Human Factors and Operating Room Safety

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There have been remarkable reductions in patient morbidity and mortality after surgical procedures over the preceding decades; however, adverse events still occur even among some low-risk patients. In many cases, surgical errors likely contribute in at least some measure to these outcomes. Historically, surgical outcomes have been attributed primarily to the technical skills of the surgeon and the medical condition and comorbidities of the patients. In general, “once patient outcomes (usually mortality) have been adjusted for patient risk factors, the remaining variance is presumed to be explained by individual surgical skill.”1 Hence, when things go wrong or surgical errors are made, it is logical from this human-centered perspective to question the particular surgeon’s competency or aptitude. This is the unspoken basis of individual surgeon rankings in public reporting.

In contrast, a human factors approach recognizes that human error is often the result of a combination of both individual surgeon factors and work system factors. Specifically, the Systems Engineering Initiative to Patient Safety (SEIPS) model is based on recognition that, in addition to surgical skill, performance and outcomes are also affected by such factors as teamwork and communication, the physical working environment, technology/tool design, task and workload factors, and organizational variables. According to this perspective, errors are the natural consequences (not causes) of the systemic breakdown among the myriad work system factors affecting performance.2 Consequently, patient safety programs are likely to be most effective when they intervene at specific failure points within the system

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rather than focusing exclusively on the competency of the individual who committed the error.3

Historically, most data concerning systemic factors that affect patient safety in the operating room (OR) have come from anecdotal and sentinel event reports, which often lack details concerning the specific nature of the systemic problems that affect surgical performance.3 However, in recent years, a growing number of published studies have used prospective data collection methods, such as ethnographic and direct observation, to identify empirically the real-time dynamics of work system factors in the OR and their impact on patient safety.4,5 Although the complexities of surgical care demand further research to fully understand the pathogenesis of surgical errors, the results of these prospective studies have begun to identify opportunities and interventions for improving surgical performance and patient outcomes. The efficacy of only a few of these interventions has been tested, and it is unlikely that any single intervention alone has a major impact on surgical care; however, most recommendations emerging from this body of research are grounded in empirical data. When considered together they provide an opportunity to develop comprehensive intervention strategies for addressing a wide variety of work system factors that affect surgical performance and patient safety in the OR.

This article reviews previous research on the impact of work system factors on surgical care. Specifically, the discussion highlights research pertaining to the following components of surgical care: (1) the physical OR environment, (2) teamwork and communication, (3) tools and technology, (4) tasks and workload, and (5) organizational processes.

THE OR ENVIRONMENT

Although most surgeons have become impervious to the complexity of the OR environment, there are numerous environmental factors that could potentially affect surgical performance. These factors include the general OR layout and clutter,6 as well as ambient factors such as noise,5 lighting,7 motion/vibration, and temperature. Among these factors, OR layout and noise have received most of the attention in the literature, and accordingly are the main focus here. However, this focus does not imply that the others are unimportant.

OR Layout

Congestion because of the location of equipment and displays, as well as the disarray of wires, tubes, and lines (known as the spaghetti syndrome), is a common scenario in the OR.8 Consequently, movement by members of the surgical team is often obstructed, wiring is difficult to access and maintain, and the risk of accidental disconnection of devices and human error are increased, all of which heighten the threat to patient safety.9 In addition, the location of workstations and the placement of equipment relative to the surgical table can hinder communication and coordination among team members. For example, in an unpublished study of perfusionists in cardiac surgery, we identified that the perfusionist’s location behind the surgeon as well as the various components of the cardiopulmonary bypass (CPB) machine that physically separated the perfusionists from the surgical table significantly hindered team performance. One of the principal problems cause by this OR layout was the inability of the perfusionists to see what was happening at the surgical field. This situation made it difficult for the perfusionist to coordinate their actions with the surgeon. As workarounds, perfusionists often anticipated the surgeon’s needs using the passage of time and inferences made from the movements of surgical personnel at the table.
Similarly, the surgeon was unable to observe the actions of the perfusionist. Consequently, this OR layout and configuration often led to poor coordination of activities that subsequently disrupted the surgical flow of the operation.

