Patient Safety in the Cardiac Operating Room: Human Factors and Teamwork: A Scientific Statement From the American Heart Association


on behalf of the American Heart Association Council on Cardiovascular Surgery and Anesthesia, Council on Cardiovascular and Stroke Nursing, and Council on Quality of Care and Outcomes Research

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AHA Scientific Statement

Patient Safety in the Cardiac Operating Room: Human Factors and Teamwork

A Scientific Statement From the American Heart Association

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The cardiac surgical operating room (OR) is a complex environment in which highly trained subspecialists interact with each other using sophisticated equipment to care for patients with severe cardiac disease and significant comorbidities. Thousands of patient lives have been saved or significantly improved with the advent of modern cardiac surgery. Indeed, both mortality and morbidity for coronary artery bypass surgery have decreased during the past decade (Figure 1). Nonetheless, the highly skilled and dedicated personnel in cardiac ORs are human and will make errors. In 1991, Leape and colleagues estimated that among the 2 million patients hospitalized in New York in 1984, there were 27,179 adverse events that involved negligence; other evidence suggests that up to 16% of hospital inpatients are harmed. Gawande and associates found that the incidence of surgical adverse events was 12% among cardiac surgery patients versus 3% in other surgical patients; 54% of the adverse events were considered preventable. Of the roughly 350,000 to 500,000 patients who undergo cardiac surgery each year, 28,000 will have an adverse event, and one third of deaths associated with coronary artery bypass graft (CABG) operations may be preventable. Refined techniques, advanced technologies, and enhanced coordination of care have led to significant improvements in cardiac surgery outcomes. However, more than 10 years after the Institute of Medicine report, there is little evidence that much progress has been achieved in reducing or preventing errors. The tools to measure potential risks and interventions to improve patient safety are still in the early stages of development and testing, and funding for patient safety studies remains inadequate. Published studies provide only limited evidence of improved outcomes. Furthermore, much of the existing research is, by necessity, qualitative and descriptive and thus does not lend itself to traditional quantitative statistical analysis. Therefore, many clinicians are not conversant with such research.

Preventable errors are often not related to failure of technical skill, training, or knowledge but represent cognitive, system, or teamwork failures (Figure 2). Nontechnical skills such as communication, cooperation, coordination, and leadership are critical components of teamwork, but limited interpersonal skills often underlie adverse events and errors. In a review of litigated surgical outcomes, communication...
failures accounted for 87% of the system failures that led to an indemnity payment. The communication failures occurred primarily between caregivers, rather than between caregiver and patient.

Breakdowns in teamwork that lead to surgical flow or operative disruptions are exceedingly common, having been noted at a rate of 17.4 per hour in one cardiac surgery study and at 11 per case in another. Importantly, such disruptions add up, leading to technical errors and adverse patient outcomes. The majority of flow disruptions are related to teamwork failures, and these disruptions have been shown to be strongly predictive of surgical errors.

Even minor events in cardiac surgical procedures, that is, those not expected to affect outcome, reduce the team’s ability

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Figure 1. Change in mortality and stroke rates in patients undergoing isolated coronary artery bypass graft (CABG) surgery, 2000 to 2009. There was a 24.4% and 26.4% reduction in the unadjusted observed operative mortality (2.4% vs 1.9%) and stroke rates (1.6% vs 1.2%), respectively, during the course of the study period. Reprinted from ElBardissi et al with permission from Elsevier. Copyright © 2012, The American Association for Thoracic Surgery.

Figure 2. Accident model. Active and latent failures in healthcare organizations, hospital management, and individual human error can all contribute to adverse events during high-risk procedures. Reprinted from Carthey et al with permission from Elsevier. Copyright © 2001, The Society of Thoracic Surgeons.
to recover from major events and appear significantly associated with both death and near misses. In one study, for every 3 minor problems above the mean of 9.9 per case, intraoperative performance was measurably reduced and operative duration increased. The accumulation of minor disruptions and events apparently reduced the ability of the cardiac team to compensate for major errors, in short, “little things matter.”

Surgical team members vary in their awareness of their own and their colleagues’ teamwork skills. In multiple studies, self-assessment of communication and teamwork skills by surgeons and anesthesiologists is disturbingly discordant with the opinions of their associated nursing and perfusion staff. Surgeons rated the teamwork of other surgeons as high/very high 85% of the time, but nurses rated their collaboration with surgeons as high/very high only 48% of the time. Objective assessment of teamwork skill reveals differences between skill level of team members and can indicate opportunity for education and training.

The present scientific statement includes data regarding many teamwork skills but focuses on communication. Communication failures were the leading root cause of 65% of sentinel events reported by The Joint Commission between 2004 and 2012 and were a leading contributor to errors in medications, wrong-site procedures, and operative and postoperative events. In one cardiac surgery study, teamwork failures occurred frequently (5.4 per case with familiar teams and 15.4 per case with unfamiliar teams); communication issues were the primary cause of these teamwork failures (89%).

The American Heart Association commissioned this scientific statement to summarize the evidence regarding risks to patient safety and clarify interventions to reduce perioperative risks and human error in cardiac surgery. A comprehensive review of all potential risks to patient safety and tested interventions would be voluminous and could include wide-ranging topics such as surgical techniques (mammary arteries in CABG surgery), various cardiopulmonary bypass (CPB) strategies, or techniques to reduce infection or retained objects. We have chosen to focus primarily on those human, environmental, and cultural factors that affect teamwork, particularly how cardiac surgery teams communicate within the OR and with other unit teams. The statement is organized to describe current knowledge about communication within and between teams, the physical work environment and how it influences teamwork (space, equipment, and ergonomics), and the organizational culture (safety climate and quality improvement [QI]) of the cardiac OR.

Our process was to focus on studies in the cardiac surgical environment regarding teamwork, but we did draw on other literature as needed to present critical concepts that were specifically lacking in the cardiac surgical literature. Although many cardiac surgery studies identify communication as a significant source of error, discussion of the concepts that underlie effective or defective communication are found primarily in the cognitive psychology literature, and we have included these references in the “Communication and Teamwork” section. Similarly, although our focus is on cardiac surgery, we have included pertinent data from other surgical disciplines. We have attempted to identify the references specific to cardiac surgery, but the reader is encouraged to consult individual references for further information. Because of our focus, we excluded many dynamic areas of research that we hope will be summarized in other scientific statements or similar reviews.

Finally, the present scientific statement aims to identify major knowledge gaps and potential areas for further research. The present statement was coauthored by a writing committee composed of members of the American Heart Association’s Council on Cardiovascular Surgery and Anesthesia, as well as collaborating members of the following nonprofit organizations: the Society of Cardiovascular Anesthesiologists and its FOCUS (Flawless Operative Cardiovascular Unified Systems) initiative (Society of Cardiovascular Anesthesiologists Foundation), the Society of Thoracic Surgeons, the Association of periOperative Registered Nurses, the Human Factors and Ergonomics Society, and the American Society of Extra-corpororeal Technology. We hope that these data and recommendations will motivate further research to address the challenges of reducing human error and improving patient safety in the cardiac OR. Such research should be widely applicable to all ORs, as well as to interventional cardiology and electrophysiology procedural settings. In particular, we hope that the present scientific statement will encourage similar reviews of patient safety in cardiology catheterization and electrophysiology laboratories, as well as in other interventional settings such as hybrid ORs designed for percutaneous management of valvular lesions, percutaneous assist devices, or stenting of aortic aneurysms.

