check is whether the intended processes are really happening. For example to double check the proper performance of a critical infusion pump means to check its settings, operation, source of power, and the lines and stopcocks from it to the patient.

Another safety strategy using double checking in anesthesia is the *"Stop-before-you-block"* (SB4YB) campaign (for more information, free poster, and implementation package see www.rcoa.ac.uk/standards-of-clinical-practice/wrong-site-block). The "block time out" campaign was initiated by the Nottingham University Hospital in the UK in 2010 and by now has been adopted worldwide (poster see Fig. 6.9). Meanwhile, several extensions to this strategy have been published.[359,360]

**PATIENT SAFETY ACTION BOX**

**Cross Check and Double Check—Never Assume Anything** A related safety strategy is "*Stop-Inject.—Check!*" (Fig. 6.10). In order to prevent medication errors, this strategy is very applicable. Whenever you intend to give an injection, do not inject ("STOP—INJECT") —and at a crucial point of no return think for a few seconds about the injection ("CHECK")—correct any issues—and only then continue with the injection safely. Because if the drug is in, it's in. This strategy is equally applicable to other interventions which cannot be reversed.

**Use Cognitive Aids (CRM Key Point 11).** The human factors literature demonstrates conclusively that cognitive functions such as memory and arithmetic calculation are vulnerable to error or even complete failure, especially during periods of stress or time pressure. Cognitive aids—such as posters, algorithms, checklists, handbooks, calculators, personal apps, and advice hotlines—come in different forms but serve similar functions. They offload memory and safeguard the correct recall of critical items. Cognitive aids ensure that critical steps are not missed. And they also help ensure the use of current best practices because during a crisis, people sometimes revert to what they originally learned, not what is the latest recommendation. Cognitive aids make knowledge explicit and applicable in the particular situation rather than only being implicit and in someone's brain.

In anesthesiology and emergency care, emergency manuals/crisis checklists, smartphone apps, electronic health record systems, posters, and algorithms are the most common kinds of cognitive aids used. The Internet has become an increasingly useful cognitive aid and may be available on computer terminals, tablets, and smartphones in hospital settings.

The use of cognitive aids is relatively easy and they help to prevent missing critical steps that can be deadly.

In 2003, the US Department of Veterans Affairs National Center for Patient Safety developed an emergency checklist set of 16 serious perioperative emergencies, in concert with the VA Palo Alto/Stanford group, and placed a set of these checklists on plastic laminated sheets in every OR of 105 hospitals. A study of the use of the VA cognitive aids suggested, that they were beneficial to VA anesthesia professionals.[144] Other research has demonstrated that (1) medical and technical performance is better during simulated crisis when a cognitive aid is used [145,361,362] and (2) it can be very helpful to the anesthesia professional leading the team if a reader is present whose job is to read the


**Fig. 6.10 Using stop moments as a valuable patient safety tool for irreversible, critical points of no return, like for example "Stop-Inject. Check!".** To avoid unnecessary drug errors, all who intend to inject drugs should take two seconds before injecting a drug ("Stop-Inject"), then confirm ("Check") that the injection is safe to perform (right patient, right medication, right dose, right route, etc....), and only after this short confirmation inject the drug. The figure shows the slogan printed on a sticker that, for example, can be put on medical equipment carts to serve as a daily patient safety memorizer for medical personnel.

relevant aid to the team and keep track of whether the relevant tasks have been performed.[363,364]

For example, Arriaga and colleagues demonstrated in a high-fidelity simulation study that the use of emergency checklists was associated with significant improvement in the management of operating-room crises, suggesting that checklists for use during operating-room crises have the potential to improve care.[145] In the study, 17 operating-room teams from three institutions (one academic medical center, two community hospitals) participated in 106 simulated surgical-crisis scenarios. Each team was randomly assigned to manage half the scenarios with a set of crisis checklists and the remaining scenarios from memory alone. Every team performed better when the crisis checklists were available than when they were not. Failure to adhere to lifesaving processes was less common when checklists were available (6% of steps missed when checklist available vs. 23% when unavailable). 97% of participants reported that they would want to use a checklist if one of these crises occurred during an operation. Further studies concerning this matter have been undertaken.[300,365-368]

Hepner and colleagues give an up-to-date overview of the history, current role, and future directions of cognitive aids in the operating room.[369] Marshall provides a review of the different cognitive aids existing in anesthesia based on a literature review and summarizes recommendations in cognitive aid design, testing, and implementation for the future.[370]

**EXAMPLES OF KNOWN COGNITIVE AIGS.** There is a growing movement toward the effective use of cognitive aids like checklists and emergency manuals in the operating room, both for routine and crisis situations. Following those movements there have been some recent large checklist implementation processes in health care:

One movement, for example, is the European "Helsinki Declaration on Patient Safety in Anaesthesiology," a shared European opinion of what currently is both worthy and achievable to improve patient safety in anesthesiology.[371] The declaration demands that *"all institutions providing peri-operative anaesthesia care to patients should have protocols [. . .] for managing [. . .] difficult/failed intubation, anaphylaxis, local anesthetic toxicity, massive haemorrhage [. . .]."*

Perhaps the most widely used checklist is the WHO Surgical Safety Checklist that was launched in 2009 by the WHO's World Alliance for Patient Safety accompanying the "Safe Surgery Saves Lives" campaign. A global study[372] showed that the rate of death was 1.5% before the WHO checklist was introduced and declined to 0.8% afterward. Inpatient complications occurred in 11.0% of patients at baseline and in 7.0% after introduction of the WHO checklist. However, there exist several challenges concerning the application of and adherence to the WHO Surgical Safety Checklist, represented by a study that assessed the application attitudes and compliance of the WHO checklist as perceived by anesthesia professionals in Germany.[373] Roughly 60% of participants had knowledge of the theoretical framework. Sign in, patient ID, and surgical site were checked > 95% of the time, allergies addressed in nearly 90%, expected difficult airway in 65%, and availability of blood products by 70%. A total of 85% of participants advocated for the timeout to include all persons present in the operating room, which was the

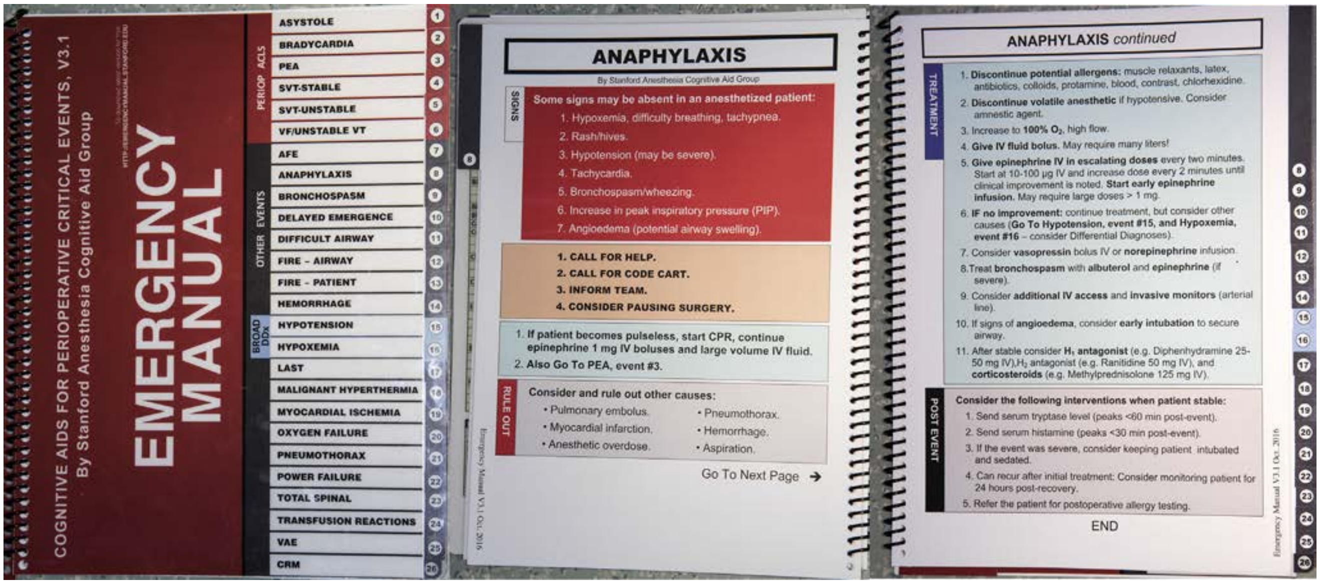


**Fig. 6.11 Emergency Manual developed by the Stanford Anesthesia Cognitive Aid Group.** (A) Front cover of the emergency manual. On the front page it shows the emergency events, thus making it easy to jump to the right page in the case of an emergency. The manual can be hung by its strong metal grommet. Experience shows that clinicians must be familiarized with the manual in advance for optimal use. (B and C) Two pages of the emergency manual for "Anaphylaxis." The content and the layout have been optimized through graphic layout and careful choice of words for easy and ergonomic use in actual operating room emergencies. (Photographs by David Gaba).

case in 57%. A total of 41% stated that the timeout was only performed between anesthetist and surgeon; in 17% of cases, the patient was simultaneously draped and/or surgically scrubbed.

Furthermore there exists a checklist for the significant reduction of catheter-/central-line-related bloodstream infections (CLABSI) in the ICU from Levy and colleagues.[374] And there exist several checklists for handovers and patient-care transition (see also earlier section "Effective Communication and Delegation of Tasks").[295,298,300] A survey[368] on the perception of anesthesia providers from a large academic U.S. institution revealed that printed or electronic aids for patient care transition and shift handoffs in general were valued (61% and 58%, respectively). To prepare for and perform routine anesthesia care, 40% of providers claimed interest in using checklists, however, the interest differed significantly with clinical experience: while both the least and most experienced providers valued aids for routine anesthesia (54% and 50%), only 29% of providers with 2 to 10 years of anesthesia experience claimed interest in using them. Distraction from patient care and decreased efficiency were concerns expressed for the use of routine checklists (27% and 31%, respectively).

Other checklists used especially in anesthesia are the checklist for the anesthesia machine (see earlier section "Pre-use Checkout of Equipment") and emergency checklists or emergency manuals.

EMERGENCY CHECKLISTS/EMERGENCY MANUALS. One known example of a cognitive aid is the use of emergency checklists or emergency manuals, also known by similar terms including emergency response protocols or critical event algorithms. The Stanford Anesthesia Cognitive Aid Group (SACAG) has conducted many years of simulation testing of cognitive aids meant for real-time intraoperative use,[362,363] with increasing levels of optimization through graphic design. SACAG has produced the *Emergency Manual: Cognitive Aids for Perioperative Critical Events ("Stanford Emergency Manual")* (at the time of this writing in version 3.1, see Fig. 6.11). An earlier version of the emergency manual was published as an appendix in the textbook "Manual of Clinical Anesthesiology."[375] In 2013 these cognitive aids were placed in all anesthetizing locations in the Stanford family of teaching hospitals.

The *Stanford Emergency Manual* is available free electronically throughout the world as a downloadable portable document format (PDF) file under a Creative Commons Attribution; Non-Commercial; No-Derivatives License, allowing free non-commercial use of the document as is, without unauthorized modifications, and with attribution of the author (emergencymanual.stanford.edu). Users are able to choose to print out the *Emergency Manual* locally or using any commercial printer; instructions are given on choices of printing paper (e.g., nonflammable and able to be wiped with disinfectant), binding, and placement in perioperative patient care settings.

An equally well-known emergency checklist was developed by the Ariadne Laboratory affiliated with the Brigham and Women's Hospital; it is also freely available and widely disseminated. The Society for Pediatric Anesthesia has a web-based and iPhone app emergency manual that is widely used in that subspecialty arena. A commercially available anesthesia crisis manual designed as a book was published in 2011 by David Borshoff with support of both the European and Australian Societies of Anesthesiology (for details, see www.theacm.com.au). The textbook *Crisis Management in Anesthesiology* while not optimized for real-time use, can also be used in real-time and contains a rather large number (99) of perioperative events.

A recent study compared the impact of paper versus electronic cognitive aids in a simulation-based study, suggesting that the mode of information does not affect performance.[376] The movement for the dissemination and use of such cognitive aids is growing. An Emergency

Manual Implementation Collaborative (EMIC) has been started, bringing together several leading centers in this arena to facilitate the development, testing, dissemination, adoption, and use of these resources. The most recent publications of the Collaborative emphasize the importance for implementation institutions to not only provide cognitive aids such as emergency manuals in accessible places, but also incorporate training mechanisms to increase clinicians' awareness, familiarity, cultural acceptance, and planned clinical use.[377] An implementation toolkit is provided by the Collaborative free of charge (www.implementingemergencychecklists.org/). The EMIC website provides links to obtain many of the available emergency manuals, most of which are non-commercial and free to download.

Collectively across all the relevant emergency cognitive aids for anesthesiology it is believed [DG] that as of late 2018 on the order of 400,000 have been downloaded or disseminated.

Conflicting data concerning the effectiveness of cognitive aids as described in the literature do not necessarily suggest that there is no benefit but suggest that the success of those tools requires complex cultural and organizational change efforts, not just providing the cognitive aid in perioperative settings. In research where no difference was found, the cognitive aids are almost always found to have been introduced without education (an approach termed "print and plunk" by experts on such aids) or to have flaws in their physical design.[370] In 2013 multiple papers and editorials in a single issue of *Anesthesia and Analgesia* discussed a number of important issues about cognitive aids and their implementation.[370,378-381] In the article "Cognitive aids: Time for a change?," Jenkins [382] among other things, draws attention to the fact that besides having checklists ready to use in OR, using them during OR team training for common emergencies would seem a logical next step.

The key elements of the successful implementation of cognitive aids is (1) a culture that embraces cognitive aids not as a sign of clinical incompetence, but as a tool to improve care (see later section on "Safety Culture"); (2) an organizational implementation process like, for example, suggested emergency checklist implementation toolkit (www.implementingemergencychecklists.org); and (3) a proper checklist development and design. Several publications give an overview of the challenges associated with development and implementation of checklists and cognitive aids in general.[383-390]

**Reevaluate Repeatedly—Apply the 10-Seconds-for-10-Minutes Principle (CRM Key Point 12).** Anesthesia in critical situations is a very dynamic activity. What is correct now may be wrong in the next minute. Some parameters may change slowly over time, and subtle changes are especially difficult to perceive. Therefore, it is critically important to perform a repeated reevaluation of the patient. Reevaluation describes the continual process of assessing the situation and updating one's individual, and at certain stages also the team's, mental model of the situation.

The process of continually reevaluating in order to update the assessment of the situation and monitoring the efficacy of chosen actions is a major part of situation awareness. No crisis manager can be certain of success at any stage in the event. It is crucial to keep thinking ahead (anticipate and plan, CRM principle 2). Do not assume that anything about the situation is certain—double-check all critical items (CRM principle 10). Trend monitoring can be helpful to detect slow but insidious changes.

Questions that should be raised repeatedly to maintain situation awareness and to check whether one is still treating the most serious problem most effectively include:

- Was the initial assessment of the situation or diagnosis correct?
- Did the actions have any effect?
- Is the problem getting better, or is it getting worse?
- Does the patient have any side effects resulting from previous actions?
- Are there any new problems or other problems that were missed before?
- What further developments can be expected in the (near) future?

One way to reevaluate the situation is the regular application of the 10-seconds-for-10-minutes principle at specific stages during the treatment of a crisis (see Fig. 6.8).