A variety of recommendations for addressing the spaghetti syndrome have been proposed, including better utilization of ceiling space, such as ceiling-mounted columns that descend to the team on request and return to their place after use. Others include color-coding and arranging cables in unique patterns on the ceiling for easier identification. The area under the operating table has been identified as an unused, vacant space for placing or storing equipment. The elimination of wiring through the use of wireless technology has also been proposed. A recent study of electronic medical devices in the operating theater and intensive care environments indicated that Bluetooth communication did not interfere with or change the function of the medical devices and argued that the utilization of wireless technology would not only eliminate clutter and the potential for confusion and errors but would also allow equipment to be arranged in a flexible manner in the different operating theaters according to the specific operation being performed or the needs and preferences of the surgical team. However, such flexibility or variability in OR layout may not always be beneficial. Brogmus and colleagues have argued that “although the needs in ORs vary according to the procedures performed, there is a good argument to be made for making the layout of ORs consistent so that efficiency is improved. For example, a consistent OR layout will have clean-up supplies on the same shelf, communication equipment in the same location, and the information monitor on the same boom. This also will reduce wasted time and, potentially, patient-threatening errors.”

Although the benefits of standardization versus flexibility have long been debated, there are general principles that can be followed when determining the arrangement of components within the OR suite. These principles include (1) the importance principle (components and equipment that are vital to the achievement of a procedure or task should be placed in convenient locations); (2) the frequency of use principle (components and equipment that are frequently used during the completion of a procedure or task should be located in close proximity and be easily accessible); (3) the function principle (components, equipment, or information/displays that serve the same function or are commonly used together to make decisions or complete a task should be placed in similar locations or close to one another), and (4) the sequence of use principle (during completion of a procedure or task, certain tools and technology may be consistently used in a set sequence or order and should therefore be arranged in a manner to facilitate this process). These principles are not always independent and may even conflict when being used to make decisions regarding the rearrangement of components in the OR suite. Component location may also interfere with face-to-face communication among surgical staff or disrupt the traffic flow or movement of personnel in the OR. Consequently, considerable research is needed to collect and combine appropriate sources of data, including task analysis, anthropometric, and architectural data before specific recommendations can be made for redesigning a particular cardiac surgery OR suite.

**Noise in the OR**

In addition to layout and clutter, the OR environment is full of noise and distractions that can hinder the ability of the surgeon and other team members to fully concentrate on the task at hand. Noise is generally defined as auditory stimuli that bear no informational relationship to the completion of the immediate task. A recent study of noise levels in the OR found that the average maximum noise level for an operation was more than 80 dB, with absolute maximum noise level observed being more than
90 dB. Sources of noise in the OR are numerous and include the low humming of ventilation systems and other electronic equipment, alarms and feedback alerts on pumps and monitors, music, telephones ringing, pagers (beepers) sounding, people entering and existing the room, and sidebar conversations among surgical staff.\textsuperscript{4,10} Noise can negatively affect surgical performance in a variety of ways, and these effects are particularly detrimental on dynamic tasks that require flexibility or rapid changes of responses to unexpected events. In particular, sources of noise can cause distraction and can hinder the ability of a surgeon to concentrate by masking acoustic task-related cues and inner speech so that surgeons cannot hear themselves think. Noise and distractions can also affect communication among the surgical team by reducing the ability to hear what others are saying or by causing statements spoken by others to be missed. Communication can also be hindered by changes in speech patterns that often occur when an individual needs to shout to overcome background noise.

Reducing noise and distractions in the OR is clearly desirable and would likely improve error management processes and surgical outcomes.\textsuperscript{11,12} Policies that limit the number of observers in the operating theater, restrict the use of radios and pagers, curb nonessential staff from entering the OR during a case and discourage noncase-related conversations among the surgical team have all been recommended. Such policies may not be practical in all organizations or may not be readily accepted by surgical staff. For example, during long surgical cases, the presence of background music may help individuals maintain levels of mental arousal needed to combat the effects of fatigue or boredom. Furthermore, the ability to engage in noncase-related conversations among surgical staff might also contribute to team cohesion and job satisfaction. Likewise the inability to communicate with others outside the OR via telephone or pagers may affect the safety of other patients in the hospital who are also under the care of the surgeon (eg, in the postoperative intensive care unit) if alternative mechanisms or procedures for communication are not established. A compromise might be selective application of the sterile cockpit rule, limiting noise and distractions only during critical phases of an operation that imposes high mental workload, such as weaning the patient from the heart-lung machine. Among the challenges to application of this approach is the spectrum of tasks that impose high mental workload, which vary considerably across surgical staff as well as across different phases of the surgical procedure.\textsuperscript{13,14}