Assessing Patient Safety

To understand how to improve patient safety, we must understand how researchers have assessed nontechnical skills and their impact. To begin with, we need a common vocabulary; terms for nontechnical skills must be defined to promote reliable comparison of studies and discussion. Second, the effect of specific nontechnical skills on the reduction of human error or on patient safety must be quantified. Third, interventions to improve individual and team nontechnical skills must be designed and tested for efficacy. Fourth, the effect of improved nontechnical skill(s) on error reduction and, hopefully, ultimately on patient outcomes must be studied to demonstrate progress.

Technical skills can be measured objectively (eg, knots tied per minute), but nontechnical skills assessment requires observational and often seemingly subjective assessment by experts. Observational research, although new to many clinicians, has already identified the number, type, and severity of adverse events that occur in the OR. Many team and individual behaviors that are precursors of adverse events, as well as the behaviors associated with surgical excellence, have been identified. Observational research, however, has limitations: Valid results require trained observers, and not all trainees will become expert. In one study, only 32% of all recorded events were captured by both observers, although events that were captured by both were rated equivalently.

Teaching nontechnical skills is particularly challenging given the difficulty in assessing performance and providing feedback. Appropriate attention is paid to assessing the quality of technical skills, but nontechnical skills also require assessment for competency and to identify opportunities for
education. As noted, observational assessment of nontechnical skills requires trained and experienced observers; to date, use of trained observers has primarily been applied in research, not in training or certification of clinical competence. During surgical simulations, a strong correlation is found between the expert’s assessment and the resident surgeon’s self-assessment of technical skills, but the same is not true for nontechnical skills. Senior surgeons’ self-assessments of technical skills highly correlate with that of an observer, but both junior and senior physician surgical trainees (resident and fellows), as well as surgical faculty, all rated themselves higher on their nontechnical skill level than did the expert observers.

Objective observers are also necessary to accurately assess disruptions, errors, communication skills, and the impact of these factors on outcome. Unlike trained observers, OR personnel judged disruptions to affect their colleagues more than themselves; surgeons perceived fewer team disruptions than did other OR team members. Nontechnical skills may need to be explicitly taught, because senior surgeons may or may not demonstrate better teamwork skills than those more junior, particularly in simulated crisis scenarios.

Teamwork Measures

Many nontechnical skill measurement tools have been used (Table 1), but there is no single accepted instrument. Many are designed to measure nontechnical skills within a specific subteam (nurses, surgeons, anesthesiologists). Behavior rating systems must be valid (measure what they purport to measure), reliable (have good intraobserver and interobserver correlation), sensitive (detect differences in behaviors when they exist), and feasible (be easy to implement and be cost-effective).

Five measurement tools, each with its own strengths and weaknesses, have been designed for surgical team and subteam skills: the Observational Teamwork Assessment for Surgery (OTAS), the Non-Technical Skills Within Team Definition (NOTSS), the Oxford Non-Technical Skills (NOTECHS), the Non-Technical Skills in Surgery (NOTSS), the Anesthesia Non-Technical Skills (ANTS), and the Scrub Practitioners’ Non-Technical Skills (SPLINTS). Of these 5, NOTSS, ANTS, and SPLINT are designed to assess the individual nontechnical skills of surgeons, anesthesiologists, and scrub practitioners respectively, whereas OTAS and NOTECHS are specifically designed to assess team behaviors and skills. The OTAS includes a task checklist and a team behaviors assessment. It has good construct validity (ie, it actually measures what it appears to measure) and strong reliability between expert observers but weak reliability between expert and novice observers, which indicates that training of observers is required.

The surgical NOTECHS was directly adapted from an aviation NOTECHS scale and measures skills in 4 domains (cooperation/teamwork, leadership/management, situational awareness/vigilance, and problem solving/decision making); some research teams have added communication/team skills. The NOTECHS has good reliability between expert and novice observers, has been used to show improvement in nontechnical skills after training, and has been used to show a significant inverse correlation between technical errors and nontechnical score. There is good correlation between the NOTECHS and OTAS scores when used in parallel; both the OTAS and the modified NOTECHS have been found to be construct valid.

Surgical flow disruptions are correlated with adverse events in several studies but are defined differently in each study. Two tools have been proposed, namely, the Surgical Flow Disruption Tool (SFDT) and the Disruptions in Surgery Index (DiSI). Both have strong interrater reliability but have not been tested by other researchers.

Outcome Measures

Poor teamwork and poor nontechnical skills have been shown to adversely affect patient outcomes. Morbidity and mortality are associated with system failures, failures of coordination and communication, reported levels of communication, poor teamwork behaviors, unfamiliarity among cardiac surgical team members, and the number of minor events (disruptions) per case. Other studies have linked teamwork quality and behaviors to surrogates such as increased length of operation, number of technical errors in an operation, number of major errors, and stress levels of team members.

The ultimate desired outcome for any safety intervention is reduction in morbidity and mortality. Mortality in cardiac surgery is quite rare; thus, studies have to be very large to achieve adequate power to discern improvement in this measure. Neily and colleagues demonstrated a significant reduction in mortality with teamwork training but included 189,000 procedures at 108 Veterans Affairs hospitals to reveal a treatment effect.

Because the safety climate of an institution correlates with communication errors, several studies have used changes in attitude toward safety or changes in team “emotional climate” as a surrogate of outcome to measure impact; these studies show training in nontechnical skills to be effective.

Table 1. Teamwork Assessment Tools

<table>
<thead>
<tr>
<th>Tools to Assess Teamwork</th>
<th>Definition</th>
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<tbody>
<tr>
<td>OTAS</td>
<td>Procedural task checklist centered on patient, equipment, and communications tasks ratings</td>
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<tr>
<td></td>
<td>• Communication</td>
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<td></td>
<td>• Cooperation</td>
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<td></td>
<td>• Coordination</td>
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<td></td>
<td>• Shared leadership</td>
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<td></td>
<td>• Shared monitoring</td>
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<tr>
<td>NOTECHS</td>
<td>Adapted from the aviation NOTECHS scale used in Europe</td>
</tr>
<tr>
<td></td>
<td>• Cooperation/teamwork</td>
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<tr>
<td></td>
<td>• Leadership/management</td>
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<tr>
<td></td>
<td>• Situational awareness</td>
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<tr>
<td></td>
<td>• Problem solving/decision making</td>
</tr>
<tr>
<td></td>
<td>± Communication/interaction</td>
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</tbody>
</table>

NOTECHS indicates Oxford Non-Technical Skills; and OTAS, Observational Teamwork Assessment for Surgery.