**Use Good Teamwork—Coordinate With and Support Others (CRM Key Point 13).** Teamwork is a very complex topic. But research demonstrates that quality of teamwork influences clinical performance in anesthesia.[326] Some of the principles of teamwork have already been introduced earlier (see section "Teamwork"). Key principles of teamwork in dynamic situations have been delineated, especially in the work of Eduardo Salas, Nancy Cooke, and colleagues.[391-395] Good teamwork depends on different attitudes and characteristics, some of which were already discussed in CRM principle 4, Exercise Leadership and Followership with Assertiveness, and CRM principle 7, Communicate Effectively—Speak Up.

**PATIENT SAFETY ACTION BOX**

**Implement Principles of Good Teamwork—Coordinate With and Support Others** Dream teams are made, not born. Dream teams support each other continuously, with everybody looking after each other in a professional manner, the safety and well-being of the patient being highest priority. In contrast to a widespread opinion, good teamwork does not depend on team members liking each other (although it probably helps). Do all players of champion sports teams like each other, or all the time? Probably not. Nevertheless, they function as a high-performing team because they share the common goal to win. Patients are depending on perioperative personnel to be part of a team with emotionless professionalism, using principles of good teamwork, regardless of their personal affinities.

Coordination within a team ideally begins when it gathers. If all members know about the tasks to be done and their roles during these tasks (briefing, see also CRM principle 7), coordination is easy. Short briefings at the beginning of certain tasks as well as short debriefings afterward are common in other complex and dynamic domains, such as aviation, and they are becoming more common in health care. Research in health care indicates that they seem worth the time spent.[217,328] During the acute phase of a crisis, it is valuable to spend a small amount of time to coordinate the team's activities (see e.g., 10-for-10 principle CRM key point 5). Information sharing in teams is important to team performance, cohesion, decision satisfaction, and knowledge integration.[355]

**PATIENT SAFETY ACTION BOX**

Surgeons are a key part of the team. Sometimes anesthesia professionals act as though they have only two options in dealing with surgeons when a problem occurs—keep quiet or demand immediate cessation of surgery. Actually there are many options (see also: Communicate Effectively) for coordinating activities and concerns. You should notify the surgeons and nurses of ongoing problems and concisely convey to them the nature of the problem, what you'd like them to do (or not do), and the immediate plan. Conversely, you should be prepared to help the surgeons or nurses in any reasonable way when they encounter problems, as long as you can also maintain safe assessment of the patient and control of the anesthetic course.

**Allocate Attention Wisely (CRM Key Point 14).** As described earlier, several performance-shaping factors (see section on "performance-shaping factors") and hazardous attitudes (see "Attitudes of Professionals as a Crucial Part of Human Performance and Patient Safety", and Table 6.3) can globally degrade your vigilance. However, there are other factors that can specifically degrade your vigilance whenever they exist in a case: one is distractions and interruptions (see sections on "Interruptions and Distractions"). The other is high task load (see section "Performance as Related to Task Density").

Referring again to the core cognitive process model of the anesthesia professional introduced earlier (see earlier section), empiric studies have clearly demonstrated that attention sharing is needed among cognitive levels, among tasks, and often among problems. The intensive demands on the anesthesia professional's attention could easily swamp the available mental resources. Human attention is very limited, and multitasking as well as multiplexing may become very difficult and unsuccessful in a stressful situation.

Attention must be dynamically allocated where it is needed by a dynamic process of constantly prioritizing the tasks requiring your attention. One should handle critical items quickly and leave the less critical problems for when the patient's status has been stabilized. On the other hand when the task load is low, one should deal even with minor problems because they might otherwise evolve to something more significant. One can also use times when the workload is low to prepare for upcoming high workload periods, such as emergence from anesthesia or termination of cardiopulmonary bypass.

Another way to allocate attention is to develop rhythms and scan patterns. For example, always asking questions during the preoperative evaluation in the same sequence makes it less likely to forget items. The ABC mnemonic that equals airway, breathing, and circulation (now CAB mnemonic per U.S. American Heart Association guidelines) is another example that is based on this principle. Other strategies include alternating between focusing on details and focusing on the big picture, and offloading certain responsibilities, tasks, or information streams to other qualified team members (CRM principle 5), with periodic update to the team leader about the situation (CRM principle 13).

**Set Priorities Dynamically (CRM Key Point 15).** Dynamic situations demand dynamically changing decisions and actions based on new information and constant reevaluation (CRM principle 12). What was not a right move at one time may become the right move at another. In addition, having one solution to an obvious problem does not guarantee that it is the best solution or that only one problem exists. Some goals are always of the highest priority—ensuring adequate oxygenation and perfusion of critical organs being the most crucial—and can never be neglected. In order for team members to understand changing priorities of the team leader, it is important to communicate dynamic priorities effectively (CRM principle 7) and to support each other the best way possible as a team (CRM principle 4 and 13). Sometimes people stick to their first decisions and actions (CRM principle 9).

### Evidence for the Benefit of Crisis Resource Management and Other Human-Factor-Related Team Training Curricula

**Improvements Following Implementation of Crisis Resource Management.** Recently several studies show evidence that CRM training improves patient safety and patient outcomes. In health care organizations, implementation of programs that deal with the concepts of CRM/NTS have been associated with many improvements following their implementation:

- increased provider satisfaction
- improved safety culture and a heightened culture of teamwork[43]
- increased clinical team performance[396]
- decreased room turnover time[397]
- increased percentage of on-time first case starts[42,397]
- decreased preoperative delays, handoff issues, and equipment issues[42]
- improved patient willingness to recommend[397]
- a decrease in medication and transfusion errors[398]
- increased antibiotic prophylaxis compliance[42]
- an increase of efficiency for clinical processes for multidisciplinary trauma teams[399]
- decreased mortality and morbidity[42,400]

Neily and colleagues[42] investigated in a retrospective study including nearly 182.500 sampled procedures whether there exists an association between a CRM-based team training program and surgical outcomes on a national level. The authors showed an 18% reduction in annual mortality compared with a 7% decrease among non-training facilities.

Haerkens and colleagues[5] introduced CRM successfully in the ICU, with data indicating an association between

CRM implementation and the reduction in serious complications and mortality in critically ill patients. The prospective 3-year cohort study was performed in a 32-bed ICU, admitting 2500 to 3000 patients yearly. At the end of the baseline year, all ICU personnel received a 2-day CRM training in small teams, followed by one year of implementation phase. The third year was defined as the clinical effect year. All 7271 patients admitted to the ICU in the study period were included. The ICU complication rate declined from 67.1/1000 patients to 50.9/1000 patients. The incidence of cardiac arrests decreased from 9.2/1000 patients to 3.5/1000 patients, while CPR success rate increased from 19% to 67%. The standardized mortality ratio decreased from 0.72 to 0.60 in the post-implementation year.

**Cost-benefit Analysis of Crisis Resource Management Programs.** Moffatt-Bruce and colleagues[41] published an innovative study, not only reporting that the implementation of a CRM program at an academic medical center resulted in a 26% reduction in observed relative to expected events, but also evaluating the program's costs and the return on investment. Costs included training, programmatic fixed costs, time away from work, and leadership time. Cost savings were calculated based on the reduction in avoidable adverse events and cost estimates from the literature. Over a 3-year period, roughly 3000 health system employees across 12 areas were trained, costing \$3.6 million. Savings ranged from a conservative estimate of \$12.6 million to as much as \$28.0 million. Therefore, the study presented an overall return on investment for CRM training in the range of \$9.1 to \$24.4 million, concluding that CRM presents a financially viable way to systematically organize for quality improvement. This study demonstrates that CRM training not only improves patient outcomes (see above) but is also very cost efficient.

## Other Curricula for Team Training: TeamSTEPPS and Clinical Team Training

By now, many different types of training strategies fall under the umbrella of team training in medicine, encompassing a broad range of learning and development strategies, methods, and teamwork competencies. Although each is unique in some aspects many of the principles advocated and behaviors taught are similar, and all draw ultimately from the same pool of underlying literature and experience.[401-408] The adaptation of aviation CRM to health care was first described at length at the beginning in the early 1990s.[348] Another team training curriculum, called TeamSTEPPS, was introduced in 2006 and revised in 2015. TeamSTEPPS originated from work done by the U.S. military and was adapted for health care by the U.S. Agency for Healthcare Research and Quality. The U.S. Department of Veterans Affairs introduced its MTT curriculum (later renamed Clinical Team Training, CTT) in 2007.

In the review of Weaver and colleagues,[409] 9 of the 26 studies reviewed used some form of CRM intervention, 7 reported using components of the TeamSTEPPS curriculum, and 3 studies used VA MTT. Seven studies reported using other team-training curriculums. Another current review is that of Marlow and colleagues.[410]

**TeamSTEPPS.** The TeamSTEPPS curriculum (Team Strategies and Tools to Enhance Performance and Patient Safety)[411,412] is an evidence-based framework that addresses aspects of the following five key elements: team structure, leadership, situation monitoring/mutual performance monitoring, mutual support/back-up behavior, and communication. For implementation, it involves three continuous organizational phases: (1) assessment; (2) planning, training, implementation; and (3) sustainment. The program consists of multiple, explicit team strategies for each of the above mentioned key elements and it provides a source for ready-to-use materials, monthly webinars, as well as a training curriculum (for details see www.ahrq.gov/teamstepps/index.html). This way the program is intended to be fully or partially implemented in an organizational structure as a holistic organizational safety intervention, composed of several explicit safety strategies. The TeamSTEPPS curriculum is designed for health care professionals in general over a wide set of clinical domains. However, health care professionals working in dynamic arenas of high intrinsic risk, like for example anesthesia, intensive care medicine, emergency medicine, etc., face a cognitive and teamwork environment different from many other medical domains.

**Clinical/Medical Team Training.** The Clinical Team Training program (CTT - formerly named VA M (medical) TT)[413] of the Veterans Affairs National Center for Patient Safety, originally was a classroom-based CRM training program. However, as the program evolved, simulation-based training came to be a crucial part of the currciulum with multidisciplinary on-site training with integrated simulation conducted by experienced faculty.[414] In the CTT program, principles of aviation's crew resource management (CRM) are introduced in a clinical context to model specific applications in the health care environment. The preparation stage requires two months, top leadership engagement being a crucial part in the concept. For initiation, learning sessions are carried out over two days. The learning session is a one-day session delivered twice to increase attendance from clinical units that cannot be closed for training. Implementation is carried out over six months following the learning sessions, and accompanied by coaching and monitoring of unit-based performance outcomes over 12 months.

In our senior author's [DG] view the key difference between TeamSTEPPS and the (A)CRM approach (see earlier relevant section) is the high focus of TeamSTEPPS on very concrete and relevant behaviors (e.g., SBAR, CUS words, two-challenge rule), whereas (A)CRM addresses a broader set of issues, some of which can encompass the particular TeamSTEPPS behaviors. However, TeamSTEPPS does not address directly the components of dynamic decision making of the individual or of some of the more generic issues of team management and teamwork (e.g., distribution of workload, mobilizing and using resources). Some implementations of TeamSTEPPS may miss the forest for the trees. The focus on concrete behaviors has the benefit of giving a wide variety of personnel specific actions they can practice and then perform in daily work. But the downside is that a variety of complex issues of clinical work and of teamwork may be rarely addressed, if at all.

Actually, it seems evident that all of these curricula, and others, are really complementary approaches to similar issues, drawing from the same underlying principles and practices. No single one of them is demonstrably superior to the other, and hybrids combining two or more of them are possible. TeamSTEPPS is popular in part because it is intended to be neutral as to clinical arena or position in the hierarchy and thus is widely applicable, lending itself to organization-wide implementation as described above. It was formulated and disseminated by the U.S. government's Agency for Healthcare Research and Quality, based on the work of internationally acknowledged experts on teamwork (albeit predominantly from non-medical domains). AHRQ provided a free extensive toolkit for TeamSTEPPS implementation. In contrast (A)CRM does not claim to be widely applicable, neutral as to clinical context, or requiring substantial analysis of or implementation by a clinical organization. It is popular especially in dynamic domains of high intrinsic risk analogous to the original one of anesthesiology. While it is successfully used with interprofessional groups in those domains, it is often aimed at physicians as team leaders. Dissemination of (A)CRM was facilitated by its long-standing existence (begun in 1990 and first described in the literature in 1992), publications on extensions into non-anesthesia domains, and an influential textbook (Crisis Management in Anesthesiology) in print via two editions since 1994.

**Further Medical Team Training Programs.** Besides these three rather well known team-training programs, there are multiple other team training programs, including Team Performance Plus (TPP), Team Oriented Medical Simulation (TOMS), LifeWings/Dynamic Outcomes Management (DOM), Triad for Optimal Patient Safety (TOPS), MedTeams, and Medical Team Management (MTM). They are mentioned for completeness, but for further details the reader is referred to the summary report of the Canadian Patient Safety Foundation[415] and further literature.

# Patient Safety on the Organizational Level

In the following part the authors consider the organizational and systems aspects of human performance in anesthesia care and patient safety. Only the organization can sustain the systematic search for and implementation of cross-cutting and practical solutions for front-line patient care. An extensive overview of organizational aspects of patient safety is given by Charles Vincent in the second edition of his book *Patient Safety*.[9]

Organizations should strive to make it easy for clinicians to follow safety-related processes, essentially turning self-interest to work for patient interest. As pointed out by Reason,[123] as well as by Cook, Woods, and McDonald,[122] what goes on in the operational domain of frontline medicine (the so-called sharp end) is extensively shaped by the organizational and managerial environment in which it is embedded (the so-called blunt end). Of course every level has its own sharp end of deliverables and its blunt end of higher influences. For example, the hospital CEO makes policy and direction and is thus the blunt end for everyone else, but is in turn, shaped by regulators, funders, or patient advocacy groups, etc., constituting the CEO's blunt end.

Ideally, senior management commits not only in spirit but also in deed to patient safety as a primary goal. It encourages individuals and teams to fully engage in system-wide patient safety strategies and to trigger change themselves. Management and managers can do this first by changing their own behavior and that of the team, second by educating and persuading others about key changes, and third by searching for and identifying systems issues and pressing for their resolution.

The upcoming sections address (1) the basic concepts of systematic approaches (system thinking) to patient safety and human performance on the organizational level; (2) four organizational patient safety elements for health care derived from high-reliability organization theory (HROT); and (3) important strategies for organizational implementation of these concepts and principles.

## SYSTEMS THINKING

To fully understand many issues in patient safety a broad systems perspective is needed. The actions and failures of individuals and teams usually play a central role, but their thinking and behavior is strongly influenced and constrained by their working environment and by wider organizational processes. The next sections provide systems thinking fundamentals, exploring (1) the definition of human failure and human error; (2) the evolution of accidents and adverse advents in relation to errors; (3) the concepts of hindsight bias and outcome bias as pitfalls in understanding events; (4) three prominent system organizational safety models: normal accident theory (NAT), HROT, and Safety-I/Safety-II; and (5) related concepts of resilience, uncertainty management, and normalization of deviance. More literature for further in-depth engagement with organizational approaches to human performance and patient safety are, for example, the works of René Alamberti, Sidney Dekker, Nancy Leveson, Richard Cook, David D. Woods, Erik Hollnagel, Jens Rasmussen, James Reason, Scott Sagan, Karl Weick, and Kathleen Sutcliffe.