TEAMWORK AND COMMUNICATION

Effective teamwork and communication have been recognized as imperative drivers of quality and safety in almost every complex industry. The Joint Commission (2006)\textsuperscript{15} has identified communication as the number 1 root cause (65%) of reported sentinel events from 1995 to 2004. Within the surgical arena specifically, we have previously shown\textsuperscript{4} that teamwork factors alone accounted for roughly 45% of the variance in the errors committed by surgeons during cardiac cases. Teamwork issues generally clustered around issues of miscommunication, lack of coordination, failures in monitoring, and lack of team familiarity. These findings are not specific to our study. Poor staff communication has been linked to poor surgical outcomes in general.\textsuperscript{3,16} For example, a study by Gawande and colleagues\textsuperscript{17} reported on the dangers of incomplete, nonexistent, or erroneous communication in the OR, indicating that such miscommunication events were causal factors in 43% of errors made during surgery. Another study by Lingard and colleagues\textsuperscript{18} found that 36% of communication errors in the OR resulted in visible effects on system processes, including inefficiency, team
tension, resource waste, work-around, delay, patient inconvenience, and procedural error.

A recent review of the teamwork literature identified many team effectiveness models. Each of these models, in turn, highlights a variety of key factors that presumably promote better teamwork performance. However, the investigators concluded that there is currently no consensus among researchers as to how teamwork should be defined or the types of strategies that should be used to improve team effectiveness. Despite this situation, the empiric research on the breakdown of surgical teams’ communication and coordination during cardiac surgery clearly indicated several possibilities for improving team performance, including strategies that focus on team training, standardized communication, team familiarity and stability, and preoperative briefings. Although each has clear potential for enhancing safety, we focus on the last 2, because of their potentially unique fit with the surgical care process.

Cumulative Experience, Team Familiarity, and Stability

One of the key factors that affects teamwork and communication is team familiarity. For example, we recently compared miscommunication events during cardiac surgical cases among primary and secondary surgical teams. Primary surgical teams were defined as those in which most team members (certified surgical technologist, circulating registered nurse, resident/fellow, perfusionist, certified registered nurse anesthetist/anesthesiologist) were routinely matched together during surgical cases, whereas secondary surgical teams consisted mostly of members who had little familiarity with the operating surgeon or other team members. Results revealed a significantly lower number of surgical flow disruptions including miscommunication events per case among familiar (primary) teams versus unfamiliar (secondary) surgical teams. An analysis of individual surgeon performance was also consistent with these findings, in that surgeons made significantly fewer surgical errors per case when working with their primary surgical teams than when working with secondary teams.

Carthey and colleagues also found that team stability significantly improved the ability of cardiac surgeons to perform the complex aortic switch operation in pediatric patients. In particular, surgeons who had a different scrub nurse for each case, or worked in institutions that used ad hoc assignment of staff to the surgical theater, had more difficulty establishing team coordination at the table than surgeons who worked with familiar teams. During conditions in which surgeons were working with less familiar team members, they experienced “repeated losses of surgical flow because the team had to stop intermittently to correct errors.” Similar observations have been made during cases in which changes of staff occur because of work breaks or shift turnover, which disrupts the continuity of the team and their shared knowledge of the events.

Team familiarity and stability can also improve process variables, in addition to reducing errors and patient safety issues. For example, surgical teams who attempted to adopt a new technology had significantly shorter operating times when original teams were kept intact. Furthermore, literature in both the medical and organizational fields has found team stability to be an independent predictor of team performance. Within the surgical arena, the cumulative experience of the team has also been shown to significantly decrease operative times, which may be secondary to fewer surgical flow disruptions because of miscommunication. In stable teams, trust develops amongst team members, which in turn produces psychological safety. Team stability also allows for the acquisition of familiarity of other team members’ nonverbal communication styles and the anticipation of others’ actions. In addition, as described in our
previous study, stabilizing surgical teams would likely decrease staff turnover and increase team satisfaction.