Summary

1. The nontechnical skills of individuals and teams affect patient safety.
2. OTAS and NOTECHS have proven construct validity and reliability. Training of observers who use these
Communication and Teamwork

Communication Within Teams

Communication

Communication is “the exchange of information between a sender and a receiver.” In the OR, multiple individuals communicate simultaneously. Unfortunately, communication skill has been measured as the worst of 5 aspects of teamwork behavior in the OR; deficits in patient safety are frequently a product of breakdowns or delays in communication. Miscommunication can occur when the sender inaccurately encodes a message (eg, by using vague or incomplete language), when the receiver decodes the sent information incorrectly, or when the information is given at the wrong time or received by the wrong individual. Communication failures are common and were the most common cause of problems in a host of studies. Miscommunication has been implicated as the root cause of error and adverse outcomes in both general and cardiac surgery. It is worse when teams are unfamiliar with each other.

Communication failures in the OR are equally related to timing, content (erroneous or missing data), purpose, and audience (directed to or received by the wrong person). Effective communication is open, adaptable, accurate, and concise, and it is more likely to occur in supportive and safe climates. Open communication fosters seamless coordinated activities; adaptable communication shows that team members are aware of and adapt to others’ workloads, and concise communication promotes efficiency.

The connection between effective communication and improved team performance/outcome has been shown in cockpit crews, navy teams, and surgical teams. A recent meta-analysis provided definitive evidence of the criticality of information sharing for effective team performance. Systematic literature reviews indicate that communication is a key feature of successful teams and is essential for high-quality patient care. Good communication enables and facilitates other fundamental team processes and states, such as coordination, cooperation, cognition, coaching, and conflict resolution.

Cooperation

Cooperation is a critical element of teamwork as well and captures the feelings, attitudes, and beliefs that drive behavior. Attitudinal components began to be studied after several tragic aviation accidents were attributed to teamwork failures. Recognizing that the lack of teamwork skills (previously considered “nonessential”) created severe consequences, the aviation industry developed and implemented CRM (ie, cockpit or crew resource management) programs to improve teamwork.

Some of the most studied attitudes include collective efficacy (a collective sense of competence), team orientation (a preference for and belief in teamwork), cohesion (a commitment to the team, its task, or both), and mutual trust (a shared belief that all will contribute to and protect the team). Although data from cardiac surgical teams are lacking, other studies of dynamic, complex environments have shown that adaptive performance is critical. Psychological safety, team empowerment (the feeling that team members have the authority to control their work and environment), and safety climate are critical. Empirical research has shown that when teams have high levels of collective efficacy, members exert more effort and take more strategic risks, which leads to better performance and higher satisfaction.

The level of trust within a team affects how much members monitor each other, how committed team members are to the organization, and performance.

Coordination

Communication also enables the behavioral skills necessary for optimal coordination and team performance. Coordination requires effective communication and is essential for successful team performance. It is, essentially, “orchestrating the sequence and timing of interdependent actions.” Coordination can be established explicitly with synchronization and awareness or implicitly with covert sequencing and communication.

Implicit coordination entails a shared understanding of the task, the environment, and individual roles and responsibilities within the team. It allows members to anticipate each other’s actions and needs without explicit communication, which enhances efficiency. A mutual team understanding allows team members to provide assistance, information, and feedback, which allows the team to modify structures and processes without detriment in performance. The ability to foresee is imperative for effective teamwork and performance, especially in high-stress situations.

Without coordinated behaviors, team members cannot ensure that actions and tasks are performed in synchrony without wasted effort.

For decades, research in the military and aviation has demonstrated that a team’s mutual understanding facilitates coordination and performance. Other studies show that teams with and without external pressures exhibit better performance when they have effective and efficient coordinating behaviors. Within medical teams, explicitly stating the team’s needs and goals or using team familiarity can build coordination skills and allow team members to develop clear expectations and understanding.

Training in coordination and adaptation, providing information updates, and distributing responsibilities improves coordinating behaviors.

Cognition

Cognition is a shared understanding that arises from team interactions, which improves with repeated interactions. Cognition refers to the team’s collective knowledge about the roles, responsibilities, and capabilities of each member. The ability to anticipate team members’ needs enhances coordination and communication. A common understanding among team members enhances shared awareness of the surroundings, critical for problem solving in dynamic situations.

Teams lacking in shared understanding have reduced coordination, which leads to poor performance.

Studies of team cognition in aviation and the military, as well as in laboratory studies with students, have shown that
experienced teams and teams familiar with one another have better team cognition (eg, shared mental model) and better outcomes than inexperienced teams.\textsuperscript{21,60,128–131} Shared knowledge affects team behaviors and performance (reviewed by Mathieu et al\textsuperscript{115}). Shared cognition improves team communication,\textsuperscript{135–138} learning and self-regulation,\textsuperscript{128,137–140} and coordination.\textsuperscript{125–127}

Within the medical domain, reflexivity training (ie, guided reflection of strategies used by the team),\textsuperscript{131,140} cross-training (ie, training on the tasks and duties of other members),\textsuperscript{126,141} and simulation-based team training\textsuperscript{142,143} have been discussed as effective interventions to improve team cognition. Improving the understanding shared among team members enhances coordination and performance.

**Conflict**

Communication is pivotal for conflict resolution. Conflict, defined as discrepancies or incompatibilities among team members,\textsuperscript{144} can center on tasks, relationships, or processes.\textsuperscript{145,146} Conflict has been found to occur during the treatment of 50% to 75% of hospitalized patients,\textsuperscript{147,148} and this may be even greater in the OR, where ostensibly equal physician teams share in the care of a single patient.

Conflict can have positive or negative implications.\textsuperscript{149,150} Task-based conflict improves group performance in the evaluation of nonroutine problems and in group decision making,\textsuperscript{144} but conflict also results in lower team member satisfaction,\textsuperscript{151} commitment,\textsuperscript{151} cohesion, and effectiveness.\textsuperscript{145} Unlike task-based conflict, relationship conflict has a profound negative effect on both performance and satisfaction and decreases members’ willingness to remain part of the group.\textsuperscript{151–153}

In the OR, conflicts are often poorly managed through avoidance, yielding, or competition, when collaboration and compromise would yield a better outcome.\textsuperscript{153} Collaboration and compromise are particularly difficult when there is status asymmetry, whereby one member has greater power or seniority, such as physicians with nurses or an attending physician with residents.\textsuperscript{147,153} Among OR personnel, 73% opined that disagreements in the OR are resolved appropriately, but 29% stated they would have trouble speaking up if they perceived a problem with patient care, and 41% felt unable to express disagreement.\textsuperscript{156} Behaviors that physicians perceive as decisive and necessary to achieve task goals may be viewed as harsh and demeaning by subordinates.\textsuperscript{157} Difficulty in seeing one’s own behavior as others see it is pervasive throughout OR and intensive care unit (ICU) teams.\textsuperscript{158,159} When watching videos of conflict scenarios, surgeons, anesthesiologists, and nurses rated the tension levels similarly but rated their own profession as having relatively less responsibility for creating or resolving the tension.\textsuperscript{160,161}

There are well-known approaches to conflict resolution in the literature (eg, the 7-step model, principle-based conflict resolution, advocacy/inquiry).\textsuperscript{144,146,162,163} Teaching conflict management to OR teams is important and possible.\textsuperscript{157,163} Effective techniques for conflict resolution are an important component of most team-training methods.\textsuperscript{63,164}