### Human Failure: Human Error and Violations

Human error has been conceptualized and investigated for a long time, initially by cataloguing errors and attempting to determine if the myriads of errors could be traced to a small set of causal mechanisms.[132,416] More recently the role of context for understanding error pathways and prevention has become prominent, while research in cognitive neuroscience has contributed to explaining individual vulnerabilities. [417]

**Categorization of Human Failure.** Different ways to categorize human failure and human error exist. Human failure in general can be categorized into two main types[418]: (1) human error, as an unintentional action

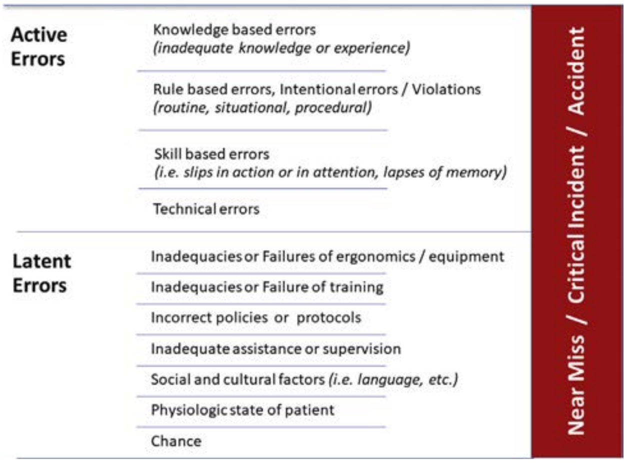


**Fig. 6.12 Active and Latent Human Errors.** Derived and adapted from the publication *Catalogue of human error* by Arnstein[419] and Rasmussen's performance levels.[420] Skill-based errors, which incorporate slips and lapses, relate to errors in conscious and subconscious (automatic) cognition. They are also summarized under the term "execution errors." Rule- and knowledge-based errors are summarized under the term "planning errors" or "mistakes." For further information see text.

or decision and (2) violations, as an intentional failure, deliberately doing the wrong thing. Derived and adapted from the error models of Arnstein,[419] Norman,[112] and Rasmussen,[420] human failure can be classified as follows (Fig. 6.12): (a) *Active errors*, including knowledge-based errors, skill-based errors, and rule-based errors (violations). (b) *Latent errors*, including, for example, failure of equipment or ergonomics, incorrect policies/protocols, inadequate training/supervision/assistance, social/cultural factors, etc.

### Active Errors

SKILL-BASED ERRORS. Those errors incorporate slips (action not as intended) and lapses of memory (forgetting to do something) and relate to errors in conscious and subconscious (automatic) cognition. They are summarized under the term execution errors. Norman has described five types of skill-based errors[112]:

- *capture error*: a common action taking over from the one intended (e.g., force of habit)
- *description error*: performing correct action on wrong target (e.g., flipping wrong switch)
- *memory error*: forgetting an item in a sequence
- *sequence error*: performing an action out of sequence from other actions
- *mode error*: actions appropriate for one mode of operation but incorrect in another mode

Mode errors are possible with simple devices but they are becoming even more frequent with the increased use of computer-based equipment.[86] An example in anesthesiology of a mechanical mode error is the bag/ventilator selector valve in the anesthesia breathing circuit, which selects between two modes of ventilation. Failing to activate the ventilator when in the ventilator mode can be catastrophic. Newer machines may activate the ventilator automatically when ventilator mode is chosen. Mode errors can also occur with monitoring or drug delivery devices if they assign different functions to the same displays or switches depending on the mode of operation selected.

Particularly dangerous slips of execution can be addressed through the use of engineered safety devices that physically prevent incorrect actions.[59] For example, newer anesthesia machines have interlocks that physically prevent the simultaneous administration of more than one volatile anesthetic. Other interlocks physically prevent the selection of a gas mixture containing less than 21% oxygen. However, all this has come at a price, not only in terms of money, but also in terms of complexity and the introduction of new failure mechanisms.

RULE- AND KNOWLEDGE-BASED ERRORS. Those errors (making an intentional decision that is wrong) are summarized by the term planning errors or mistakes. Additionally, three further forms of error are described as fixation errors (see section "Prevent and Manage Fixation Errors [CRM Key Point 9]").[109] These may be seen as cognitive tunnel vision.

**Latent Errors.** James Reason, who literally wrote the book on human error, introduced the concept of latent errors, for which he also used the metaphor of resident pathogens: "*… whose adverse consequences may lie dormant within the system for a long time, only becoming evident when they combine with other factors to breach the system's defenses. [They are] most likely to be spawned by those whose activities are removed in both time and space from the direct control interface: designers, high-level decision makers, construction workers, managers and maintenance personnel*" (p. 173).[59]

Latent errors evolve from latent threats like organizational culture, professional culture, scheduling, management policies and decisions, organizational processes, etc.

This threat and error model was articulated by the aviation-oriented psychologist Robert Helmreich, distinguishing between (1) latent threats (national and organizational culture, professional culture, scheduling and policies, management decisions, and organizational processes), (2) individual threats (team factors, patient factors, organizational factors, environmental factors, and individual staff factors), and (3) management threats (error management strategies and countermeasures).[421]

A variety of latent failures/threats/errors can exist in the anesthesia environment.[14] They may include such issues as how surgical cases are booked, how cases are assigned to specific anesthesia professionals, what provisions are made for preoperative evaluation of outpatients, and what relative priority is given to rapid turnover between cases or avoiding cancellation of cases as opposed to avoiding risk.[422] Latent errors can also result from the design of anesthesia equipment and its user interfaces, which in some cases lead clinicians to err or are unforgiving of errors. Manufacturing defects and routine maintenance failures are also types of latent failure, as well as training, supervision, etc.

### Evolution and Investigation of Accidents: One Error is not the Cause of an Accident

Traditionally, one speaks of errors arising in decisions and actions that lead to a mishap or an accident possibly with patient harm. However, the term error is increasingly considered inappropriate as it typically jumps to

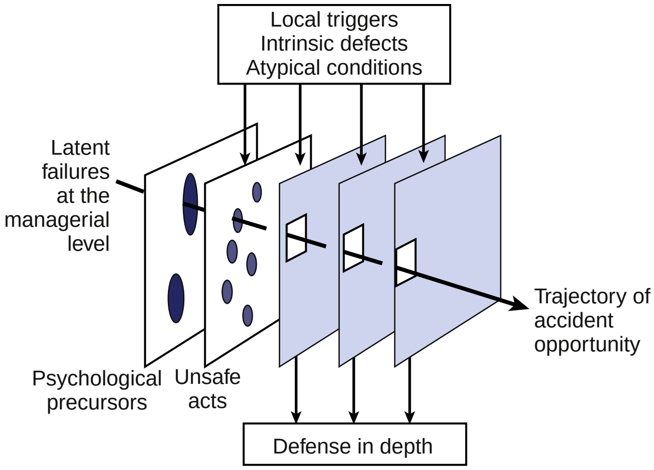


**Fig. 6.13 James Reason's model of the causation of accidents.** The model shows the different "defense shields" an organization possesses. Those shields prevent accidents at different levels. But each shield has weak spots, envisioned by the holes in the different shields. As work and the work environment in health care are dynamic, the diagram should be envisioned as being three-dimensional and also dynamic—with the shields moving around and holes opening and closing. If now, for example, latent failures at the managerial level combine with psychological precursors and active event triggers at the operational level, an accident sequence can be initiated. As long as there is no direct trajectory through the shields, the accident sequences are trapped at one or more defensive shields of the system. But if there develops a direct trajectory, the unforeseen combination of organizational or performance failures with latent errors and triggers may lead to breach the system's defenses and allow the accident to take place. This model is also known as Reason's "Swiss Cheese Model." Charles Vincent adapted Reason's model and published an extended model named "Organizational Accident Model."[9] (Figure redrawn from Reason JT. *Human Error*. Cambridge: Cambridge University Press; 1990.)

conclusions of attribution and blame. Current organizational accident models indicate that errors are usually the consequence of a combination of several underlying factors and conditions (i.e., root causes and contributing factors) that yield an event (Fig. 6.13).[59] Vincent and colleagues published a framework of contributory factors, called the seven levels of safety.[423] In their work, the error-producing conditions and organizational factors are classified as: patient factors, task factors, staff and team factors, work environment factors, organizational/management factors, and institutional context factors. This classification is used in the London Protocol,[424] an investigation and analysis tool for the processing of incident reports.

**Human error—a window to the system.** Human error can be seen as a window onto the usually hidden dynamics of the work system.[9,425,426] Sidney Dekker, pilot and human error expert, wrote:

*"You can see human error as the cause of a mishap. In this case, 'human error' under whatever label—loss of situation awareness, procedural violation, regulatory shortcomings, managerial deficiencies—is the conclusion of your effort to understand error. [Or] you can see human error as the symptom of deeper trouble. In this case, human error is the starting point for your efforts. Finding 'errors' is only the beginning. You will probe how human error is systematically connected to features of people's tools, tasks, and operational/organizational environment." (p. xi)*[427]

Whereas the first statement describes the old view on human error (person approach), the latter describes the new view on human error (system approach), albeit itself being a few decades old.[428] The new view focuses not on finding where people went wrong but rather to understand what triggered their assessment, actions, and decisions at the time, given the circumstances that surrounded them. Errors and violations should be addressed on a systems level as opposed to just with the individual(s) involved.

**Investigation.** Investigation of untoward events (see later section on "Critical Incident Reporting") should address both latent and active failures, and both the organizational/managerial environment and the operational domain. Focusing primarily on active failures may miss the fact that frontline personnel are often victims of the system in a Catch-22 situation, typically pushed to maximize production while admonished to be safe. Condemning only their actions—and not the latent pressures and conditions under which they work—will make them defensive and uncooperative. Cook and Woods pointed out that if one looks at the chain of events in an accident sequence, one can always find a failure on the part of an operator.[429] If the analysis stops at this point, the operator may be wrongly blamed in part or in whole while the real systemic root causes may not be detected; they will remain to cause other adverse event chains in the future (see later section on "Critical Incident Reporting").

**PATIENT SAFETY ACTION BOX**

Admonishing personnel to *"Try harder!"/Be more careful!"/"Next time you have to pay more attention!"* is known to be a fruitless way to address safety issues; such situations need explicit practical changes in the way the work is being performed and organized that make it easier to comply.

### Evaluation of Errors and Accidents: Hindsight Bias—"I knew it all Along" and Outcome Bias—"No Harm no Foul"

**Hindsight Bias.** The psychological phenomenon called hindsight bias plays an important role in the attribution of causes to accidents and adverse events. The bias is sometimes called *"Monday morning quarterbacking"* or the *"I knew-it-all-along effect."* After an event, it seems easy to conclude what went wrong, what the people involved did or did not do, what information turned out to be critical, and to recognize exactly the kind of harm that should have been foreseen or prevented: "*There is almost no human action or decision that cannot be made to look flawed and less sensible in the misleading light of hindsight. It is essential that the critic should keep himself constantly aware of that fact*" (p. 147).[430] Similarly Leveson wrote "*Before the event [accident], such insight is difficult and, perhaps, impossible*" (p. 38).[12] Hindsight bias, which typically underestimates complexity and cannot represent a comprehensive analysis of what and how factors interacted to lead to an error or accident, is linked to the old view of human error presented earlier. Hindsight bias still is insidious and very hard to overcome, bearing the danger to impair organizational learning, to contribute to personal overconfidence, and to even to misjudge reasonable actions as medical malpractice.[431,432]

**Outcome Bias.** A related bias is the outcome bias, sometimes—when the outcome is good—using the sports metaphor of “no harm no foul.”[431] It occurs when the judgment of a situation is made dependent on the outcome (known only in hindsight) rather than on the decision-making process itself. Harsher judgments are often made when an outcome is bad, becoming even harsher depending on the severity.[433]

**PATIENT SAFETY ACTION BOX**

When trying to make sense of events it is important to ask *“Why”* or *“How come?,”* to fully understand the problem and the thought processes in the moment of those involved. Jumping to conclusions prematurely can lead to solutions that are inappropriate or ineffective because they do not address the actual roots of the problem.

## System Error Models: Normal Accident Theory and High Reliability Organization Theory

Several schools of thought about organizational safety in highly hazardous activities exist. Two complementary theories, Normal Accident Theory (NAT) and High Reliability Organization Theory (HROT), have dominated the discussion of system safety in many domains and have been applied to health care with increasing frequency since the 1980s.[59,123,434] NAT was originally promulgated by the sociologist Charles Perrow in the wake of the Three Mile Island (Pennsylvania) nuclear accident.[54] It has been applied by him and others to such diverse fields as commercial aviation, maritime transport, and the handling of nuclear weapons. A different theory, HROT, was put forth initially by Todd LaPorte, Gene Rochlin, and Karlene Roberts,[435-437] and later Karl Weick and Kathleen Sutcliffe.[438-441] It has been applied to diverse domains, including aircraft carrier flight decks, offshore oil platforms, air traffic control, nuclear power production, and the financial transaction industry. Both NAT and HROT agree that interactive complexity and tight coupling can lead to a system accident. However, they hold different opinions on whether those system accidents are inevitable or manageable.

In brief, the rather pessimistic view of NAT suggests, that disasters are the unwanted but inevitable (normal) results of complex socio-technical systems one cannot design around; the rather optimistic view of HROT sees disasters as preventable and manageable by certain key design characteristics or response systems of the organization.

A number of comparisons of these theories have been provided, giving an overview of the two theories, their advantages and limitations, and sometimes suggesting approaches that move beyond them.[442-446] Hollnagel and colleagues have promoted another influential error model called resilience engineering,[447-451] which has been compared to HROT by Haavik and colleagues.[452] One can argue that none of the other theories have replaced either NAT or HRO, and nearly all experts now believe that these exist in parallel, each providing a complementary view of the same set of issues.

**Normal Accident Theory.** NAT focuses primarily on three features of a system: (1) the complexity of interactions

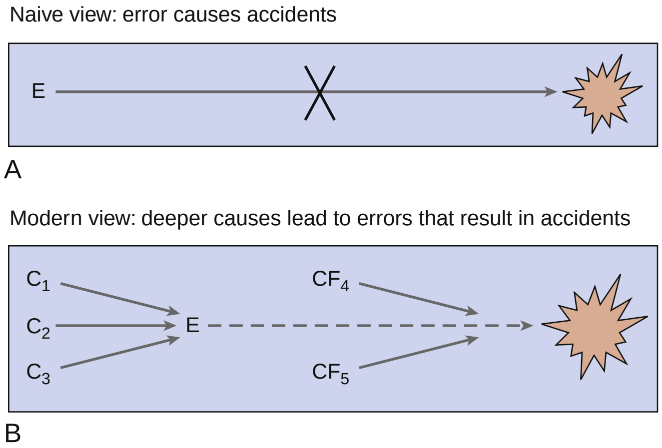


**Fig. 6.14 Relationship between errors and adverse events.** (A) Errors are the cause of accidents. Rather naïve views see the causes of accidents directly and solely linked to errors (*E*), as errors oftentimes lead directly to the accident. But errors are not the cause of accidents alone. (B) Errors are not the cause of accidents. In the more modern view, errors are one part of a multifactorial environment, when accidents occur. Multiple root causes (*C1, C2, C3*) lead to the error (E). For the most part, in an accident sequence additional contributing factors (*CF4, CF5*) are necessary to allow the error to evolve into an accident, explaining why profound analysis of an accident or incident is necessary in order to prevent similar consequences. (Modified from Rall M, Manster T, Guggenberger H, et al. Patient safety and errors in medicine: development, prevention and analyses of incidents [in German]. *Anesthesiol Intensivmed Notfallmed Schmerzther*. 2001;36:321–330 with permission.)

in the system, (2) the presence of tight coupling among the system’s elements, and (3) the catastrophic potential of the system. Perrow[54] argues that the coexistence of interactive complexity and tight coupling in socio-technological systems leads to unpredictability of interactions and hence system accident is inevitable or normal. NAT suggests that when complexity and tight coupling coexist, abnormal sequences of events can be hidden and have complex or unpredictable consequences. Active errors in the system may not result in an accident only if, they are trapped at some point by the system’s multiple layers of checks and defenses (Fig. 6.14; see also Fig. 6.13).