It may be difficult within most institutions to allow only primary surgical team members to operate as a unit from a logistical standpoint; however, it is important that team members acquire an acceptable level of familiarity with one another. For example, at a minimum, one might strive for team stability during each surgical case. Team stability is important for developing and maintaining a shared mental model or awareness of the progression of the case, the potential problems that may have occurred previously during the case, or an understanding about any problems that may arise as the case progresses. One possible way of increasing team stability during an operation is to prohibit shift turnover (eg, the changing of surgical assistants or circulating nurses during a case), thereby requiring all surgical staff who began the case to remain in the OR until the operation is completed. However, such a strategy may be logistically implausible because of workload issues or professionally unacceptable given the culture within an organization (the topics of workload and organizational culture are discussed in depth in later sections). However, further research is clearly required to determine the effect that shift turnover might have on teamwork, as well as potential ways of remedying its impact.

**Preoperative Briefings**

Team meetings, such as preoperative briefings conducted before an operation, have the potential to address a variety of communication and teamwork issues. Preoperative briefings are not synonymous with the universal protocol or presurgical pause to ensure the right patient, right site, and right procedure. Briefings are meetings that are often conducted before the patient enters the OR and involve a more in-depth review of the case. Briefings also allow team members to ask questions or clarify uncertainties. Thus, preoperative briefings can be beneficial for all types of surgical teams, in terms of planning different aspects of the case, but may be principally beneficial for unfamiliar teams who may not be acquainted with a specific surgical procedure or the preferences of a particular surgeon. For example, DeFontes and Surbida developed a preoperative briefing protocol for use by general surgical teams that was similar to a preflight briefing used by the airline industry. A 6-month pilot of the briefing protocol indicated that wrong-site surgeries decreased, employee satisfaction increased, nursing personnel turnover decreased, and perception of the safety climate in the OR improved from good to outstanding. Operating suite personnel’s perception of teamwork quality also improved substantially. Within cardiac surgery, we found a significant reduction in the case frequency of surgical flow disruptions after implementation of preoperative briefings. Specifically, there was a reduction in the number of procedural knowledge disruptions and miscommunication events per case. On average, teams that conducted the briefing had significantly fewer trips to the core and spent less time in the core during the surgical case. There was also a trend toward decreased waste for teams that were briefed compared with teams that did not conduct a preoperative briefing.

Despite the potential benefits of preoperative briefings, and the recent endorsement of briefings by the World Health Organization (2008), their utilization remains low within many surgical specialties. This situation is likely a result of multiple factors. For example, there are no standardized protocols for conducting preoperative briefings. Each surgical specialty has unique issues that may need to be addressed before each operation. Therefore, a generic off-the-shelf checklist may not suffice. The development of a common template for designing briefing protocols is not unattainable, rather the specific content needs to be tailored to each surgical specialty. Other
barriers impeding the use of preoperative briefings include individual attitudes or resistance to change by surgical staff, as well as organizational barriers such as case schedules, lack of facilities, and limited resources. As documented by DeFontes and Surbida, the successful development of a preoperative briefing protocol takes several months of research and development, beginning with understanding the needs and views of key stakeholders (ie, surgical staff) and the nuances of the organization in which such briefings are to take place. There may also be confusion between 1-way communication via a checklist compared with bidirectional communication via an interactive and participatory briefing.

TOOLS AND TECHNOLOGY

The practice of surgery demands daily interface with highly sophisticated technologies. However, few of these medical technologies have been designed with the end user in mind, increasing the likelihood of user error. However, poor design is not the only issue that can negatively affect performance and use of medical technology. The process by which new technology is introduced and implemented can also have an impact on user acceptance and use, affecting the delivery of safe and efficient surgical care. Even when technology is properly designed, its implementation can have unintended consequences on the work process, some of which may be consequential and others may be profound.