**Coaching**

Team coaching, defined as “direct interaction with a team intended to help members make coordinated and task-appropriate use of their collective resources in accomplishing the team’s work,”\textsuperscript{166} can be used to improve the performance of underperforming individuals and to enhance the skills of those who show promise as future high performers.\textsuperscript{166} Coaching behaviors include identifying problems and leading consultations among the group members.\textsuperscript{122}

Positive effects of coaching include better team member relationships, member satisfaction, team empowerment, and emotional security and safety.\textsuperscript{132} A strong relationship exists between leadership and both personal and team empowerment (ie, the sense of personal or team control and motivation to complete a task), and team empowerment enhances team performance.\textsuperscript{167} Within health care, coaching has been shown to increase nursing innovations\textsuperscript{168} and reduce mortality.\textsuperscript{63}

Leadership coaches can model desirable behaviors, provide constructive feedback to enhance team performance, and encourage open communication and speaking up.\textsuperscript{56} Although cardiac surgeons are often viewed as the primary leaders in cardiac surgical teams, other team members can provide leadership and beneficial coaching to teammates. This intrateam coaching involves team members using constructive feedback to identify areas of poor performance and enhance task completion.\textsuperscript{112} Intrateam coaching involves such behaviors as “providing advice, suggestions, guidance and instructions, calling attention to potential error, and confronting members who break norms.”\textsuperscript{112,165} These coaching behaviors are beneficial only when team members are receptive to suggestions and constructive criticisms.\textsuperscript{112,169}

**Interventions to Reduce Errors**

Within the hospital and OR, interventions designed to improve teamwork are team training and structured tools and protocols; interventions often fit more than 1 of these categories.\textsuperscript{170} These interventions lead to increased patient and staff satisfaction and reduced mortality.\textsuperscript{171–177} Standardization of critical interactions by use of protocols (eg, handoffs) improves the content and structure of information and increases participation\textsuperscript{21,77,176,177} but is often met with ambivalence at best and hostility at worst.\textsuperscript{45,178} Physicians typically overrate their nontechnical skills; downplay the effects of stress, fatigue, and disruptions; and view the imposition of checklists or guidelines as limiting their ability to provide individualized patient care, or as an insult to their intelligence and skill.\textsuperscript{26,44,62,156,179,180} The impact of nontechnical skill training, checklists, briefings, simulation training, and structured communication protocols on aviation safety is undeniable; the evidence that these interventions can improve surgical care is increasing.\textsuperscript{181–185}

In surgery, as in aviation, even the best of protocols and teamwork efforts will not totally eliminate errors or accidents (errors that reach the patient). As postulated by Perrow,\textsuperscript{186} accidents are the norm in high-risk industries and cannot be totally eliminated even by the best of teams; only the time interval between accidents can be increased or decreased. Vannucci and colleagues\textsuperscript{187,188} described a series of 4 retained guidewires after central line insertion, 2 of which occurred after an extensive training program to eliminate retained guidewires; the operators who failed to remove the guidewires had successfully completed the training program. Therefore, continued review of adverse events will be required to
identify not just teamwork issues but system issues that can improve safety. Review of all of those techniques (root cause analysis, sentinel event capture, competency review of clinicians, etc) is beyond the scope of this statement but is critical to patient safety.

**Team Training**

The ample evidence that poor teamwork skills (communication, leadership, situational awareness) contribute to errors and adverse outcomes suggests that teamwork training to improve nontechnical skills should reduce errors. After the Institute of Medicine published “To Err Is Human,” the Institute studied the successful use of CRM to reduce error in aviation and recommended that team-training programs be implemented in critical care areas of medicine. Implementation of these recommendations has taken time; the CRM principles had to be adapted for use in medicine, team-training methods had to be developed, and the results of team training had to be evaluated. Nonetheless, recent reviews have found that CRM-type strategies consistently increase desirable teamwork attitudes and improve teamwork practices and outcomes (eg, complication rates). Team perceptions of and attitudes toward patient safety are correlated with the quality of patient safety.

An early report of the benefits of formal team training demonstrated a significant improvement in the quality of emergency department team behaviors and a reduction in clinical error rate from 31% to 4.4%. Halverston et al reported that a team-training curriculum, with 4 hours of classroom work and in situ coaching, increased the use of preoperative briefings and reduced communication errors by half. Dedicated training sessions significantly improved communication composite scores in the OR.

In a preintervention and postintervention observational study in vascular and general surgery, Oxford researchers implemented CRM-based teamwork training (9 hours of didactic and interactive teaching). Teamwork scores and teamwork climate scores improved, and technical and procedural error rates were reduced. A national prospective study of the Veteran’s Administration Medical Team Training program based on CRM principles showed an 18% reduction in annual mortality. There was a dose-response relationship between Medical Team Training and mortality: For every quarter (3 months) of the team-training program, a reduction of 0.5 deaths per 1000 operations was observed. Implementation of Medical Team Training program was also associated with a reduction in wrong-site surgery and improved compliance with best practices.

Another national team-training effort is TeamSTEPPS, an evidence-based, resource-rich, government-sponsored program. Although TeamSTEPPS has been implemented in hundreds of facilities, few empiric studies have examined its impact on patient outcome. One recent study verified that this program of team training significantly improved OR teamwork and communication scores, reduced surgical mortality and morbidity, increased OR efficiency, and improved patient satisfaction. However, many of the initial gains were lost within 12 months, which indicates that sustained improvement may be difficult to achieve.

Few data exist to define the components of effective team training. Training times range from a few hours to several days. Program content is variable, and sustaining improvement may be difficult. In one posttraining observational study, surgical teams that had undergone training were compliant with only 60% of the safety practices included in the program. In another such study, communication and team skills improved immediately but extinguished after 3 months. However, the calculated threat-to-outcome score improved immediately and remained significantly improved 3 months later. From the data available, it appears that teams should be trained as teams, not as individuals; that use of simulated scenarios is effective; that both executive leadership and nurse managers are critical to effective implementation; and that repetition, continued coaching, or both are required to strengthen and maintain benefits.

**Time-outs, Checklists, Briefings, and Debriefings**

Timeouts, checklists, and briefings can reduce errors in communication. Checklists and timeouts typically are close-ended, with specific information called out and verified, whereas briefings are quick discussions guided by a structured but open-ended checklist. Checklists are the same every time, covering the steps common to all procedures, whereas briefings should be different every time and focused on the unique aspects of the procedure. Briefings establish a dialogue and provide an opportunity for all OR personnel to “confirm details, exchange information, ask questions, and identify problems or concerns.” Debriefings are intended to facilitate sharing of what was learned after a complex task has been completed and often include the questions, “What went right today?” and “What can we do to make sure tomorrow goes more smoothly?”

Timeouts were first proposed, and then mandated by The Joint Commission in 2003, to reduce wrong-site procedures. The Joint Commission universal protocol requires verification of the patient’s identity, marking of the operative site, and a “timeout” just before the operation or procedure.