NAT also proposes that professionals delude themselves by believing that they can perfectly control hazardous activities and forestall disaster all the time. In reality, many of the efforts people make at management and design tend only to increase the opacity and complexity of the system (making more holes in the barriers, Fig. 6.13) thereby increasing the likelihood of accidents. The combination of these factors with normal everyday faults, slips, and incidents provides fertile ground for the occurrence of accidents.

NAT considers safety as one of many competing organizational objectives, but often not of sufficiently high priority. For preventing adverse events, Perrow suggested that attention should be directed at strengthening the recovery pathways by which small events can be properly handled before they evolve into a serious accident. In fact, this suggestion by Perrow in the book *Normal Accidents*—plus the apparent success in commercial aviation—were direct inspirations for Gaba and colleagues to develop simulation-based CRM-oriented training, and to create and disseminate emergency manuals (cognitive aids).

## BOX 6.7 Characteristics High Reliability Organizations Hold in Common…[454]

- Hypercomplex environment—extreme variety of components, systems, and levels.
- Tight coupling/interdependent teams—reciprocal interdependence across many units and levels.
- Extreme hierarchical differentiation—multiple levels, each with its own elaborate control and regulating mechanisms.
- Multiple decision makers in complex communication networks—characterized by redundancy in control and information systems.
- Degree of accountability that does not exist in most organizations—substandard performance or deviations from standard procedures meet with severe adverse consequences.
- High frequency of immediate feedback about decisions.
- Compressed time constraints—cycles of major activities are measured in seconds.
- More than one critical outcome that must happen simultaneously—simultaneity signifies both the complexity of operations as well as the inability to withdraw or modify operations decisions.

## BOX 6.8 Organizational Strategies[438] that Guide the Thinking of People in High Reliability Organizations:

- Preoccupation with failure
- Reluctance to simplify interpretations
- Sensitivity to (front-line) operations
- Commitment to resilience
- Deference to expertise

**High-Reliability Organization Theory.** In contrast to these rather pessimistic views of NAT concerning the organizational challenges to safety, HROT suggests that proper organization of people, technology, and processes can handle complex and hazardous activities at acceptable levels of performance.[373,453] In fact, consider the many endeavors in which HROs manage to achieve nearly failure-free results despite high intrinsic risk and high throughput.

Box 6.7 shows the common characteristics of HROs.[454] It is important to note that many organizations display some of these characteristics, but true HROs display them all simultaneously. Box 6.8 shows the organizational safety strategies that guide the thinking of people in an HRO. Although these elements point in the right direction, they remain theoretical if not—in our case—translated to health care, and then embedded into the fabric of an organization's operations. An HRO-based safety strategy tool in the form of a reference sheet is available at no cost from the Institute for Healthcare Improvement (IHI).[455] Fig. 6.15 shows four strategic key elements of HROs, which are explained in more detail in Boxes 6.9 and 6.10 and in the following section.

Anesthesiology has traditionally been strong at some elements of HRO, particularly in redundancy and technical safety measures. A movement is growing in anesthesia to implement HRO philosophies and techniques more fully.[456] In fact, anesthesiologists not only have been promoters of the patient safety movement in general but also have been leaders at applying HROT principles to health care. In 2003, the APSF began initiatives in high reliability perioperative health care (see special issue of the *APSF Newsletter*, summer 2003, at www.apsf.org). More recently, HROs have been conceptualized as one of three approaches to safety: ultra-adaptive (which embraces risks, e.g., trauma center), high-reliability (which manages risks, e.g., scheduled surgery), and ultra-safe (which avoids risk, e.g., radiotherapy).[10] Providing anesthesiology to an ASA1 patient is considered between the high-reliability and ultra-safe approach.[10]

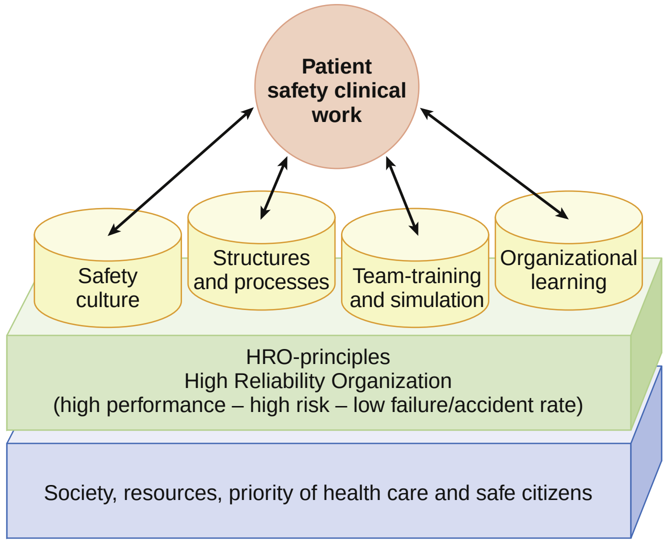


**Fig. 6.15 The fundamentals and principles of a high reliability organization.**

## BOX 6.9 Elements of a Culture of Safety[437,441,454,560]

**Values**

- Safety is most important goal, overriding production or efficiency
- Preoccupation is with possible "failures," not past "successes"
- Necessary resources/incentives/rewards are provided for optimal safety, not only for optimal production

**Beliefs**

- Safety must be actively managed
- Processes and routines of care are as (or more) important to safety as individual dedication, skill, or effort
- Openness about safety and errors is essential; learning from normal and adverse events should be thorough

**Norms**

- Low-ranking personnel raise safety issues and challenge ambiguity regardless of hierarchy or rank
- Calling for help is encouraged and occurs frequently, even by experienced personnel
- Explicit communication is frequent
- The hierarchy is flat—leaders listen to juniors; juniors speak up; and calling for help is routine regardless of rank
- People are rewarded for rationally erring on the side of safety, even when their credible concerns turn out to be wrong

Modified from Weick KE. Organizational culture as a source of high reliability. *Calif Manage Rev*. 1987;29:112–127.

BOX 6.10 **Key Elements of a High-Reliability Organization in Medicine**[437,441,454,560]

**Established Culture of Safety (see elements Box 6.9)**

**Optimal Structures and Procedures**

- Decision making rests with those with greatest knowledge or experience about specific issues regardless of rank or job type.
- The unit integrates crews from different departments (e.g., cardiac surgery, cardiac anesthesia, OR nursing, perfusion, ICU) into a coherent clinical team. Teamwork and resiliency are emphasized.
- Formal procedures are in place to maximize transfer of information to all team members before a case (e.g., briefings or time-out procedures).
- Schedules are designed to keep work hours and duty periods at reasonable levels to avoid undue fatigue. Personnel under excessive stress are supported or replaced as needed.
- Standardized procedures, techniques, and equipment are adopted whenever possible so that similar tasks or operations are performed similarly regardless of the personnel involved; conversely, when necessary (in an emergency or adverse event), the team is resilient and responds as needed to the situation without slavish dependence on standard routines.
- The use of preplanned algorithms, checklists, and cognitive aids is actively encouraged.
- Easy access to current information systems is available at all times and all locations.

**Training and Practice in Routine Procedures and Simulations**

- Debriefings are conducted after each case.
- Nonpunitive assessment instruments are used on a regular basis to provide current feedback and identify elements requiring special training.
- Initial and recurrent simulation-based single-discipline and multidisciplinary training in crew resource management occurs (see Chapter 7).
- Actual clinical crews and teams conduct periodic drills or simulations of critical situations in the real OR, PACU, and ICU.
- Resident training uses a guided curriculum; training goals and the level of responsibility assigned to a resident match the current proficiency level of the trainee with the complexity of the procedure.

**Organizational Learning**

- Robust mechanisms are in regular use for organizational learning, both prospectively (considering in advance how to optimize protocols and procedures, such as failure mode and analysis of effects) and retrospectively (from analyzing reports of adverse events, near misses, or problems such as root cause analysis).
- Problems are analyzed primarily to determine what can be improved, rather than whom to blame. Altered procedures are assessed and adopted as appropriate. Process changes reflect appropriate analysis.

*ICU*, Intensive care unit; *OR*, operating room; *PACU*, postanesthesia care unit.

## Safety I and Safety II: Ensuring that as Few Things as Possible go Wrong or that as Many Things as Possible go Right…?

As indicated above, perspectives on safety are changing. In recent years several scientists questioned the definition of safety as the absence of errors. A new view of safety has evolved, defining it as maximizing the ways that work can evolve in a correct way and focusing primarily on why human performance succeeds most often despite myriad challenges. Erik Hollnagel labelled this new approach Safety-II, as opposed to Safety-I, which denotes the traditional approach investigating errors, incidents, and accidents.[457] *"Safety management should therefore move from ensuring that 'as few things as possible go wrong' [Safety-I] to ensuring that 'as many things as possible go right [Safety-II]'"* (p. 4).[458]

The Safety-II approach aims to understand how good performance is actually produced: how people adapt the workflow, their use of devices, and their organization of tasks to achieve good performance even in challenging circumstances. In this regard it is quite similar to HROT. Safety-II also sees successful performance as a learning space:

> *this "…approach assumes that everyday performance variability provides the adaptations that are needed to respond to varying conditions, and hence is the reason why things go right. Humans are consequently seen as a resource necessary for system flexibility and resilience. In Safety-II the purpose of investigations changes to become an understanding of how things usually go right, since that is the basis for explaining how things occasionally go wrong." (p. 4)*[458]

Perhaps the most important new ideas of Safety-I and -II are the analytical character of the models. The focus on positive performance provides a different lens and rather than emphasizing the individual's success it addresses how and why such success occurs. One specific method that Hollnagel[459] describes is functional resonance analysis, which identifies the different pieces of a system and investigates in detail how they interact with each other dynamically. Many phenomena emerge from the interplay of the system parts, but this emergence might not be easy or possible to explain on a causal basis. A detailed description of the Safety-I and Safety-II approach by Hollnagel, Wears, and Braithwaite is available in PDF format online (*"From Safety-I to Safety-II: A White Paper. The Resilient Health Care Net"*).[458]

## Resilience and Uncertainty Management: Safety is a Dynamic State, not all Risks can be Eliminated

System safety is not a static property of hospitals and departments; rather it is dynamic, often on short time scales. Even with the implementation of robust patient safety strategies and regulatory regimes, (1) not all risks can be eliminated in the system and (2) safety, even once established, is not omnipresent or infinitely persistent. Whether risk in any setting can credibly be lowered to zero is widely debated. Admitting that risk cannot be prevented while striving to find more appropriate ways of handling adverse occurrences, for example through improving system resilience [447,448] or the ability to manage uncertainties,[460-465] seems appropriate regardless of the theoretical approach. Whereas some system safety methodologies view even a domain's own professionals as unreliable components, the theories of HRO, Safety-I, and Safety-II view people as core elements in creating reliable systems.

**Resilience.** The term resilience in respect to patient safety is derived from resilience engineering and is an important characteristic of HROs. The introduction to health care was promoted by Hollnagel and colleagues. Resilience describes the intrinsic ability of individuals, teams, and the system to cope with and adjust to new or changing demands and to respond effectively and safely to unforeseen, unpredicted, and unexpected problems or demands as they occur, even after a major mishap or in the presence of continuous stress. A resilient system owns the ability to produce success despite conditions that could easily lead to failure.

**Uncertainty Management.** Grote argues that *"in order to improve risk management and safety more generally deliberate increases in uncertainty may be beneficial"* (p. 71).[460] Grote furthermore distinguishes two uncertainty paradigms[461]: (1) Uncertainty may be minimized by high levels of standardization, central planning, automation of work/processes, and high levels of specialization with few degrees of freedom for employees (stability). (2) Newer organization theories in contrast stress the need for flexible adaptation in highly uncertain and networked processes, empowering everyone in the organization to cope with uncertainty by providing them with options for action rather than fixed plans and standards. As a consequence, organizations must find a way to balance stability and flexibility as both can mutually enable each other.[466] It sometimes can be worth tolerating some degree of uncertainty—relying on flexible adaptation of intelligent, well-trained personnel and stability by well-functioning systems—rather than to attempt to eradicate every possible uncertainty by standardization. From an HROT perspective's view one could say to standardize where possible (or sensible) while remaining flexible and resilient. Clearly there is a sweet spot between these extremes, although how to achieve that balance remains under debate.[467]

### Normalization of Deviance and Flirting with the Margin

**Normalization of Deviance.** Normalization of deviance is a term first coined by American sociologist Diane Vaughan who conducted a detailed organizational analysis of the Space Shuttle Challenger disaster.[468] The phenomenon occurs when people within an organization become so insensitive to deviant practices or occurrences that do not cause a problem that the practices themselves no longer seem wrong—essentially creating a *"new normal."* Such normalization of deviance emerges insidiously, sometimes over years. Once this happens on a large scale, no one within an organization is able to see the shortcomings in the behavior. They become resistant to suggestions that they are in fact abnormal and deviant, dismissing allegations that *"the emperor has no clothes."* Because disaster indeed does not happen without a number of critical factors lining up, their resistance is reinforced by the continued good outcomes—until a catastrophe occurs. Many have applied these concepts to health care including anesthesiology.[48-50,445] Banja[47] gives an overview of the topic in health care overall and identifies a number of reasons why normalization of deviance occurs in organizations, including:

- The existing rules are considered stupid and inefficient
- Knowledge is imperfect and uneven
- The work itself, along with new technology, can disrupt work behaviors and rule compliance
- "I'm breaking the rule for the good of my patient!"
- "The rules don't apply to me"/"You can trust me"
- Workers are afraid to speak up
- Leadership is unaware of or downplays reports or findings on system problems

**Flirting With the Margin.** Cook and Rasmussen published two related models to normalization of deviance that can be understood as flirting with the margin.[469] Their so-called dynamic safety model identifies three different states of a system in which an organization can operate (stable systems, unstable systems, stable but high-risk systems). The model points out that the states can be floating, depending on the set of organizational boundaries (i.e., economic, workload, acceptable performance) and the pressures within the system (i.e., management, safety campaigns/culture, staff). Typically the highest economic yield lies near the margin and the system may be pushed toward or even over the marginal boundary that safeguards systems from errors, accidents, and adverse events. The constitutive flirting with the margin model draws attention to the risk that repeated shifts outside the marginal boundary may lead to the original margin being judged as too conservative, resulting in a shift of the marginal boundary (normalization of deviance). When this happens regular operations in a system take place in an already dangerous marginal zone, implying a false sense of safety and raising the probability of accidents.

## ACHIEVING HIGH RELIABILTY AND SYSTEM THINKING: FUNDAMENTAL ELEMENTS FOR A SYSTEMATIC SAFETY APPROACH

**How can clinical departments and health care institutions transform into a high-reliability organization?** Addressing safety at the individual and team level has yielded some useful improvements in health care. However, more comprehensive improvement will require transforming whole organizations. Altering particular care processes is not enough; the work culture needs to be transformed. The AHRQ published a report in 2008—*"Becoming a High Reliability Organization: Operational advice for Hospital Leaders"*—that summarizes the topic in depth.[470]

As displayed in Fig. 6.15, HROs can be characterized essentially by four key structural pillars: (1) creation and sustainment of a culture of safety; (2) global and profound organizational learning, including incident reporting systems (IRS); (3) continuous training of individuals, teams, and work units including the regular use of simulation; and (4) continuous optimization of safety-relevant structures and processes. The four pillars are intended to provide anchor points for systematic organizational improvement. They are explained in more detail in the subsequent sections.