Ensuring that Technology is Usable and Acceptable

New technology is often difficult to use because it differs from its predecessors in terms of the method by which information is displayed, inputs are performed, and automation is provided. Adjustment to new technology is even more difficult when systems are poorly designed. The role that poorly designed technology can play in producing errors that cause patient harm is becoming increasingly apparent. Roughly half of all recalls of medical devices result from design flaws, with specific types of devices being associated with unusually high use-error rates, such as infusion delivery devices. For example, in a previous human factor study of CPB machines, we identified several problems with the design and usability of these devices that predisposed surgical teams to make perfusion-related and other technical errors that threatened patient safety. In particular, these design shortcomings included problems with the format, legibility, and integration of information across displays, the location, sensitivity, and shape of input controls, and problems with indistinguishable, unreliable, disarmed, or nonexistent audible alarms. Such problems have also often been cited as factors contributing to user error of medical devices in anesthesia and other health care settings.

Research also suggests that health care providers are not passive recipients of new technology. Rather they are active agents who tailor technology to meet their needs, even if it is not effectively designed to do so. For example, Cook and Woods studied cardiac anesthesiologists’ use of a new computer-based physiology monitoring system during CPB procedures. Results revealed several characteristics of the new technology that reflected clumsy automation. Specifically, the benefits of the new computer system occurred during low workload situations but it also created new cognitive and physical demands that tended to congregate at times of high demand. As a result, anesthesiologists attempted to overcome these problems by adapting both the technology and their behavior to meet the needs of the patient during surgery, increasing the potential risk of errors. Other studies have found that users, rather than adapting to technology that is difficult to use, simply discontinue its use altogether.
Ensuring that medical devices and technology are designed to optimize their effective and safe use is clearly a priority in health care. The US Food and Drug Administration, US Department of Health and Human Services, and Center for Devices and Radiological Health jointly published the report *Medical Device Use Safety: Incorporating Human Factors Engineering into Risk Management*, which stated, “The field of human factors provides a variety of useful approaches to help identify, understand and address (medical device) use-related problems. The goal is to minimize use-related hazards, assure that intended users are able to use medical devices safely and effectively throughout the product life cycle.” Performing usability testing and heuristic evaluations to ensure that medical devices meet minimal design standards is one basic approach for achieving this objective.4 However, even when devices are deemed to be ergonomically designed, ensuring that end users have an opportunity to participate in the implementation process is vital to the acceptance of new technology. As noted by Lorenzi and Riley,25 “a ‘technically best’ system can be brought to its knees by people who have low psychological ownership in the system and who vigorously resist its implementation.” Training on the use of new technology is also important. For example, a recent study reported that surgeons are generally slower to adopt new information technology than their colleagues even when they believe it could potentially benefit patient care, because they often lack the appropriate training to use it effectively.26 Although many of these issues regarding technology design and training are common knowledge to human factor engineers, challenges remain with regard to how to implement these best practices within the context of cardiac surgery.

**Anticipating Unintended Consequences**

New technology, even if well designed, can have complex effects on work systems and can fundamentally transform the nature of the work process in unforeseen ways and with unanticipated consequences.23 The introduction of new surgical technology not only changes the nature of the task of the surgeon and the required psychomotor skills to accomplish it, it can also dramatically change the dynamics among the entire surgical team. For example, the introduction of minimally invasive cardiac surgery systems and surgical robots has been found to change the location of information sources, the information needs of surgeons, the nature of the visual information at the surgical site, and the flow of information exchange among the surgical staff.27 Even changes to seemingly benign tools such as the whiteboard in the OR can have significant effects. A recent study examined the use of whiteboards and the potential impact that introducing electronic whiteboards might have on collaborative work within a trauma center operating suite.28 Results suggested that the advantage of an electronic whiteboard with regard to automatic updating of information needed to be balanced against discouragement of active interaction and adaptation by surgical staff.28 In particular, large electronic display boards do not necessarily replicate the social functions of the whiteboard, such as resource planning and tracking, synchronous and asynchronous communication, multidisciplinary problem solving and negotiation, and socialization and team building.