Checklists are simple cognitive tools that can improve the performance of both simple tasks (eg, shopping) and complex tasks (eg, flying an aircraft) and can be effective as reminders of routine tasks that might otherwise be overlooked. The World Health Organization (WHO) developed and strongly advocates universal implementation of the “Surgical Safety Checklist,” a series of standardized timeouts at 3 times during an operation: (1) before induction of anesthesia, (2) before skin incision, and (3) before the patient leaves the OR. It includes a comprehensive check of patient identity, site of surgery, use of antibiotics and pulse oximetry, and drug allergies; its use has been shown to reduce mortality (Figure 3).

Checklists can be used to identify critical steps in a commonly performed procedure such as laparoscopic cholecystectomy, or to provide direction in rare, crisis situations. Ziewacz and colleagues identified 12 of the most frequently occurring OR crises and developed corresponding evidence-based metrics of essential care for each crisis scenario (failed intubation, pulseless electrical activity, air embolus, malignant hyperthermia, etc). The crisis checklist was studied initially by 2 surgical teams who managed 4 simulated crises with and without the checklist. Checklist use resulted in a
Briefings allow teams to develop a shared mental model of the work ahead and have been widely used by the military, commercial aviators, and longshoremen. A preoperative briefing allows team members to share their knowledge and their particular concerns about the task ahead. In aviation, the cockpit briefing is critical to verify technical details, but a key non-technical role is establishing that a team member who sees anything of concern must speak up. The pilot verbally affirms that all information regarding safety is welcome, even if it means questioning the pilot. In surgery, as was typical in pre-CRM aviation, a strict hierarchical framework can exist that inhibits lower-status team members from questioning someone with higher authority. As noted above, many OR personnel report that they would have trouble speaking up or expressing disagreement.

Before team training or formal implementation, few if any briefings occur. Among the challenges in instituting briefings is the difference in opinion among caregivers as to what constitutes a briefing. Although 39% of surgeons in a United Kingdom practice survey stated they always perform briefings, only 4% of their nurses agreed. This was also the case when efforts were made to institute briefings in cardiac surgery at Mayo Clinic (unpublished observation, T.M.S.). In the Safe Surgery Checklist study of 3733 cases, few included preoperative briefings.

One checklist, the Surgical Patient Safety System (SURPASS) checklist, includes a briefing and debriefing. A closed-claims review indicated that one third of the factors that contributed to adverse events could have been intercepted and nearly 40% of deaths might have been prevented by use of the SURPASS checklist with its imbedded briefings. Implementation of SURPASS reduced complication rates from 27.3% to 16.7% and dropped in-hospital mortality from 1.5% to 0.8.

Implementation of the SURPASS checklist with its imbedded briefings,219 and nearly 40% of deaths might have been prevented by use of the SURPASS checklist with its imbedded briefings. Implementation of the SURPASS checklist with its imbedded briefings,219 and nearly 40% of deaths might have been prevented by use of the SURPASS checklist with its imbedded briefings.
had nearly identical results, reducing mortality from 1.5% to 0.8% and complications from 11.0% to 7.0%. This study included >3500 cases done at 8 institutions in 5 continents and included rudimentary to sophisticated procedures. In a recent study of 25513 patients, van Klei and colleagues showed that implementation of the WHO checklist, including a preoperative briefing, resulted in a reduction of in-hospital 30-day mortality from 3.15% to 2.85% (odds ratio, 0.85; 95% confidence interval, 0.73–0.98). The effect was driven by checklist compliance: The odds ratio for improved outcome with full checklist completion was 0.44 (95% confidence interval, 0.28–0.70), compared with 1.09 (95% confidence interval, 0.78–1.52) and 1.16 (95% confidence interval, 0.86–1.56) for partial compliance or noncompliance, respectively.

Recently, the use of briefings was mandated as part of a larger teamwork training intervention in the Veterans Health Administration; mortality decreased by 18% after team training was implemented.63 In 2 other studies, compliance with antibiotic and deep venous thrombosis prophylaxis improved after the implementation of briefings and debriefings.196 Briefings can reduce distractions and flow disruptions, which are a significant source of serious surgical error.20 Gillespie and colleagues,21 observing planned and unplanned surgeries, found an inverse correlation between the familiarity of a team and the number of miscommunications, as well as a positive correlation between number of interruptions in surgery and the number of miscommunications. Implementing a short, structured briefing halves the frequency of flow disruptions, lack of knowledge of the case, and miscommunications between staff even when instituted within a “familiar” team.22 Nurses made fewer trips to the sterile core for supplies, and spent less time there, whereas wastage was decreased.22 In another intervention study, preoperative briefings decreased unexpected delays in surgery by 31%.68

In addition to improving patient outcome, briefings enhance teamwork climate, behaviors, and performance. In one survey, respondents who said that briefings are common reported a better safety climate than respondents who reported no briefings.218 Briefings are associated with perceptions of reduced risk and with enhanced collaboration.66 In one study,16 participants commented after the briefing, “Your opinions seem to matter. You feel more valued,” and, “Now people are willing to say when they are not happy. They are not worried about backlash anymore.” An Israeli study found that briefings reduced nonroutine events by 25% and that members “felt most valuable for their own work, the teamwork and patient safety.”217 In a United Kingdom study of briefings conducted over a 6-month period, staff members perceived that the team culture was improved, and potential problems were highlighted.223 O’Neill noted that leadership must create a culture wherein employees are treated with dignity and respect and that habitual excellence requires transparency and sharing of problems. Briefings and debriefings can provide the needed transparency and sharing.

Briefings do not prolong surgical procedures225 but shorten them by decreasing interruptions and distractions.222 In one study of >35000 cases, the length of the briefing averaged 2.9 minutes (range, 1–5 minutes).215 Despite the strong evidence supporting briefings, there are organizational and psychological factors that “constrain safety in the OR.”222 The tendency of physicians to misperceive their nontechnical skills as better than they are may lead to the view that no improvement is needed.26,178,213 Not all surgeons agree that briefings improve teamwork, although surgeons who have instituted briefings report greater efficiency and increased team morale.179 Surgeons randomly assigned to a checklist intervention group performed more positive safety-related team behaviors than control surgeons but also reported lower levels of comfort, team efficiency, and communication, which indicates that adapting to checklists or briefings may be uncomfortable initially.220 The role of facility and leadership and local champions is critical to effective implementation221 but insufficient by itself, because a wide range of responses (from acceptance to resistance) to briefings and debriefings can hinder their implementation and must be understood before effective implementation of these practices can occur.178,179,218

Debriefings have been less well studied, although some outcome studies included debriefings, as did the large Veterans Health Administration study.63 The debriefing allows members of the medical team to assess what went well and what did not, to coalesce as a team, and to improve their performance in their next case.176 Debriefings provide teams the opportunity to formulate future plans, develop and implement system improvements, and address areas of communication weakness.215 Debriefing methods and implementation processes have been described previously.228–230

In conclusion, a growing body of literature suggests that surgical briefings and debriefings can result in impressive reductions in morbidity and mortality. More research into impediments to implementation will be useful, but the evidence to date supports case-by-case structured briefing and debriefings in cardiac surgery.