### Culture of Safety

**Creating a culture of safety** is an important element of enhancing patient safety.[471-473] Safety culture is part of the

**BOX 6.11 Key Features of High Reliability Organizations Based on the AHRQ's Definition**[561]

- acknowledgment of the high-risk nature of an organization's activities and the determination to achieve consistently safe operations
- a blame-free environment where individuals are able to report errors or near misses without fear of reprimand or punishment
- encouragement of collaboration across ranks and disciplines to seek solutions to patient safety problems
- organizational commitment of resources to address safety concerns

overall culture of an organization. Opposed to the widely spread culture of blame (also called negative safety culture), the culture of safety is also referred to as the culture of no-blame or is reinforced in its meaning by the expression positive safety culture.

One prominent definition of culture is: "*A pattern of shared basic assumptions learned by a group as it solved its problems of external adaptation and internal integration*" (p.12).[474] More simply, culture is "*the way we do things around here,*" or "*what you do when nobody is looking.*" The Joint Commission defines safety culture as follows: *"Safety culture is the sum of what an organization is and does in the pursuit of safety. [. . .] the product of individual and group beliefs, values, attitudes, perceptions, competencies, and patterns of behavior that determine the organization's commitment to quality and patient safety"* (p. 2).[475]

Edgar Schein described three elements of culture that can be observed: (1) artifacts that are used in the organization (e.g., charts, clothes/uniforms, meetings, rituals), (2) espoused beliefs and values (some measurable in surveys and some by interviews or by watching and listening to everyday work), and (3) underlying assumptions that are so ingrained that they are hardly noticeable any more (e.g., what is meant by a patient vs. a client or partner; by illness vs. health; or by safety vs. quality or outcome). Box 6.9 shows the major elements of a culture of safety based on shared values (what is important), beliefs (how things should work), and norms (the way things work).

The Joint Commission published behaviors that undermine a safety culture and suggests respective counteractions.[476] Two reviews on the current literature of safety culture are available.[477,478]

A health care HRO's commitment to safety needs to start at the top—with full buy-in from chief executives and boards of directors or trustees and palpably extend through all levels of middle managers and fully into frontline personnel (professionals and others). This commitment encompasses the key features (based on AHRQ's formulation) shown in Box 6.11.

When an organization does not promote a culture of safety, staff members often are unwilling to report adverse events and unsafe conditions because they fear reprisal or from prior experience believe reporting rarely results in change (see later sections "Organizational Learning" and "Incident Reporting").[471]

A variety of techniques have been developed to help organizations create and sustain a safety culture. Some of these address getting senior managers and executives more directly in touch with what is happening at the sharp end of work, by activities such as Patient Safety Leadership Walk-Rounds[479] or Leveraging Frontline Expertise (LFLE).[479,480] Other interventions suggested by the IHI include: designation of a patient safety officer, involvement of patients in safety initiatives, appointment of a safety champion for every unit, safety briefings, and simulation of possible adverse events (see later section on "Periodic Team Training and Simulation Team Training" and Chapter 7).[481] Other widely available guides to address an organization's safety culture come from The American College of Healthcare Executives and IHI/NPSF Lucian Leape Institute[482] and the Joint Commission.[483] It is hard to demonstrate which, if any, of these strategies and techniques are most effective, and it may depend heavily on a variety of local factors in each organization.[484]

It is problematic that, sometimes, safety culture is thought to mean culture of no blame. Safety culture is actually a much broader concept and the notion of no blame or blame-free has widely given way to the concept of a just culture. While no blame is appropriate for many unintended errors, other actions do seem blameworthy and demand individual accountability. A just culture focuses on identifying and addressing systems issues that lead individuals to engage in unsafe behaviors, while maintaining individual accountability by establishing zero tolerance for reckless behavior. It distinguishes between human error (e.g., slips), at-risk behavior (e.g., taking shortcuts), and reckless behavior (e.g., ignoring required safety steps). Gross negligence, behavior violations, and destructive acts are not tolerated.

Nonetheless, unjust cultures of individual blame still appear to be dominant.[476] Khatri and colleagues reported an increased likelihood of a culture of blame in health care organizations that (1) rely predominantly on hierarchical, compliance-based management systems; (2) attach less importance to employee involvement in decision making; and (3) neglect human resource management capabilities to help foster a safety culture.[485]

**PATIENT SAFETY ACTION BOX**

Mind your language! Ensure that dialogues, interviews, discussions, and reports avoid judgmental or blaming language (e.g., *"You should/could have...," "Why didn't you...?," "Do you think that was a good idea?," "The professional failed to..."*). Instead, use language that encourages systems thinking.[486]

Anesthesiology as a specialty has played a leading role in the attempt to turn the rather predominant culture of blame into a culture of safety—putting safety first and trying to understand how errors, incidents, and adverse events evolve.[11,40,456,487-490]

**Measuring Safety Culture.** Measuring safety culture is difficult. Strictly speaking, it may only be possible to investigate culture by anthropologic means—embedding ethnographers into the workplace for deep understanding of how work is conducted. This can be supplemented by structured interviews. Such methods are difficult and costly. More frequently safety culture is measured through written surveys of health care personnel. Essentially these measure safety climate—the attitudes of personnel as represented by survey responses. It is difficult to extrapolate from these results to the culture as actually enacted. Nonetheless, surveys are relatively simple and low cost, especially since the advent of online administration of the instruments.

Several validated survey tools are available to measure hospital safety and teamwork safety climates, including, for example, the Patient Safety Culture in Healthcare Organizations (PSCHO),[491-493] the AHRQ Survey on Patient Safety Culture, and the Safety Attitudes Questionnaire (SAQ). Each of the various instruments have a somewhat different focus, and the methods of administration of such surveys can be very important.

Among the issues that influence what can be learned from such surveys are: (a) Who is asked to complete the survey? Is it hospital-wide or just in one or a few work units? Sometimes the work unit is the appropriate unit of analysis but often the target may need to be broader.[494] (b) Are managers and senior leaders sampled in the same fraction as other workers? If so, this will mean that their views will not be well represented because they make up such a small fraction of the overall workforce. Oversampling of important but small populations can compensate for this. (c) Are the surveys truly confidential or anonymous? (d) How are the data interpreted? Looking primarily at the views of the majority of respondents may not be sufficient. If only a modest fraction (the rule of thumb from some experts is about 10% or more) respond in ways antithetical to a culture of safety that may represent a serious lack in its uniformity, and show a problem. For example, elements of the PSCHO survey have been asked also in different surveys of military aviators, acknowledged HRO. The negative safety views almost never were near the 10% level but this was seen substantially more often in the health care population.[495] Teamwork and communication dimensions of safety culture have been significantly related to adverse clinical events.[491,496-498]

Despite the past decade's focus on improving patient safety, most health care organizations are still striving to achieve high-reliability organization status[445,499]—consistently providing high quality care, with substantial load while minimizing adverse events.

In an update of the sentinel event alert from 2009, the Joint Commission 2017 calls again for senior health care leaders to establish a culture of safety within their organizations, use just culture principles to establish transparent and fair policies for addressing errors by clinical personnel in the front lines, and maintain robust structures for analyzing and responding to adverse events. Specific suggested actions include involving hospital boards and patients in safety efforts and making safety performance an explicit part of the evaluation for leaders. Adherence to sentinel event alert recommendations is assessed as part of Joint Commission accreditation surveys.[475]

**PATIENT SAFETY ACTION BOX**

Mind your attitude! Pursuing a culture of safety oftentimes is about one's attitude and reactions when safety concerns are raised. For example: If a patient's condition is deteriorating and someone else calls the rapid response team (RRT) when you think you might have things under control, don't say *"Why did you call the RRT? It's fine, do you think I'm an idiot?"* Instead it's better to say *"Thanks for calling the RRT—I think I know what's going on and have it under control, but it can't hurt to have them here."* Conversely, when a team arrives, if they find that there is no active crisis, they should not complain (or roll their eyes). Instead they should thank the clinician for calling them and offer to help in any way even though they seem to have things well in hand. In health care, one sometimes rewards people verbally for a good pickup, noticing something that is clearly of importance to the patient's care. Yet one rarely rewards people for raising their credible concerns when they turn out not to be an issue. Providing such rewards regardless of outcome will strengthen the safety culture and foster the desired speaking up.

## Organizational Learning

An important strategy for improving patient safety and a core content of HROs is organizational learning. Organizational learning "*is defined as the process of creating and applying valid knowledge to enable an organization to improve.*"[500] Such learning should be both prospective (i.e., using Failure Mode and Effect Analysis; FMEA) and retrospective (i.e., using [critical] incident reporting systems; [C]IRS). In analogy to aviation, Donaldson referred to organizational learning in health care as "passing the orange wire test":

*"Imagine that a Boeing 757 aircraft engine contained an orange-coloured wire essential to its safe functioning. Imagine that an airline engineer doing a preflight inspection spotted that the wire was frayed in a way that suggested a systematic fault rather than routine wear and tear. Imagine what would happen next. It is likely that most 757 engines in the world would be inspected—probably within days—and the orange wire, if faulty, renewed."*[501]

**So, what about health care and the orange wire test?** Over the last two decades IRS have generated a lot of momentum in enhancing system safety in health care by organizational learning. The next sections focus on: (1) basic information on prospective (FMEA) and retrospective (IRS) organizational learning; (2) more detailed information about the purpose of IRS, their challenges, and their effectiveness; (3) barriers and facilitators for IRS; (4) characteristics of successful IRS; (5) legal issues of IRS; and (6) the linked idea of independent medical accident investigation boards is discussed based on a recent pioneering safety movement in the United Kingdom.

**Failure Mode And Effect Analysis.** FMEA has been adapted to health care from engineering systems analysis; it is sometimes used as a tool to analyze adverse events in retrospect. The FMEA approach is to lay out comprehensively the possible failure modes and their effects that could have led to the events and the outcome that occurred. This helps define ways in which the chain of accident evolution could have been prevented or thwarted. A prospective approach to safety can use FMEA techniques to identify safety gaps in advance and implement corrective measures. This can be especially useful for assessing proposed changes to the system—such as introducing a new piece of equipment or a new set of surgical procedures (e.g., starting a liver transplant program where none had existed). Contemplating in advance the ways that things might fail will help determine whether the benefits outweigh the risks organizationally, how best to structure the change, as well as how best to prevent or mitigate problems when they inevitably occur.

**(Critical) Incident Reporting System†.** The retrospective approach to organizational learning means maximizing the learning to be had from understanding incidents or near misses that have already happened. Even though the terms vary in the literature, based on the *WHO Draft Guidelines for Adverse Event Reporting and Learning Systems*[502] an incident is any deviation from usual medical care that causes harm to a patient or presents a risk of harm. It includes (1) adverse events, where harm is caused to a patient, sometimes also referred to as sentinel events (SE) or critical incidents, as well as (2) near misses. A near miss is a situation that potentially could have turned into a critical incident, but was somehow prevented beforehand. Yet another kind of incident is termed a never event, an incident that results in serious patient harm or death, classified as one that is never the natural result of disease or therapeutic side effect.

Apart from certain mandatory legal reporting and disclosure requirements, (critical) IRSs, sometimes also called patient safety reporting systems (PSRS), are usually voluntary. While original IRS were paper-based, technological progress has allowed the development of mostly electronic or web-based systems. Although IRS adopt various formats, most have the same core operating model: frontline staff, usually those directly involved in an event or actions leading to it, anonymously or confidentially provide detailed information about something that has occurred. In the next step, this report is analyzed—usually free of blame to the reporter—by expert analysts to identify contributing system and human factors, and if applicable, develop strategies for preventing such occurrences. A simplified overview of the core processes of IRS is given in Fig. 6.16. IRS aim to provide systematic organizational learning from local to global levels, recognizing that an incident that occurred in one unit might also be a problem in another unit.

Most HROs have made special efforts to create IRS for incidents of various severity and near misses. Despite several limitations, if IRS is used in a successful way, to quote Charles Vincent,[487] it can serve as a powerful *"window on the system,"* enabling understanding of system problems and safety gaps. In order to function well, IRS need to be easy to use, organizationally integrated and coherent, supported by a culture of safety (see earlier correspondent section), free of sanctions, and linked to feedback about what is being done about the issues reported.

**Other methods for organizational learning.** Neither FMEA nor IRS alone can optimally enhance patient safety. They are just two of many strategies for soliciting input from frontline staff to creating snapshots of safety issues in the patient care arena. Information from many sources

†While reading this section American readers will need to break their ingrained habit of seeing "IRS" as the tax collecting agency of the U.S. federal government (Internal Revenue Service).

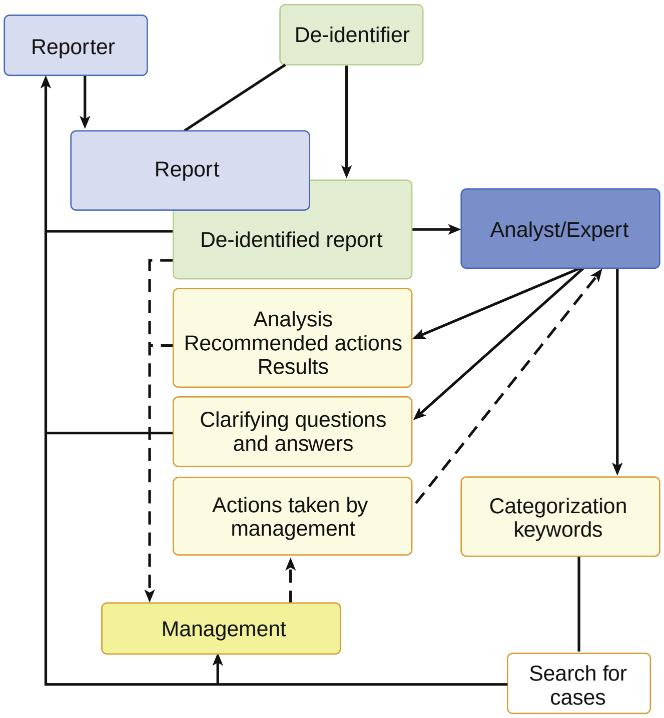


**Fig. 6.16 Data handling in a modern incident reporting system with deidentification.** The incoming reports are first completely deidentified by a trained deidentifier. Only after this step is the report ready to be analyzed. It is important that the reports are analyzed by a multiprofessional team and that recommendations be fed back to the management of the organization from which the report came. The analysis and feedback should be transparent for all stakeholders.

needs to be combined through a systematic assessment of error and harm to obtain the full picture. The U.S. Agency for Healthcare Research and Quality provides a detailed discussion of methods of identifying errors and latent safety problems for organizational learning.[503] Walk rounds by senior leaders and executives also offer a way of collecting data from frontline staff about possible safety hazards.[479]

IRS in health care have drawn their inspiration especially from commercial aviation and the nuclear industry. Unfortunately, the word reporting is a word with a variety of (mostly negative) connotations. In the context of organizational learning it is intended to be regarded as something positive and means communicating safety-relevant information. Anesthesia professionals experience weaknesses and strengths of their work sites during everyday work—valuable information of potential safety gaps that are already out there. By reporting, IRS can help the organization and staff at the rather blunt end of medicine (risk managers, executives, etc.) to extract safety-critical information from frontline staff at first hand, analyze it, and learn from it as an organization. Hence, IRS in a more positive way are often referred to as learning systems, such as the National Reporting and Learning System of the National Patient Safety Agency in the National Health Service (NHS) of the United Kingdom.