Clearly, the introduction of new technology can have unexpected interactions within the surgical team and can potentially induce new forms of error. New technology often requires adjustments in team communication, the development of new procedures, and altered roles of OR personnel.27 Consequently, efforts need to be made before deployment to better understand how collaborative work may be affected in order to inform design and implementation strategies. Basic usability testing and heuristic evaluations can help in this process. However, simulation might serve as a more effective method for identifying unanticipated changes to work processes and it can also be
useful for training in new procedures associated with adapting to the technology. Simulation should be designed into the implementation process because it provides a safe and efficient means of planning, training, and learning about how the introduction of the new technology changes the current work system and what changes need to be made to allow the new work system to function safely before the technology is adopted. However, not all organizations have the resources or facilities to conduct elaborate simulation evaluations, nor can simulations always adequately mimic the real-world scenarios surrounding the use of the technology in practice. Therefore, pilot testing of new technologies is also important because it allows for additional problems to be identified that may not have been discovered during usability or simulation testing. Nevertheless, the process of identifying unintended effects of new technology remains more of an art than science. Research is needed to develop and refine methods for reliably determining the impact of new technology before it is implemented.

**TASK AND WORKLOAD FACTORS**

Job task factors such as physical and mental workload can dramatically affect performance and safety. Physical workload is often affected by task duration, strength requirements to complete the task, and behavioral repetition, whereas mental workload factors generally refer to the cognitive complexity (mental demand), time pressure, and criticality or risk of a task. Neither task dimension is completely independent of the other. Both types of workload can reduce levels of cognitive function by increasing levels of stress and fatigue, as is often the norm in complex high-intensity fields such as cardiac surgery. As with most work system factors in the SEIPS model, several recommendations have been used in other industries for reducing both mental and physical workload, including the use of new technology (eg, automation) and the development of standardized procedures and checklists, as well as the incorporation of rest breaks into the work scheduling process. Issues related to the last 2 recommendations are discussed in the next section.

**Developing Standardized Procedures and Checklists for Critical Tasks**

Standardized procedures and checklists have long been used in other dynamic safety-critical environments such as aviation to decrease errors of omission (forgetting critical steps) and errors of commission (improper implementation of a procedure or protocol), and to reduce decision errors under stressful situations. In general, a checklist is “a list of action items, tasks or behaviors arranged in a consistent [standardized] manner, which allows the evaluator to record the presence or absence of the individual items listed.” As a result, the use of a checklist can be particularly beneficial when there is a long sequence of operations or multiple steps in a procedure, there are critical aspects or timing of a task that cannot be missed or forgotten, there are important or mandatory tasks that must be performed, or there are multiple tasks distributed across time or personnel. Under these conditions, the use of checklists and memory aids within critical care settings has been found to reduce errors and improve the quality and reliability of medical care through the use of best practices. Checklists have also been shown to be beneficial and life saving in medical situations that require rapid systematic or standard approaches to crisis management such as anesthesiology and emergency medicine. Checklists are particularly useful when dealing with the human/machine interface.

Despite the proven benefits of checklists in improving the delivery of patient care, their integration into practice, including cardiac surgery, has not been so widespread
as in other fields. Perhaps one reason for this limited deployment of checklists is the concern that they reduce the flexibility of the health care provider. The implementation of a checklist might imply that it must be strictly adhered to in all situations, thereby potentially compromising the efficacy of the clinical process and infringing on clinical judgment. The design of a checklist is also critical to its effectiveness. Poorly designed checklists can lead to errors and accidents, as has been shown in the aviation industry. There are no published data to indicate that checklists have contributed to adverse events in health care settings or delays in treatment because of length or poor design.

Care also needs to taken when identifying which processes and procedures require the use of checklists so that they do not create an additional burden or layer of complexity. As noted by Hales and colleagues, "if each detail of every task were targeted for the development of a checklist, clinicians may experience 'checklist fatigue' whereby they become overburdened with completing these lists." Even when checklists are well designed, interruptions and distractions can still cause steps in a procedure to be missed or skipped. In addition, after several iterations of a procedure, complacency regarding task performance can arise, producing a perception that the checklist is unnecessary and therefore no longer used. Consequently, users of checklists need to be trained in their use and committed to incorporating them into their practice. To achieve this goal, considerable human factor research is needed to understand the context and goals of checklist use, including the application of cognitive task analysis methods, as well as the inclusion of a multidisciplinary research team to ensure that checklists are properly designed and endorsed by users.