**Simulation**

In aviation, simulation training is widespread and is used to train individual skills, assess the technical and nontechnical skills of individuals and teams, and study how errors occur and how they can be prevented.89 Medicine has been slow to adopt simulation training, but the technical and educational tools and techniques that underpin high-fidelity simulation training in medicine are undergoing rapid evolution and development.231,232 Simulators are emerging as a valuable tool for teaching procedural skills233–235 and measurement of skills.236 Such assessment is becoming part of the licensure process in some areas of medicine.236,237

Simulators show promise for assessing and training personnel in nontechnical skills.36,128,238–240 Current patient simulators provide highly realistic physiological data with real clinical equipment, presenting accurate and believable clinical scenarios. This technology requires educators to design curricula and evaluation rubrics and to document the validity of the educational environment.241–244 Although much of the initial research focused on technical skill training and assessment,36,38 recent evidence supports simulation for team training and the development of nontechnical skills.231,243,245,246 Simulation also allows the scientific testing, without exposing a patient to risk, of the effect of human factors (eg, fatigue, stress) on technical skill,32,247,248 communication patterns
during crisis, testing of educational methods, and the relationship between technical and nontechnical skills or between teamwork and clinical performance.

High-fidelity simulation may provide an optimal learning environment. This can be especially effective in crisis situation training, enabling individuals and teams to experience the cognitive challenge, stress, and physical demands of emergencies without potential for patient injury. Catastrophic incidents require the delivery of a complex, coordinated response by the team under time pressure, but they occur rarely and cannot be practiced in the “real world.” In the simulated OR, team communication and tactical responses to challenging clinical problems can be practiced, evaluated accurately, and measurably improved. In a now famous study of learning in mice, Yerkes and Dodson showed that learning was demonstrably improved. In a now famous study of learning clinical problems can be practiced, evaluated accurately, or team communication and tactical responses to challenging clinical problems can be practiced, evaluated accurately, and measurably improved. In a now famous study of learning in mice, Yerkes and Dodson showed that learning was enhanced with moderate stimulation (arousal) but degraded with intense arousal.

Simulation is particularly suited for training in CPB emergencies and was first described in 1977. Computer-controlled hydraulic models of the adult and pediatric human circulation exist for training in CPB and can be configured to simulate routine or crisis scenarios. Virtually 100% of perfusionists surveyed in 2002 believed that such practice would be beneficial, but only 17% reported that such drills occur. In a recent study of education of whole cardiac surgery teams in crisis management using high-fidelity simulation, participants reported 2 areas of highest priority and improvement: encouraging outspokenness about critical information and improved interprofessional communication by clearly defining the intended recipient (using the name of the person to whom communication is directed) and by attention to “closing the loop” in verbal communications.

Structured Communication Protocols
Communication is improved by information exchange protocols that facilitate presentation and recall and closed-loop communication to acknowledge receipt of information and verify content. Closed-loop communication is particularly important in stressful contexts and when the intended recipient is not clear. This style of communication ensures that the team has shared goals, expectations, situation awareness, and plan execution.

Structured communication techniques, such as using words for letters (alpha, bravo, charlie) or saying the individual digits of numbers (“one one” instead of “eleven,” which sounds like “seven”) can reduce ambiguity, enhance clarity, and specify the intended recipient. Read-backs, Situation-Background-Assessment-Recommendation (SBAR), critical assertions, and advocacy/inquiry have been used effectively for decades by the armed forces and aviation to standardize information transfer, reduce information loss, and facilitate communication to superiors. Few data exist about effectiveness in medical settings. Nevertheless, structured communication protocols are commonly part of the core curriculum of team-training programs that are effective in reducing errors and mortality. Implementation of protocol-driven communication during CPB reduces surgeon/perfusionist communication errors by nearly 40%. Simulation-based studies of comprehensive team-training programs designed to measure communication skills have proved these interventions’ content validity but rigorous studies of the effectiveness of communication training or structured communication protocols in cardiac surgery are lacking.

Communication Between Teams
The transfer of patients and patient information from one team to another, termed handoff or handover, is frequent in medicine. Handoff failures have been identified as a significant source of medical errors, both between and within teams. The Joint Commission defines a handoff as a contemporaneous, interactive process of passing patient-specific information from one caregiver to another to ensure the continuity and safety of patient care; standardized handoff communications was a patient safety goal for 2006 (goal 2E). Cardiac surgery patients are handed off many times: from cardiology (preprocedural testing, evaluation), to the surgeon and OR team, to the ICU team, to the ward team, and often back to the cardiology team for long-term follow-up and care.

Gawande and colleagues analyzed surgical errors in closed claims at 4 malpractice insurance companies and provided results in 2 publications. In the 258 surgical malpractice cases in which an error led to patient injury, 60 cases involved communication failures and resulted in injury to patients. Forty-three percent of the communication failures occurred during a handoff between providers, and 19% of these communication failures occurred across departments (ie, between teams). The majority (92%) of communication failures were verbal, involved a single transmitter and a single receiver, and were caused by omission of critical information (49%) or incorrect interpretation of information (44%).

Much of the original research of handoff failures focused on transfers of care within a team, such as residents crossing over patients. In one survey conducted at Massachusetts General Hospital, 59% of responding residents reported that 1 or more patients had been harmed in their last rotation because of poor handoffs, and 12% reported that the harm was major. Only a minority of the handoffs occurred in a quiet setting, and interruptions were frequent. A similar study found that 31% of residents reported a patient event that involved their patient for which the handoff had not prepared them. In one study of incidents involving transfer of patients from team to team, 29% involved no handoff procedure at all.

It is not surprising that the majority of patient transfers involve communication failures, given the complexity of patient information, nuances of physiology difficult to objectively translate for the next team, and frequent distractions. The literature supports the perception that the handoff process is highly variable, unstructured, and fraught with environmental noise, distraction, and competing task priorities (eg, resetting monitors during the verbal transfer of information). In an observational study of cardiac surgery handoff events, important content items were reported only 53% of the time; an average of 2.3 distractions occurred per minute of communication.

Patient information transfer failures occur across the continuum of surgical care; the majority occur during the preprocedural and postoperative handoff phases. Only 30% of surgical information was transmitted verbally, and often
not by surgeons but by anesthesiology personnel. In a study from Great Britain, transfers of care between OR and recovery room were nonstandardized and varied depending on the staff involved. Varying expectations of content and timing of the information transfer were held by anesthesiology and recovery personnel, and there was no standard point during the handoff when responsibility was transferred. In a study of a process that first rigorously defined, and then measured, critical information to be transmitted and tasks to be completed during an OR/recovery handoff, nearly a third of critical facts were not transmitted (median of 9.1 omissions among 29 defined items), and a third of tasks (median 2.9 task errors of the 8 defined tasks) were not completed. Critical members of the multidisciplinary team were often not present during the handoff process.

The quality of the handoff information degrades across the continuum of care: Only 56% of essential information was transmitted from OR to recovery, and only 44% from recovery to the ward. Seventy-five percent of observed patients had at least 1 clinical incident or adverse event attributable to such failures.