**Different Operating Modes of Incident Reporting Systems.** IRS around the world vary widely in terms of design and operational processes (see Appendix 6.1).[346,502,504-509] IRS can operate at different levels within the health care system: some IRS operate primarily at the local level (i.e., as a tool for local hospital quality and risk management), which may or may not feed into a larger scale; others operate on a larger regional or national scale (i.e., ASA' AIRS). The latter allow (a) a recognition of a pattern of (rare) events that otherwise could not be discerned, and (b) a wider dissemination of lessons learned and solutions created. Both on a local and national level, IRS can be related to a single specialty, or include a broader suite of professional domains. Some IRS accept reports of all kind of events and deviations (i.e., near misses, adverse events, sentinel events, never events, etc.). Others restrict their reports to incidents that match specific narrow criteria.

**The Goals of Incident Reporting Systems.** The applicable goals of reporting systems are currently under debate with respect to the way in which data can be used, particularly whether for different combinations of the following: (1) help health care organizations learn and improve, (2) benchmark and compare organizations, (3) hold organizations accountable for safety performance, or (4) help regulators and funders make judgments.[502,510-513] Some of these IRS goals, while compatible in theory, may be mutually exclusive in practice. The emphasis applied to each goal influences system design features, such as whether reporting is mandatory or voluntary, whether reports are confidential or made public, and what kind of incidents are allowed to be reported.

**Are IRS effective?.** In the United States, all hospitals are required to maintain a confidential event reporting system. In Germany, this has been the case since 2013. Almost two decades ago, Lucian Leape wrote: "If reporting is safe and provides useful information from expert analysis, it can measurably improve safety."[504] Despite their current ubiquity, the actual contribution of these systems to any of their stated goals is uncertain and questions about their effectiveness remain.[514,515]

**Challenges and Misunderstandings About Incident Reporting Systems.** In a recent paper *"The problem with incident reporting,"* Macrae summarizes a variety of issues surrounding IRS.[512] These include, among many others:

1. Underreporting has been recognized as a major limitation of incident reporting. Of the errors and adverse events that occur in hospital settings, reporting systems capture fewer than 10%.[516] A detailed review of causes of underreporting is described in the section on barriers of reporting. While increasing the absolute number of reports can be useful, their quality is of greatest importance. Charles Vincent stresses that analyzing a small number of incidents thoroughly is probably more valuable than a cursory overview of a large number of incidents.[487]
2. Another widespread misunderstanding of IRS is the idea that the goal of reporting is to provide a numerical metric of harm to patients. In contrary, merely counting incidents is largely uninformative and probably a waste of time.[517] It is sometimes described as a box-checking exercise. Many reports can describe similar events and the relative learning per event shrinks markedly after the first few, whereas some kinds of events are not reported and hence the system may be blind to them. All reporting systems, whether voluntary or not, have serious selection-bias issues—many events are never reported both because it takes effort to do so and because doing so seems to expose the individual and the work setting to risk of reputation loss or other negative consequences.
3. Even at best, IRS provide only partial views on the organization. For a variety of reasons 50% to 80% of the reports are filed by nurses. Physicians file only 1% to 3% of incident reports.[518,519] But many issues involve physician care—up to 94% of the events based on a landmark study.[520] It is likely that to fully understand a system it would be necessary for trained observers (ethnographers) to be embedded in it. Moreover, even if all events were known about in detail the tasks of analyzing and understanding them and finding practical but robust solutions to problems uncovered are far more difficult than merely collecting the information.

**BOX 6.12 Important Characteristics of Effective Incident Reporting Systems**[11,502,523,527]

- Integration of the incident reporting system into the organization and full support by management
- The absence of negative sanctions for reporters and people involved
- Confidential or anonymous reporting option, with active deidentification (domain expertise required)
- Legal protection and state-of-the-art data security
- Independence of the organizational hierarchy: reports are sent to a trusted subunit outside the hierarchy of the organization or outside the organization (external trust center, e.g., NASA for the ASRS)
- Orientation to a system that enables all stakeholders of patient safety, including physicians, nurses, and technicians, to file reports easily
- Easy and fast reporting
- Training of stakeholders to file valuable reports (e.g., focusing on human factor issues, as well as medical-technical aspects)
- Timely feedback about reception of the report, its analysis, and proposed measures to be taken from it
- Analysis of each report by experts (a multiprofessional team that has a background not only in the medical domain but also in issues of human performance and analysis methods)
- Deep analysis of selected cases by using root cause analyses or failure modes and effect analyses with the aim of improving systems safety in the future
- Timely implementation of improvements to confirm the "reactivity" of the system and to *make a difference*
- Evaluation of improvements and special care to avoid "improvements for the worse" (quick fixes without improving the underlying latent dangers)
- Organizational support of reporting and analysis of cases, as well as the implementation of improvements
- Supports continuous improvement of the positive proactive safety culture in the department (systems perspective!)

*ASRS*, Aviation Safety Reporting System; *NASA*, National Aeronautics and Space Administration.

### Characteristics of Successful Incident Reporting Systems

**Reporting Environment.** The details of successful IRS are covered in a number of publications,[1,502,505-507,521-527], and summarized in Box 6.12. A culture of safety is a prerequisite for an effective IRS.[502,506] If people fear negative consequences from reports or think that nothing will change, they will not file reports.

Additionally, successful IRS need top management to spread the message of a blame-free and non-punitive objective of IRS and to ensure that the actual activities of the organization comply. Furthermore, health care organizations should be accountable for investigating their own reports.[513]

**BARRIERS AND FACILITATORS TO REPORTING.** IRS live on the willingness of the staff to report. Common barriers reported by health care professionals include[508]: fear of blame; legal penalties; the perception that incident reporting does not improve patient safety; lack of organizational support; inadequate feedback; no incident follow-up; lack of knowledge about IRS; and lack of understanding about what constitutes an error. Additional aspects found by Firth-Cozens and colleagues[528] were a too-narrow definition of reportable errors and the effort of making the report. Lack of feedback appeared also as the most important barrier in another study of doctors and nurses.[529]

Common facilitators included a non-judgmental environment; the perception that incident reporting improves safety; clarifying what to report and how to do it as well as how the system uses reports; role models (such as managers); legislated protection of reporters; ability to report anonymously.[508] Additional aspects found by Firth-Cozens and colleagues were[528]: improved leadership about safety and errors; learning groups and learning timeouts; cultural change to make clear what is acceptable behavior; action by management to bring about change and to support employees; middle-grade staff on policy committees; support for each other and from management.

**WHAT SHOULD BE REPORTED IN INCIDENT REPORTING SYSTEMS AND BY WHOM?** In aviation, the cradle of IRS, there are separate reporting systems for incidents (deviations without a negative outcome) versus accidents (with negative outcome). Aviation accidents are investigated by an independent national body (see later section on "Accident Investigation Board"). In contrast to aviation, where the occurrence of an accident is usually quite public and events with negative outcomes are never supposed to happen, in the health care setting every human being will become ill and die someday so that most negative outcomes are inherent to the progression of disease. It is often difficult to determine which outcomes are the result of deviations versus those due to disease itself or inherent side effects.

From the authors' point of view, the invitation to staff to report should be very broad with few limitations on reporting criteria. This way, reporting is simpler for clinicians and staff and a wide net can be cast to identify as many safety-relevant occurrences and system gaps as possible. For this reason many experts believe that for health care event reporting systems, all adverse incidents should be reportable to the system regardless of whether there was a negative outcome. Whereas all health care organization staff should be included for reporting,[506] another interesting approach is to also give patients and relatives the opportunity to report.[502]

Recently Macrae[512] and other experts have argued that the "report it all, catch it all" approach misses an important opportunity to use specific reporting criteria to shape attention to certain events and set priorities on key risks. This becomes increasingly important as an IRS becomes established in an organization and receives a higher volume of reports. In their literature review Stavropoulou and colleagues found evidence that IRS seem more effective if there are explicit criteria for what counts as an incident.[515]

A rather new approach to incident reporting is called learning from excellence,[530] an approach that is in line with the idea of Safety-II (see earlier section). Learning from excellence means that analysis of reports of positive events and excellent performance in which the outcome was good despite challenging clinical circumstances may be as useful as analyzing failures.

There is a risk that certain kinds of IRS can end up being dominated by self-interested claims and complaints.[9] This can happen if staff members are not fully introduced to the goals and operating principles of what to report and why. IRS can also be used as a means for one or more individuals to attempt to exert power over other individuals or groups.

**WHAT SHOULD REPORT FORMS LOOK LIKE?** Typically, incident forms are partly standardized—to collect basic clinical details—while including the possibility to describe the incident in a free-text field. So-called narrative reports provide the opportunity to capture the rich context and storyline that allow the conditions that contributed to the error to be explored and understood. IRS that rely largely on an array of checkboxes for the reporter to choose relevant causes of the incident have not proven to be as useful.[502,506]

While traditional event reporting systems were paper-based, technological enhancements have allowed the development of web-based systems. On the reporting form, staff should be encouraged to also propose solutions for incidents.[513] Ideally, it should not take long for personnel to complete the form.[529] In the future, IRS reporting might use digital resources such as smartphones, enabling staff to report in near real-time using a device that they are accustomed to.[507]

**CONFIDENTIALITY AND ANONYMITY.** Usually, reports are submitted by staff members who were directly involved in the events; these professionals may have legitimate concerns about potential effects the reporting could have on their reputation or their employment performance record. Some IRS are entirely anonymous—neither the patient nor the reporting professional can be identified. This grants a high level of protection, although unique aspects of clinical events may make them self-identifying. For organizational learning, anonymous reports carry a major disadvantage: analysts cannot go back and ask for further information to clarify the report (which is often incomplete).

Other IRS, in contrast, are confidential but not anonymous, meaning that the identity of the reporter is known to the system but kept as secret as possible. Ideally there will be strong legal protection from disclosing the reporter's identity (sometimes with exclusions about purposeful professional misconduct or criminal acts). In general, confidential reports should be deidentified as fully as possible, once the full story has been elicited by the analyzing team.[9] Experts suggest that confidential systems should also allow for anonymous reports, as obtaining any report is more important than missing it entirely.[502,506]

Deidentifying reports can tricky. It is not always easy during the deidentification process to balance retaining the key information required to understand the situation versus deleting all possibly identifying data. The combination of facts about a case may be unique and may thus be intrinsically identifiable, even when seemingly all objective identifiers are stripped.[531] Those involved in the deidentification process proper need special training and supervision to ensure that the appropriate balance is achieved.

**PATIENT SAFETY ACTION BOX**

To learn from errors or incidents and to improve system and patient safety systematically, the primary questions of incident reporting should not address *"who was wrong"* but address *"what was wrong and how/why."* In a next step, incident reporting needs to focus on *"who can do what to prevent such things from happening again."*

Another widespread concern in relation to confidentiality and anonymity is fear of repercussions if reported event is disclosed internally to supervisors or managers. This fear likely influences what is reported, generating a counterproductive filter that prevents important information being passed up the hierarchy.[512] A typical model drawn from aviation is that IRS are operated and managed by an independent safety team that has no influence on personnel decisions and performance records.

**Incident Categorization.** The next step of the IRS is to categorize it to make it easier to find or link to it internally and to compare data across care providers, possibly using a standardized format.[502,506,513] The most commonly used framework for categorization is the WHO Framework of Critical Incidents (www.who.int/patientsafety/implementation/taxonomy/ICPS-report/en/).

**Analysis.** A structured and defined mechanism should be in place for analyzing reports.[521] A widely used framework for analysis of reported incidents among many others and variants is the London Protocol by Taylor-Adams and Vincent.[424] Reports should be interpreted by someone who knows the work and knows the context.[517] For health care incident reports to be of most value they should be reviewed by clinicians, perhaps working also with people who can identify the human factors and organizational system issues.[532] The value of multidisciplinary and multiprofessional investigating committees for analyzing incidents is stressed by experts.[522,533] Common findings of an analysis should characterize the problem, draw conclusions, and set out an action plan.[506]

**Action.** One of the major problems with incident reporting in health care as it stands is that *"we collect too much and do too little."*[512] Structured approaches to developing action plans and change may be helpful.[521] Reporting systems, both local and national, are sometimes overwhelmed by the volume of reports filed. As a consequence, they often fall short in defining recommendations for good and sustainable solutions. In the worst case, so-called quick fixes are produced that themselves trigger new risks. Even well-meaning activities of promoting lessons learned as organizational safety alerts, an updated policy, or new clinical recommendations, will not by themselves promote learning.[512] Learning is a complex social and participative process that involves people actively reflecting on and reorganizing shared knowledge, technologies, and practices.

Apart from an optimal organizational embedding, IRS can be particularly effective when they are successfully integrated and intertwined to other safety measures. For example, linking simulation team-training programs with an IRS allows for mutual input. Using reported incidents in anesthesia as a basis for simulation scenarios makes the training experience and message for the anesthesia professional very relevant to everyday clinical work. Conversely simulations can deepen the understanding of how and why things happened the way they did, and the experience of simulations can trigger participating clinicians to be more interested in reporting to the IRS in the future.

**Feedback.** Timely feedback should be given to the reporter, confirming that the report was received and is being processed so that they do not feel that their report was just tossed aside.[497,504] In the course, the reporter should be individually kept informed of next steps and actions taken. Failure to receive feedback after reporting an event and the perception that incident reporting neither brings change nor improves patient safety frustrates reporters. Summaries of reported events (deidentified) should be disseminated in a timely fashion to staff.[521] A variety of complementary feedback modes have been described.[507,534] Researchers have described a safety action feedback loop. This feedback loop unfortunately receives inadequate attention in many organizations,[512,522] leading to the perception of IRS as black holes (reports go in but nothing useful ever seems to come out). Clinical managers should seek to use action feedback information to motivate their staff.[535]

In the past 15 years, research about IRS have focused primarily on setting the stage for technical infrastructure, report collection forms, and categorization and analysis tools. Although those foundations are important, *"over the next 15 years we must refocus our efforts and develop more sophisticated infrastructures for investigation, learning and sharing, …"* (p. 74).[512] Leistikow and colleagues controversially argue that "the journey, not the arrival matters," meaning to focus more on how hospitals learn from incidents and less on what hospitals learn.[511]

**LEGAL ISSUES OF REPORTING SYSTEMS.** Especially in jurisdictions for which medical liability litigation is common, certain legal issues affect reporting systems. For some kinds of events in some settings, legal requirements to report the event to a governmental body may be in place. This is true in the United States for certain kinds of adverse drug events or for certain failures of medical devices. Moreover, some U.S. states have started mandatory reporting programs about certain never events. In general, voluntary IRS operate completely separate from these governmental types of reporting systems.

In the United States there are various aspects of law in individual states and at the federal level that can provide statutory protection (shield) from discovery (in litigation) of certain kinds of reports to certain organizations. The U.S. Congress passed the Patient Safety and Quality Improvement Act of 2005 (Public Law 109-41)—implemented in 2009—providing for the Department of Health and Human Services to certify patient safety organizations (PSOs) to collect confidential reports about events and to analyze the information. The act provides strong legal protection (privilege) from any compelled release of the information, as in the process of discovery in a lawsuit. Separate privilege from discovery may be granted in states that provide it for internal reporting systems within hospitals that are quality improvement activities, but state laws vary widely on this matter. In addition, the quality improvement protections are often challenged during litigation, and whether the privilege will be applied depends on the ruling of a judge in each individual case. Reporting systems in other countries have used different strategies. For example, in Germany, national IRS have constituted themselves as a press office (informing the anesthesia public domain as journalists would); this then brings them under the protection of the free press act and rights, and makes it almost impossible to use its data in litigation.