ORGANIZATIONAL INFLUENCES

Several organizational factors have the potential to affect the delivery of safe and reliable health care, and many of these factors have been discussed in the literature. However, the topic of establishing and promoting a culture of safety within health care organizations “has become one of the pillars of the patient safety movement.” The general concept of a safety culture is not new and is generally traced back to the nuclear accident at Chernobyl in 1986, in which a poor safety culture was identified by the International Atomic Energy Agency as a major factor contributing to the accident. Since then, safety culture has been discussed in other major accident enquiries and analyses of system failures, such as the King’s Cross Underground fire in London and the Piper Alpha oil platform explosion in the North Sea, as well as the crash of Continental Express Flight 2574, the Columbia Space Shuttle accident, and the explosion at the British Petroleum refinery in Texas City.

The concept of safety culture has also been applied to patient safety. Patient safety culture is defined as the enduring value and priority placed on patient care by everyone in every group at every level of a health care organization. It refers to the extent to which individuals and groups commit to personal responsibility for patient safety, act to preserve, enhance, and communicate patient safety concerns, strive to actively learn, adapt, and modify (both individual and organizational) behavior based on lessons learned from mistakes, and be rewarded in a manner consistent with these values. Although safety culture may not be the only determinant of safety in organizations, it plays a substantial role in encouraging people to behave safely and to report errors when they do occur. There is also growing evidence that interventions aimed at improving safety culture can reduce accidents and injuries and within health care settings can reduce medical errors. Several strategies have been proposed for improving safety culture. However, as may be gleaned from its definition, the 2
interventions that seem to have the biggest potential are leadership engagement and accountability.

**Improving Leadership Engagement**

Leadership style has been shown to have a major impact on how patient safety initiatives are viewed and accepted among medical staff. Leaders who are considered engaging, transformational, and rewarding seem to have the most influence on improving safety culture. For example, Keroack and colleagues found that chief executive officers (CEOs) at top performing institutions tended to be passionate about improving quality and safety, and tended to have a hands-on style. They were frequent visitors to patient care areas, either as part of structured leadership walk-rounds or as unscheduled observers. In contrast, CEOs at institutions that had struggling safety cultures were generally unsure of their leadership roles in quality and safety initiatives. In addition, staff reported rarely seeing them in care areas and indicated that they did not feel comfortable raising safety or quality concerns with CEOs directly. Others studies have also shown the benefits of improving leadership engagement through executive walk-rounds. For example, monthly executive walk-rounds have been shown to have a significant impact on improving safety culture among nurses in tertiary care hospitals. Pronovost and colleagues reported that improving leadership engagement in patient safety activities within an intensive care unit significantly improved safety culture, reduced length of stay, nearly eliminated medication errors in transfer orders, and decreased nursing turnover.

According to the Institute for Healthcare Improvement, executive walk-rounds show a leader’s commitment to safety and dedication to learn about the safety issues within their organizations. They also reflect an “organization’s commitment to building a culture of safety.” However, several issues need to be considered during the implementation of a walk-round strategy. For example, executives generally require training on how to conduct walk-rounds and how to ensure that walk-rounds remain informal. They also may need to be provided with tools or scripts to help them talk with front-line providers about safety issues and to show their support for staff-reported errors. In addition, some organizations are large and provide patient care around the clock, reducing the feasibility of having senior executives perform regular walk-rounds throughout all care units at different times of the day (or night). An alternative approach therefore has been to use an adopt-a-unit strategy, in which executives limit their walk-rounds to selected sites in a hospital rather than attempting to visit all units during a given period of time.

Perhaps even more problematic is the process of attempting to conduct walk-rounds in surgical care units. In particular, a key component of walk-rounds that presumably makes them effective in changing culture is that leaders are seeking to actively engage front-line staff and providers in their own care setting. However, talking with cardiac surgeons, anesthesiologists, nurses, and perfusionists during bypass surgery would likely prove challenging. Consequently, executive walk-rounds with surgical staff may have to occur in the cafeteria or break room, or possibly in a town-hall setting such as during monthly staff meetings. However, whether such modifications to the walk-rounds strategy will prove to be equally effective in changing culture within a surgical care environment has yet to be determined.