Few studies have analyzed why communication failures occur during handoffs, or what information is essential. No study has tested the validity of what they designate as “essential information.” Despite these limitations, virtually every intervention designed to improve handoff quality has shown positive effects. In a prospective study of congenital cardiac surgery handoffs from OR to ICU, implementation of a teamwork-driven process and protocol reduced errors from 6.24 per handoff to 1.52 and reduced critical verbal information omissions from 6.33 to 2.38 per handoff. Implementation of a protocol based on Formula 1 pit stops that specified the pre-handoff preparation, tasks to be completed before information transfer, and specific information to be transferred reduced technical errors, reduced the number of information omissions, and shortened the handoff from 10.8 to 9.4 minutes.

Another study found that implementation of a simple fill-in-the-blank, 1-page tool improved total handoff scores, as well as surgical intraoperative information subscores, but did not prolong handoff duration. Craig and colleagues echoed these results in their pediatric cardiac study of a different handoff tool; implementation resulted in a significant improvement in attentiveness, organization, and information flow and a reduction in interruptions. Finally, implementation of a standardized handoff protocol for cardiac patients between OR and ICU increased the presence of all critical personnel at the handoff from 0% to 68% of the time, decreased omitted information from 26% to 19%, and increased satisfaction scores from 61% to 81% among the ICU nurses. However, the fact that the percentage of missed information remained at 19% after implementation indicates the scope of the problem.

The use of electronic technology in handoff protocols has been proposed, but few data exist. The framework of an automated protocol termed MAGIC (Multimedia Abstract Generation of Intensive Care) integrates cognitive and quantitative methods to create an electronic prompted briefing that provides a consistent set of handoff information. The Association of periOperative Registered Nurses has developed resources with sample handoff documents and educational materials for clinicians.

A less prescriptive protocol specifies only the type and order of basic topics to be covered, often using the mnemonic SBAR (situation-background-assessment-recommendation). The use of SBAR during handoffs has been suggested to facilitate more accurate communication of patient, anesthetic, and surgical information and has been used by cardiac nurse practitioners to facilitate a patient’s progress through the cardiac surgery continuum of care. A curriculum that used videos and role playing to teach SBAR reduced the rate of order-entry errors.

Communication between physically separated teams (referring cardiologist and cardiac surgeon) can be even more difficult. The use of a dedicated Internet connection between catheterization centers and a surgical center for electronic transmission of angiography data shortened the time between catheterization and surgical decision from 36 hours to 1 hour. The time interval between diagnosis and emergent or urgent surgery decreased from 56 to 18 hours. No outcome or economic data were collected, but electronic transmission of essential patient data may well reduce errors and speed the delivery of care.

Several interventions have been tested across the continuum of care, which can involve multiple handoffs. One approach is to reduce handoff errors by minimizing the number of handoffs, primarily by using a universal bed. With this approach, a given patient can receive ICU, step-down, or ward level of care in a single physical location, with a single team of nurses and surgeons. Compared with national norms (Society of Thoracic Surgeons database, http://www.STS.org), universal bed patients had decreased ventilation time, ICU stay, and hospital stay and no sternal wound infections (0/610), with average cost savings between $6200 and $9500 per patient.

Summary Statements

1. Communication skills have been measured as the worst aspect of teamwork behavior in the OR.
2. Multiple general and cardiac surgical studies have shown that communication failures are the most common root cause of errors and adverse outcomes.
3. The critical elements of teamwork can be summarized by 6 “C’s”: communication, cooperation, coordination, cognition (collective knowledge and shared understanding), conflict resolution, and coaching (team training).
4. Interventions to reduce human error include teamwork-training efforts. Studies such as the Veteran’s Administration Medical Team Training (MTT) and the TeamSTEPPS program (government-sponsored by the Agency for Healthcare Research and Quality and the Department of Defense), have demonstrated significant improvements in OR teamwork and communication scores, as well as reductions in surgical mortality and morbidity; however, sustained improvement requires repetition and/or continued coaching.
5. Other interventions to reduce errors include checklists, such as the Surgical Safety Checklist (developed by WHO), and preoperative briefings and postoperative debriefings. Studies have demonstrated that the process
of adoption of checklists improves outcomes, including reduction in central line infections, ventilator-associated pneumonia, and mortality.
6. Other studies have demonstrated that briefings reduce distractions and flow disruptions, enhance team performance, and may reduce complications, although widespread implementation of these practices has been hindered by psychological and cultural impediments.
7. Simulation is a promising tool for assessing and training surgical personnel in nontechnical skills, including communication, cooperation, coordination, cognition, conflict resolution, and coaching, as well as the relationship between technical and nontechnical skills.
8. Transfer from one team to another occurs many times for patients undergoing cardiac surgery, and communication failures are common during these handoffs. Although few studies have analyzed why communication failures occur, or what information is truly essential, all studies of interventions designed to improve handoff quality have demonstrated improvements in omitted or misinterpreted information.

Physical Environment

Human Factors Issues
“Environment” is defined as “the circumstances, objects, or conditions by which one is surrounded.”289 In the OR, the environment comprises the physical space, the equipment, and the people (staff and patients). Ergonomics, defined as “an applied science concerned with designing and arranging things people use so that the people and things interact most efficiently and safely,”289 has been suboptimal with respect to patient safety in the OR.289–292 Improvements in OR design and space have lagged behind changes in surgical practices.293,294 and the past 10 years have seen an enormous influx of new technologies, creating an overcrowded environment.99 Many consider poor room and equipment ergonomics to be a major factor in the flow disruptions that contribute to technical errors; poor room and equipment ergonomics may be related to surgical-site infections.8,295–296

Space and Design
Both the size and layout of the OR can influence safety. In small ORs, equipment clutters the space and results in flow disruptions, whereas excessively large OR suites require staff to traverse longer distances. Brogmuers and colleagues297 reported that same-level slips, trips, and falls are the second-leading cause of workplace injury and cite 3 tripping hazards: cords and cables, low-profile equipment and supplies, and protective and absorptive mats. Cesarano and Piergeorge298 described the “spaghetti syndrome,” a phenomenon in which cluttered equipment and entangled lines obstruct clinicians from safely reaching the patient, endangering both patients and staff. Bringing power and equipment to the patient creates a significant challenge.299

Personnel and Traffic
The presence and flux of personnel in an OR are unavoidable but can be detrimental to OR safety, both because of the creation of distractions and the increased potential for infection. Approximately 20% of OR traffic is related to staff requests for information, 25% is related to staff breaks, and 20% is attributable to the delivery or retrieval of equipment.300 Healey et al301 correlated OR traffic with interference levels, such as shift changes that distract the operating surgeon, and concluded that these distractions are poor OR practices that can be improved.