**The Anesthesia Incident Reporting System in the United States.** In 2011 the Anesthesia Quality Institute, affiliated with the ASA, initiated the Anesthesia IRS (AIRS) to collect reports of critical events in anesthesia. Incidents can be reported by secure web-based data collection, either confidentially or anonymously. Confidential reporting allows the AIRS analyst to contact the individual for clarification or follow-up. Legal protection is provided by U.S. federal legislation described above. The law also imposes strict guidelines on how confidentiality of the work must be preserved. The AIRS publishes regularly on their Homepage as well a monthly column in the ASA Newsletter, in which it describes—in deidentified form—an interesting case report and its analysis by the AIRS Committee (Lit: https://www.aqihq.org/casereportsandcommittee.aspx). As of October 2018, AIRS has published a case analysis every month since October 2011. AIRS has instituted 4 specialty modules to collect data about events in certain categories of special interest: (1) cases that involved a respiratory depression event; (2) cases that involved a lack of necessary medications (drug shortage); (3) cases that fall under the OB/GYN procedural service type or took place in an institution's OB ward; (4) cases for patients under the age of 18 (pediatrics).

**Should Health Care have an Independent Organization for Accident Investigation?** As noted, serious incidents and transportation accidents in aviation and other industries are investigated by an entirely independent, interdisciplinary governmental safety investigator. For example the National Transportation Safety Board (NTSB; www.ntsb.gov) in the United States; similar agencies exist in most countries. These generally provide for rapid—usually in well under 24 hours—deployment of expert accident investigators to the scene of accidents with extensive laboratory and analytical facilities and expertise headquarters.

For several decades, suggestions have been made to establish an NTSB-like body to investigate accidents in health care. Especially in the past few years, new calls have been made to establish such an organization.[536] Until 2017, the complexities and pitfalls of such an investigation, including the fact that adverse outcomes are several orders of magnitude more common in health care than in commercial aviation, have obstructed any progress toward creating such a program. In April 2017, the United Kingdom began to operate the first independent investigation body, the Healthcare Safety Investigation Branch (HSIB; www.hsib.org.uk). Even though funded by the Department of Health and hosted by the NHS Improvement, the multidisciplinary team of experienced safety investigators operates independently. Future developments will show what benefit and usage will derive from this activity.

The debate about the feasibility and advisability of such high-level investigating organizations in different jurisdictions will probably continue for a long time. We believe professional investigation of safety critical events and harm, with rapid deployment and expert analysis, will lead to new insights and the implementation of practical, robust, and effective solutions.

### Continuous Training including simulation

Small groups of individuals work together throughout perioperative care. Anesthesia professionals, surgeons, nurses, and other health professionals must coordinate their activities in order to make safe and efficient patient care the priority. Whereas teams in the classical sense work together over a longer period of time, the configuration of teams in the dynamic and frequently changing setting of the OR or ICU environment contains particular challenges of so-called action teams (see earlier section on "Teamwork"). Members of action teams are rarely trained together, and to-date, few are trained at all specifically in how to manage challenging situations providing safe care, for example, by applying the CRM concept (see earlier section on "Crisis Resource Management"). Moreover, they come from distinctly different disciplines and diverse educational backgrounds to the extent that they are often described as being in silos or tribes. The varied nature of the work and the necessity for cooperation among those who perform it make team training an ideal tool in the drive to improve patient safety and reduce medical errors.

How the CRM concept can be learned, trained, and implemented best is explained more in detail in the upcoming section. More detailed information on the conduct and modalities of modern simulation team training for health care professionals can be found in Chapter 7.

**How Can Crisis Resource Management-related Skills be Learned, Trained, and Sustained?** Despite the growing evidence, systematic interventions to improve patient and system safety have only partially penetrated medical thinking and teaching. CRM-oriented training and behavior should be one component of a comprehensive approach to addressing human factors issues in anesthesia safety, but few if any institutions have deployed such integrated approaches. There have been several reviews on the variety of MTTs, the latest published by Weaver and colleagues in 2014.[409] The targeted teamwork competencies of the programs they discuss are similar, but the curricula differ widely: in content, duration, participation frequency of clinicians and staff, delivery strategies (didactic, seminar, simulation/debriefing), maintenance strategies, and evaluation effort. One major question seems to be the degree to which simulation adds to simple classroom activities.

**Two Different Approaches of Team Training: Simulation-Based or Classroom-Based?** The oldest medical CRM curriculum, namely the ACRM curriculum, relies heavily on high-fidelity simulation-based training, introducing the CRM principles to the participants and then highlighting CRM aspects of medical care in the post-scenario debriefings. A pocket card of the 15 CRM key points is shown in Fig. 6.17.


**Fig. 6.17 Crisis resource management (CRM) pocket cards.** One side of the cards shows the 15 CRM key principles by Rall and Gaba. The other side of the card shows two graphics. One shows a tool for formalizing decision-making and avoiding fixation errors called "FOR-DEC," which is derived from aviation. Another shows the "10-seconds-for-10-minutes" concept, a reminder to take the necessary time to organize into a team, whenever appropriate. The cards are handy and pocket sized, and can be carried around during work as a reminder or can be distributed in the department as reminder, an interest-gaining or a multiplication tool. During the CRM courses or simulation training sessions of the authors, CRM pocket cards are given to each participant. (Photograph by M. Rall.)

Much simpler than simulation-based training is purely seminar-based training about human factors, CRM principles, teamwork, and team communication. Several team training programs, including MedTeams, MTM, and DOM, rely on classroom-based approaches only and use didactic lectures, group exercises and role plays, discussion, and analysis of trigger videos.

The different concepts of these training programs, probably as well as the cost and manpower of high-fidelity simulation and the small number of participants per simulation session, raised the question whether simulation-based CRM training is needed compared to classroom-based training and whether they are equally effective. Only a few studies have investigated the effectiveness of classroom-based team trainings versus simulator-based programs.[537] Weaver's summary of review findings reported similar positive effects on learner reactions, knowledge or skills, and clinical practices, as well as patient outcomes.[409] Riley et al. compared perinatal work areas in three different hospitals; one participated in a didactic team-training program, one participated in an in situ simulation program, and one served as a control.[538] Results indicated that significantly greater reductions in patient harm were achieved by the group that participated in the in situ simulation program compared with both the didactic and control groups (37% reduction vs. 1% reduction vs. 43% increase in harm, respectively). The lessons learned from the implementation of the Veteran Affairs (VA) MTT program introduced earlier also suggest that simulation is a crucial part of CRM-based team training interventions.[414]

Drawing parallels to the translated CRM training curriculum in aviation, the classroom-based approach correlates with what the Federal Aviation Agency (FAA) calls phase I (awareness), whereas the simulation-based approach correlates with phase II (skills practice and feedback), which is followed by phase III for maintenance (recurrence training). This is in accordance with the comprehensive approach to teamwork training of Salas and colleagues.

This didactic approach suggests three elements needed for adult education: (1) convey knowledge about teamwork, (2) develop skills of teamwork, and (3) enhance attitudes concerning teamwork.[539,540] Gaba wrote in a point-counterpoint discussion about the question "What does simulation add to teamwork training"[541] the following, proposing the benefit of simulation-based CRM training:

*"Didactic training may address knowledge and can influence attitudes, but to fully develop skills and alter attitudes, experiential training [like simulation-based training] is likely to be the most effective. Thus, given the complexity of the topic, it is likely that multiple approaches will be necessary to maximize learning and transfer to real patient care."*

Pratt and Sachs challenge this view, arguing that the rather complex and costly simulation approach is replaceable with classroom-based teaching and intensive coaching of clinicians during and after real patient care activities.[542] A rather new approach is the concept of teaching CRM-related topics with a screen-based interactive virtual simulation featuring typical clinical situations.[543,544] Even though virtual simulations permit flexible, cost-efficient, and asynchronous learning, the role and the effectiveness of such virtual activities away from a physical team intervention have to be further evaluated.

Gaba continued in the aforementioned discussion:

*"Moreover, it is also likely that no single course or exercise can change such complex behaviors permanently—only long-term repetitive training and practice, combined with solid reinforcement of the principles and skills in the actual work environment, has any chance of developing new and optimal teamwork patterns that become deeply ingrained in the work culture."*[541]

It seems reasonable to combine best practices from classroom-based and simulation-based training for an optimal CRM team-training experience. More and more CRM-related organizational or departmental interventions now do so, following the classical phases I (awareness) and II (practical skills and feedback) of the aviation CRM curriculum: that is, ACRM curriculum, TeamSTEPPS, VA CTT, and several CRM implementation studies. Primarily, staff participates in seminar-based CRM interventions in order to learn about the concepts and to create awareness. Simulation-based training is then used after or during the classroom introduction to apply the theoretical knowledge during practical medical case scenarios and to get feedback or to refresh knowledge in order to reach a sustainable base over time. More details on the simulation-based approach are provided in Chapter 7. More details on different ways of teaching ACRM—both simulation- and classroom-based—can be found in the second edition of the book *Crisis Management in Anesthesiology*.[14]

We believe that practicing the reliable execution of CRM skills in routine and emergency situations requires, among other things, exposure to challenging clinical situations in realistic simulation scenarios, followed by detailed group debriefings led by qualified instructors to analyze what transpired. As discussed in Chapter 7, Such CRM-oriented simulation training may be available in dedicated simulation centers or as in situ simulation training in actual work environments. Many simulation centers offer mobile simulation training whereby a simulation team can bring the simulator and simulation equipment to another facility to train the staff in institutions that do not have a simulator or the relevant instructors. Another way is to prepare a few of a site's own clinicians to conduct CRM-based simulation team trainings by sending them to one of the instructor courses for CRM-based simulation team training. Although there are many such courses, the three best known sites of instructor training in the United States are at the Center for Medical Simulation in Boston, the Center for Immersive and Simulation-based Learning at Stanford School of Medicine, and WISER at University of Pittsburgh. In Europe, among others there is the InPASS InFacT instructor course (by Rall), the instructor courses run by DIMS (by Dieckmann), and the EuSiM instructor course.

When choosing a train-the-trainer course, it is important to understand that simulation is a technique, not a technology. It takes many forms: from nontechnological modalities (e.g. verbal simulation, role-playing) to simple skills training models to computerized full-body mannequins; from training students to training professional teams, from rather simple mega-code training scenarios to complex emergency scenario design. Each training form requires a different amount of manpower, logistics, and costs. But crucial under all circumstances is the special skills of the simulation instructors in course and scenario preparation, scenario execution, and debriefing (see Chapter 7). In order to use simulation successfully, the simulation instructors need to be specially qualified in CRM-based training (see Chapter x), the learning objectives of the simulation training need to be set (see Chapter x), and the needs of learners at each stage of education must be targeted (see Chapter x). Furthermore, for simulation to be effective it needs to be integrated into the strategic concept of an organization in a way that promotes transfer of the ideas and skills learned to clinical practice.


**Fig. 6.18 Example of the organizational integration of "Speaking up" and "STOP! 10-seconds-for-10-minutes."** The photo shows a laminated sign with the words "Speak up" above the trauma room door (red arrow) and a laminated sign with the words "Stop! 10-seconds-for-10-minutes" on the floor (blue arrow) at the University Hospital of Zurich, Switzerland. The signs are placed as a reminders for safety tools for clinical teams and at the same time show the organizational effort and support for patient safety issues. (Photos published with permission of University Hospital Zurich [USZ], Center for Simulation [Chair: M. Kolbe]).

**Reinforcement and Sustainability of Team Training Effects.** Sustainability of team training effects over time is a common question among both improvement scientists and practitioners. Many early evaluations of team training limited follow-up evaluations to 6 months post-training or less.[409] Positive responses after a simulation-based CRM intervention have been found to last for up to 6 months after training.[347] Patterson found gains in teamwork knowledge sustained at follow-up conducted 8 to 10 months post-training.[242] In studies examining the implementation of the VA's team training program, results indicated both significant improvements in perceptions of teamwork climate up to 11 months following implementation[545] and statistically significant reductions in surgical mortality 1 year post training.[42] Those numbers mimic the findings of Armour et al. who indicated a decay in gains 1 year post training.[397]

While a great deal of work has been dedicated to examining optimal refresher training intervals for clinical procedural skills (e.g., resuscitation or intubation skills), relatively minimal work has been done to understand optimal refresher intervals for teamwork competencies. Moffatt and colleagues offered a recurrent training two years after the initial training.[41] The VA CTT program conducts mandatory recurrent training one year after the initial training session, viewing this approach *"critical to re-enforcing key CRM concepts in the program."*[546] Nothing is stated in the program about further training frequency after one year. Based on the literature findings and also drawing parallels to the CRM curriculum in aviation (phase III: recurrence training), a refresher interval of one year for CRM team trainings would seem rational, but we do not know of any institutions that do full-day sessions for experienced clinicians this frequently.

It is important not think about simulation as a one-shot thing once or every now and then, but rather about a career-long set of activities. These might sometimes take place in a dedicated simulation center or a hospital simulation area and sometimes in situ, directly where patients are treated and cared for.[547] If simulation activities are combined this way it stands to reason that there will be an accumulation of change in individual and team skills, knowledge, attitudes, and behaviors as well as in systems probing and systems change.

**Organizational Aspects of the Implementation and Sustainability of Team Training.** As with nearly all patient safety principles, application of CRM key points to patient care must be supported by top leadership and reinforced in the actual work environment (Fig. 6.18). It is of less use to study these principles (or even practice them in simulations) only to find that the pressures and culture of the real OR make them impossible to implement. Fully integrating the concepts underlying the CRM key points into the structures and processes of clinical practice has proven to be a significant challenge. The Joint Commission Journal on Quality and Patient Safety outlined several critical factors for developing successful team training in 2009.[539] In brief, those are:

- Align team training objectives and safety aims with organizational goals.
- Provide organizational support for the team training initiative.
- Get frontline care leaders on board.
- Prepare the environment and trainees for team training.
- Determine required resources and time commitment and ensure their availability.
- Facilitate application of trained teamwork skills on the job.
- Measure the effectiveness of the team training program.

Box 6.13 shows characteristics of the implementation of team training interventions that have proved to be successful characteristics.

### Continuous Optimization of Safety-Relevant Structures and Processes

HROs try to continually alter the way that they work to improve safety—the structure of their organization, its work units (sometimes described as microsystems), and teams, as well as the usual processes and protocols of care. Sometimes, but not always, these changes can also improve efficiency as well as safety. Since individual workarounds succeed only one patient at a time, addressing the flow of everyday work, and the preparations for anomalies or crises, will be critical to making lasting improvement.

In order to optimize structures and processes continuously in regard to patient safety, it is important to maintain a culture of safety (see above) so that frontline staff are willing and enabled to contribute actively. Furthermore, when talking about the optimization of structures and processes in regard to safety, it is important to define and generate structured ways to transfer safety-critical information and topics, for example from IRS (see earlier section) and team training events (see earlier section) to those who are in charge of structural changes.

Surely, there are many different ways to optimize structures and processes. Starting points, for example, could be the aforementioned use of walkrounds[479] and closing performance gaps by using debriefing as formative assessment[548] after routine and non-routine events.