**The Role of the Surgeon**

Within the current conceptualization of the SEIPS model, the central component around which all other OR work system factors revolve is the surgeon. However, the SEIPS model contrasts with traditional person-centered approaches that focus
specifically on the negative consequences of surgical errors and disciplinary reactions to address them. Rather, the model focuses on factors that foster surgical excellence, as well as work system interventions to ensure that excellence is achieved and maintained. The SEIPS model clearly views the surgeon’s cognitive flexibility, adaptability, and resiliency as being an important safety barrier between the work system factors in the OR and their potentially negative impact on patient safety. For example, Carthey and colleagues found that surgeons who were able to cope with unexpected complications during surgery showed effective cognitive flexibility. Cognitive flexibility refers to the ability to consider multiple hypotheses when attempting to generate potential causes of a patient’s unstable condition. Cognitive adaptability is also an important factor that can affect problem solving during surgical cases. For example, threats to patient safety decrease when surgeons are able to change their technique or strategy in light of unexpected patient anatomy, disruptions to surgical flow, or other unanticipated changes in work system events.10

When work system factors do disrupt surgical processes, a surgeon’s mental resiliency is a key factor in ameliorating their impact on patient care. Mental resilience is reflected by the surgeon’s ability to remain calm after ineffective attempts to remedy problems, as well as the capacity to maintain a belief throughout a problem that it is resolvable.11 According to de Leval and colleagues, a marker of surgical excellence is not error-free performance but rather the ability to manage errors and problems during an operation. Effective error management consists of several interdependent processes, including error recognition, error explanation, and error recovery. For example, in our previous study of cardiac surgeons, we found that surgeons made roughly 3.5 errors per hour; however, most of these errors were detected and remedied by the surgical team without any observable intraoperative impact on the patient.4 Another study by Bann and colleagues found that the ability of general surgeons to detect common surgical errors during a surgical skills training course significantly predicted their surgical performance on 2 subsequent surgical tasks (ie, cystectomy and enterotomy).

Surgeons can also play a vital role in buffering the impact that work system factors have on other members of the surgical team. For example, Carthey and colleagues found that surgeons who were capable of adapting their surgical and communication style when operating with new or inexperienced team members were able to foster effective team coordination in a manner that reduced errors and improved patient outcomes. A study by Pisano and colleagues identified several characteristics of cardiac surgical teams that predicted successful or unsuccessful adoption of new technology associated with minimally invasive cardiac surgery. Of primary importance was the surgeon’s outlook toward the new technology. Those surgeons who actively encouraged team members, created an environment of psychological safety, and viewed the technology as a fundamental change in the way surgery is performed had greater success compared with those who viewed the technology as simply a plug-in program, making no effort to challenge the surgical team.

A surgeon’s ability to manage errors or adapt to dynamic changes in work system variables is vital to ensuring patient safety. However, not all surgeons are equally adept or proficient in these areas. Some investigators have argued that these nontechnical abilities are generally intractable because they reflect the inherent skills and personalities of surgeons. On the contrary, at least 1 study suggests that these skills can be improved with the use of a well-designed training curriculum. Surgeons are the final safety barrier between the work system factors in the OR and the potentially negative impact they might have on patient safety. Surgeons also play a pivotal role in ensuring that interventions to improve work system factors and reliability of cardiac surgical care are successful.
SUMMARY

In the past 50 years, significant improvements in surgical care have been achieved. Nevertheless, considerable variability in surgical outcomes still exists across institutions and individual surgeons; moreover, surgical errors that significantly affect patient safety continue to occur. Historically, surgical errors have been viewed as being determined primarily by the technical skill of the surgeon. However, focusing only on individual skill assumes that surgeons and other members of the surgical team perform highly and uniformly, regardless of the variable working conditions within the OR environment. Alternatively, a work systems approach recognizes that surgical skill alone is not sufficient to determine outcomes, because the process of delivering surgical care involves several interdependent variables, many of which vary across hospitals, ORs, or surgical cases, and most of which are not normally under the control of the surgical team. In this article, the SEIPS model is used to highlight the nature of many of these work system factors that affect surgical performance, including the OR environment, teamwork and communication, technology and equipment, tasks and workload factors, and organizational variables. If further improvements in the success rate and reliability of cardiac surgery are to be realized, interventions need to be developed to reduce the negative impact that work system failures can have on surgical performance. Some recommendations have been proposed here; however, several challenges remain.

REFERENCES