In many places, the optimization of structures and processes lies in the hand of quality and risk managers. However, we have observed gaps between what is optimized by those working at the blunt end and what is acknowledged and played out by personnel at the sharp end.[549] In order to master this challenge, from the authors' point of view and based on the view of other experts, it is important to:

- focus on the four main elements of safety culture, organizational learning (i.e., IRS), team training, and optimization of structures and processes in a very balanced manner
- develop and optimize structures and processes together and with close involvement of clinical teams (participatory development and user-centered iterative design)

### BOX 6.13 Characteristics of Successful Team Training

Studies[5,41,42,414,546,562] that evaluated the positive impact of the implementation of a CRM team-training program and that were successful, show the following, or part of the following, characteristics for the implementation and training process:

**Preparation and Implementation**

- Assess measures of collaboration and standardization (i.e., 2 months), followed by planning the implementation (i.e., 1 month) based on individual organizational aspects
- Appointment of a "steering committee" consisting of hospital medical and nursing leadership
- Create leadership support and engage departmental teams for planning and preparation

**Initiation**

- Administrative Training: Intensive training of the leadership group, for example, chief executive officer, chief financial officer, dean, chief medical officer, chief quality officer, department chairs, division heads (i.e., 2 days)
- Administrative Training: Training of executive and senior leadership, board members, and perioperative departmental leadership attending the same CRM training that all perioperative physicians and staff attend.
- Staff Training: Mandatory CRM training session for all physicians and nurses participating in the intervention. Some programs first started on a voluntary basis ("pilot")
- Interactive training and training in interprofessional teams
- Small groups (i.e., 15 participants/group) and sufficient exposition time for the lectures and interactive training sessions (i.e., 2 day à 9 h[5]; 1 day[42]; 4 h[41])
- Introduction of CRM with en bloc-training (all department staff participates in the training in a short time span, i.e., within 2 or 3 months)
- Team training provided by CRM qualified and experienced instructors; peer-to-peer communication is helpful
- Sufficient Trainer: Participant ratio is 2:15 for moderated interactive group work
- Training is a mixture of lectures and interactive elements (i.e., workshops, discussions, etc.)
- The potential for disturbance is as low as possible (i.e., no duty calls, no pagers, etc.) Eventually ORs must be closed for the training sessions
- Training tailored to organizational/departmental needs

**Maintenance**

- Creation of a CRM work group consisting of frontline clinicians, giving input to CRM every now and then (posts, bulletin notes, CRM as standard item during morning rounds and staff meetings, etc.), translating CRM into the organizational needs (professional ownership), and organizing several CRM activities (i.e., "week of CRM," refresher lectures, CRM "awards," etc.)
- CRM as part of the yearly individual evaluations
- Nomination of local "champions"
- Coaching and monitoring of unit-based performance outcomes (i.e., over 12 months) or "follow-up support" is provided
- Mandatory team training of all new staff members
- Mandatory "practical training" (i.e., CRM-based simulation team training)
- Mandatory "recurrence training" (after 1 year of initial training, not mandatory after 2 years of initial training)
- Steering committee continues to meet monthly to monitor progress
- Initiation of a "train-the-trainer program" to promote hospital's own CRM facilitators and internalize CRM training and implementation

- introduce and implement new processes and structures systematically, taking whatever time is needed to do this effectively rather than just rolling it out haphazardly. This likely needs change control to determine first how and where the new processes will involve and influence other activities, information that will best come from discussions with clinical personnel and their managers.
- adjust processes and structures in regard to findings from human factors engineering; sometimes it is the work environment or equipment that need to be changed and adapted to the realities of human performance rather than the other way around.

As it is rarely possible to implement or strengthen the four main elements of an HRO all at the same time; it is important to proceed step by step and balance the focus between the elements. Establishing a culture of safety is one of the most important goals as this element is incredibly intertwined with the success of the other elements. Nevertheless, a strong focus on human performance and patient safety within organizations lies in the optimization of structures and processes and IRS. At the same time, organizations should continually train their medical personnel about issues of human performance and patient safety, because there are three related challenges:

- **What do frontline personnel do until all structures and processes are optimized?** The development of strong and safe structures and processes cannot be achieved overnight. Many processes and structures need optimization. While this is going on clinical teams continue to treat patients day after day. They need to hone their skills even while working with outmoded structures and procedures.
- **Even when improved, no system and no process is perfect.** Even optimized processes and structures hold pitfalls; clinical teams will always need to compensate for them and for safety gaps. Only if the individuals and teams have learned and trained together in how to do so can they can operate safely—essentially *"people create safety"* (p. 267).[9]
- **At the very end of any structure or process there always stands a human being.** Regardless of whether the structures and processes are optimized, for the foreseeable future a human professional is at the sharp end of patient care, executing those processes and procedures, and consciously or inadvertently altering or bypassing them. Therefore they need to know and be able to use all relevant safety strategies. These professionals are indeed the last barriers against catastrophe and hence each should individually also exemplify the ideals of HROs, promoting resilience and flexibility at the same time (see earlier sections).

The behavior, commitment, and engagement of frontline staff itself is the crucial key to translate organizational intentions into practice. Our experience is that CRM-based simulation team training (clinical action and clinical relevance) with focus on human performance elements and patient safety can be a good starting point to gain the understanding and buy-in of clinical personnel to organizational changes.

# The Bigger Picture: Patient Safety Efforts on the U.S. National and International Level

## PATIENT SAFETY MILESTONES AND MOVEMENTS

The field of anesthesiology can rightly be proud of introducing the idea that patient safety is not just a byproduct of clinicians doing a good job, but rather is something to be studied, sought, and fought for as a matter in its own right. This was in large measure achieved by Jeffrey B. Cooper (at Massachusetts General Hospital) and Ellison C. (Jeep) Pierce, Jr., (when president of the ASA), who created a Committee on Patient Safety. Jeff, Jeep, and a few other like-minded innovators created the Anesthesia Patient Safety Foundation. These developments are acknowledged to be the founding milestones of the patient safety endeavor, and the inspiration for further development of similar organizations for all aspects of health care across the world.

In part through the efforts of such PSOs the medical community became more open to taking a harder look at medical human performance, error, and negative outcomes. Since the 1990s, many landmark publications and activities have addressed patient safety and the organizational aspects of reducing errors.[9,11,174,434,550-552]

Although many scholars within and outside of anesthesiology had been addressing these issues for some years, the report of the IOM in 1999, *To Err Is Human,*[174] was a highly publicized awakening in the United States about the problems of patient safety. Summarizing the primary literature, the report stated that *"tens of thousands die each year from errors in their care and hundreds of thousands suffer or barely escape from nonfatal injuries that a truly high-quality care system would largely prevent."* The subsequent report of the IOM Committee on Quality of Health Care in America in 2001, entitled *Crossing the Quality Chasm: A New Health System for the 21st Century,*[434] took a systematic approach to improvement of the entire health care system. It stated that *"between the health care we have and the care we could have, lies not just a gap, but a chasm"* because the health care system today harms too frequently yet routinely fails to deliver its potential benefits. The report concluded: *"The current care system cannot do the job. Trying harder will not work. Changing the systems of care will."*

Various other efforts have taken place, including the *"100,000 Lives Campaign"* (2004) by the IHI; the WHO patient safety program (2004); the patient safety enhancing *TeamSTEPPS* program (2005 and revised 2013); the *Patient Safety and Quality Improvement Act* establishing a voluntary IRS and providing privilege and confidentiality protections for reported patient safety information; the introduction of the *WHO Surgical Safety Checklist* (2008); and the *WHO Patient Safety Curriculum* (2011).

Fifteen years after the IOM report "*To Err is Human,*" the National Patient Safety Foundation (NPSF) convened an expert panel in 2015 to assess the state of the patient safety field and set the stage for the next 15 years of work. Among the recommendations[471] are: establishment of a total systems approach and a culture of safety, and calls for action by government, regulators, health professionals, and others to place higher priority on patient safety science and implementation. The Helsinki Declaration on Patient Safety in Anesthesiology[553] in 2010 from the European Board of Anesthesiology (EBA) and the European Society of Anesthesiology (ESA) emphasized the role of anesthesiology in promoting safe perioperative care in Europe.[371]

### Institutions Engaging in Patient Safety

Several governmental and non-governmental patient safety institutions have emerged over the past two decades, including the National Patient Safety Foundation (NPSF), the Agency for Healthcare Research and Quality (AHRQ), and the IHI in the United States; the National Patient Safety Agency (NPSA) in England; the Canadian Patient Safety Institute (CPSI); and many more.

### Raising the Awareness for Patient Safety

In 2003 the NPSF initiated a patient safety awareness week that takes place yearly, highlighting different patient safety topics. Two years later, in 2005, the WHO launched a yearly Patient Safety Day for increasing the awareness of patient safety.

### Certified Education in Patient Safety for Health Care Professionals

The NPSF created the Certified Professional in Patient Safety (CPPS) credential to establish core standards and benchmarking for the field and set an expected proficiency level for those seeking to become professionally certified in patient safety. By 2018, more than 2000 professionals have achieved the CPPS credential. They represent physicians, nurses, pharmacists, patient safety professionals, quality and risk management professionals, health care executives, nonclinical health care professionals, and others with the requisite background throughout the United States and nine other countries. The content of certification covers knowledge in the following five key elements: safety culture, leadership, patient safety risks and solutions, measuring and improving performance, and systems thinking and design/human factors. The VA National Center for Patient Safety, in cooperation with the VA Office of Academic Affiliations, offers one-year fellowships in patient safety to provide in-depth education in patient safety practice and leadership.

### National and International Evaluation of the Benefits of Patient Safety Programs

Over the last years the focus of patient safety initiatives has been put more and more on the question of economy and efficiency. Two major reports demonstrate the cost benefits of patient safety programs: (1) The report provided by the AHRQ in 2016 displays interim data on national efforts from 2010 to 2015 to improve safety in health care.[44,554] The report showed that hospital acquired conditions (HACs) have been declining since 2010 with many fewer deaths and substantial dollar savings. (2) The report launched by the international Organization for Economic Cooperation and Development (OECD) on the economics of patient safety in 2017. [472] The report estimated patient harm being the 14th leading cause of global disease burden and resulting in a considerable cost to patients, health care systems, and societies. Key messages emphasized the important role of leadership and the building of a positive safety culture. Similar economic success, but on the organizational level, was demonstrated in 2017 by Moffatt-Bruce and colleagues at an academic medical center.[41]

### Patients for Patient Safety

Furthermore, more and more attention is drawn to the support of patient engagement as a vital contributing component of safe care. The WHO launched the safety program Patients for Patient Safety and provides several toolkits for patients. Several programs in Canada, Australia, and the United States, for example, have been launched, following the idea of patients being the extra sets of eyes and ears that should be integrated into the safety processes.[555-557] Patients are more likely to participate and speak up if they feel authorized and supported to do so by health care workers. As a consequence, the successful setup of patient empowerment strategies requires the understanding of benefit by health care workers to buy in and then requires their full support.

## Conclusion and Outlook

Avoiding errors and harm to patients is crucial for every anesthesiologist. For the safety of the patients, but also for the psychological well-being of us as professionals, as professionals commonly suffer from patient harm as a second victim. Clinical knowledge and skills are not sufficient to harm any patient during care. This chapter has summarized, in regard to anesthesiology, how human performance issues matter. As can be gleaned from this chapter, there are many challenges to individual, team, and system performance that can degrade the ability to achieve safe and high-quality care. Knowing and teaching about these is the first of many steps to address them. Recurrent training and practice, with simulation as an important component, organizational learning after both successes and failures, and continuous fostering of a culture of safety and improvement will be needed. As Sir Liam Donaldson stated in 2004 to the Alliance for Patient Safety Conference in Washington: *"To err is human, to cover up is unforgivable, and to fail to learn is inexcusable."*

Anesthesia professionals can and should collaborate with their partners in surgery, nursing, and beyond; however, ultimately anesthesia professionals need to take responsibility for ensuring that we as individuals, the teams we work in, and our workplaces, are ever ready to provide the very best care.

Patient safety has generated a lot of momentum over the last 30 years. Many achievements have been made, although a lot of issues remain to be addressed satisfactorily in part because at their root are fundamental aspects of the way that health care is organized. Even countries that are pioneers in patient safety still struggle. In the developing world and low-resource settings, even basic aspects of patient safety still need to be addressed. Patient safety is a never ending battle, regardless of resources, and as Charles Vincent put it: "Safety in health care is a moving target."[558]

Many patient safety pioneers in medicine, including us (the authors), thought that many of the issues introduced in this chapter would be roughly a decade-long proposition. Now, with many of us being in our fourth decade of the patient safety journey, we know that the road goes ever on…

… and we all just have to keep on trucking.

## Acknowledgment

The editors, publisher, and Drs. Marcus Rall, David M. Gaba, and Peter Dieckmann would like to thank Dr. Steven K. Howard for his contribution to this chapter in the prior edition of this work. It has served as the foundation for the current chapter.

**Complete references available online at expertconsult.com.**

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## APPENDIX 6.1 **Online Links and Valuable Public Sources**

- Links to patient safety and crisis resource management resources
  - National Patient Safety Foundation: www.npsf.org/
  - Veterans Affairs National Center for Patient Safety:
    - Patient Safety: www.patientsafety.va.gov
    - VA Clinical Team Training program (CTT): www.patientsafety.va.gov/professionals/training/team.asp
  - The Joint Commission on Accreditation of Healthcare Organizations: www.jointcommission.org/
  - United Kingdom National Health Service National Patient Safety Agency: www.npsa.nhs.uk
  - Stanford School of Medicine, Center for Immersive and Simulation-based Learning https://cisl.stanford.edu/
  - Agency for Healthcare Research and Quality (AHRQ):
    - Patient Safety: www.ahrq.gov/patient-safety/index.html
    - TeamSTEPPS™: www.ahrq.gov/teamstepps/index.html
    - Patient Safety Organization Program: https://pso.ahrq.gov/
  - World Health Organization (WHO)
    - Patient Safety: www.who.int/patientsafety/en/
    - Multiprofessional Patient Safety Curriculum Guide (2011): www.who.int/patientsafety/education/mp_curriculum_guide/en/
    - Patient Safety Curriculum Guide for Medical Schools (2009): www.who.int/patientsafety/education/curriculum_guide_medical_schools/en/
    - The Conceptual Framework for the International Classification for Patient Safety (ICPS): www.who.int/patientsafety/implementation/taxonomy/ICPS-report/en/
    - Surgical Safety Checklist: www.who.int/patientsafety/topics/safe-surgery/checklist/en/
  - Patient Safety Education Program (PSEPTM): www.patientsafetyeducationproject.org/index.php
  - Australian Commission on Safety and Quality in Health Care: www.safetyandquality.gov.au/national-priorities/australian-safety-and-quality-framework-for-health-care/
- Links to different incident reporting systems and related topics
  - The American Society of Anesthesiologists Incident Reporting System (AIRS): www.aqihq.org/airs/airsIntro.aspx
  - United Kingdom National Health Service National Patient Safety Agency reporting system: www.nrls.npsa.nhs.uk/report-a-patient-safety-incident/
  - Pronovost's intensive care unit safety reporting system[85]
  - WHO Draft Guidelines for Adverse Event Reporting and Learning Systems—from Information to Action: www.who.int/iris/handle/10665/69797
  - U.S. Department of Veterans Affairs Patient Safety Reporting System (PSRS): https://psrs.arc.nasa.gov/
- Root Cause Analysis (RCA) Tools
  - United Kingdom National Healthcare Service: www.nrls.npsa.nhs.uk/resources/collections/root-cause-analysis/
  - VA National Center for Patient Safety: www.patientsafety.va.gov/professionals/onthejob/rca.asp
- Failure modes and effects analysis (FMEA) tools https://www.patientsafety.va.gov/professionals/onthejob/HFMEA.asp

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