Increased traffic implies a higher frequency of door openings, which has been shown to decrease the effectiveness of the ventilation system in clearing potential contaminants.301 More door openings also may increase bacterial counts by permitting the mixing of OR air with corridor air.302 In orthopedic and general surgery cases, the average number of door swings per hour ranges from 37 to 135 and approaches 1 every other minute.300,303 In cardiac surgery, the mean rate of door openings is 19.2 per hour, and 22.8 per hour if prosthetic devices are involved.304 This equates to an average period of 6.4 minutes per hour in which the door is open. Microbiological counts in unoccupied ORs increase significantly when a door is left open to the hallway.305

Additional personnel in the OR may contribute to infection risk. Having 5 additional OR personnel above the required minimum increased the microbiological counts >15-fold.305 Another study of orthopedic trauma surgery found a strong positive correlation between the number of colony-forming units and the number of people in the operating room.306 This relationship between the number of people in the OR and the incidence of surgical infection may be attributable to the number of people per se or to the greater amount of traffic into and around the room.306,307

Equipment
Although equipment and machines improve our lives and improve patient care, they can cause harm by injuring patients directly, by increasing errors related to poor design, and through poorly designed alarm systems that contribute to noise. Equipment-related problems account for ≈11% of flow disruptions in cardiac surgery.20,75,308 In a review of hazards in cardiac surgery, Martinez and colleagues4 noted numerous issues with equipment (eg, esophageal injury caused by transesophageal echocardiography probe insertion), CPB (eg, aortic dissection with onset of bypass), and surgical equipment (eg, air emboli caused by a blower-mister device). Machines and technology were identified to cause patient harm in 4 ways: (1) Misuse (poor training or negligence), (2) the inherent risks of using the device, (3) poor maintenance and upkeep, and (4) poor machine design. Poor training or lack of certification in the use of the device, improper risk balancing by clinicians, and failure to follow best practices in equipment maintenance can increase the risk.8 In addition, a common theme among published reports of equipment-related adverse events is a failure to explore the contributing systematic errors.8

Much of modern equipment is designed with the focus on mechanical efficiency and biocompatibility, with little emphasis on how design can impact human error. Wiegmann and colleagues8 studied CPB machines using a failure mode effect analysis and found that information displays suffered from problems with placement, legibility, and format. Components were poorly integrated into the machine, and the space-design and placement of the components was not ideal. Alarms were found to be too quiet or too loud or to have inappropriate tonality.
In fact, one of the most troublesome contributors to OR distractions is alarms generated by machinery. Alarms are designed to make the operator aware of conditions outside of predetermined norms and can identify dangerous conditions. A typical cardiothoracic OR, however, has around 18 different alarms with a mix of visual and audio alerts. Schmid et al. reported that 359 alarms occurred per cardiac surgery procedure, at 1.2 per minute. Unfortunately, up to 90% of all alarms are false-positives, which desensitizes OR personnel to true alarms. One study analyzed 731 warnings during cardiac surgery by linking them to the response of the anesthesiologist: only 7% were useful, whereas 13% followed a planned intervention and could have been predicted and eliminated.

Noise
As noted above, the OR traffic, conversations, alarms, and, in some cases, music can lead to a deafening noise level in the OR that exceeds both Occupational Safety and Health Administration and National Institute for Occupational Safety and Health standards. This noise level can be dangerous to the hearing of both patients and physicians and can affect patient outcomes. In one study, abdominal surgery patients who subsequently developed a surgical-site infection had operative environments with significantly higher sound levels. Conversations about non-surgery-related topics were associated with significantly higher sound levels.

An observational study conducted by Moorthy et al. concluded that OR noise reaching 80 dB was associated with a significant increase in medical errors during in situ laparoscopic procedures. Clinical impairment may be compounded by inexperience; a randomized controlled trial found that music had a detrimental effect on the surgical performance of novice laparoscopic surgeons. Some research, however, suggests that the appropriate use of music in the OR can reduce stress and improve the performance of some OR staff. Nevertheless, 25% of surveyed anesthesiologists stated that OR music impaired their ability to effectively communicate with other staff. Music that is pleasing and helpful to one practitioner might be distracting to other OR personnel. Compounding this issue is that each subteam in the OR has a different cognitive workload at different times during a case (Figure 4), potentially leading to casual conversation just when another team member needs absolute quiet.

The Optimal OR
There is a paucity of scientific literature regarding optimal OR design and layout, with many editorial suggestions but few studies showing better outcomes. Two studies have linked improvements in the physical environment to (1) reduction in staff stress and fatigue, which increases effectiveness in delivering care; (2) improvement in patient safety; (3) improvement in outcomes; and (4) improvement in overall healthcare quality. Optimal size may reduce adverse patient events and surgical interventions can curtail alarm fatigue and alarm-related distractions. Kruger and Tremper proposed 3 key areas for future research: (1) Design of these systems to bridge
the gap between academic prototypes and integration into clinical practice; (2) integration of various types of medical domain knowledge into comprehensive physiologic and disease models and (3) advanced algorithms to use this domain knowledge for high-sensitivity and -specificity alerts.

Finally, high-fidelity simulation laboratories can be used to investigate where the human-machine interface can be improved, providing insight into how industry can make the next generation of machines safer. Simulation laboratories can also permit testing of optimal room design and layout without putting patients at risk.

**Summary Statements**

1. Poor OR ergonomics (size and layout) contribute to human error and safety hazards, including procedure-flow disruptions, technical errors, and surgical-site infection, as well as workplace injuries for surgical personnel.
2. Optimal OR design ensures standardization of the location of the head of the patient bed and surgical table, adequate space for equipment and staff movement, maintenance of focus on the patient, and use of technology to help workflow.
3. Reduction of traffic in the OR may reduce patient risk (procedure-flow disruption and surgical-site infection).
4. Noise levels in the OR, caused by equipment alarms, conversations, and music, present hazards for patients (surgical performance, surgical-site infections) and surgical personnel (hearing loss).

**Safety Culture**

**Organizational Culture**

Deficits in safety culture have been implicated in adverse outcomes after cardiac surgery. A climate of teamwork and collaboration, along with safety-minded work processes and communication styles that focus on error prevention, is ideal, allowing those in high-risk clinical environments such as cardiac surgery to identify and prevent patient harm. Many cardiac surgery safety studies have been retrospective studies, with the goal to identify trends. Few have been prospective studies, and fewer have tested interventions designed to improve safety. Nevertheless, they indicate where improvements can be made. For example, underdeveloped quality assurance programs contributed to unexpectedly high mortality rates in pediatric cardiac hospitals in Bristol, United Kingdom, and Winnipeg, Canada. Providers at the Bristol Infirmary had raised concerns about poor outcomes that went unheeded, attributable in large part to the absence of a central quality assurance department to identify and address problems. In Winnipeg, the low volume of cases exacerbated a troubled quality assurance program that was inadequate to detect and respond to sentinel events. Both cases illustrate the dual danger of a culture reluctant to acknowledge issues, even when raised internally, and poorly responsive quality assurance systems.

In this section, we review organizational culture in healthcare, identify behaviors that undermine safety, and explore organizational contributors to safety attitudes, including the sparse literature specific to cardiac surgery.

**Organizational Culture in the Healthcare Environment**

An institution’s organizational culture, that is, its aggregate beliefs, assumptions, and value systems, greatly influences the attitude manifested by its personnel toward keeping patients safe. Seemingly similar institutions can have quite different cultures and subcultures. Most hospital personnel are unaware of how they contribute to and shape the safety culture in their own environment. The current hierarchical structure of health care has evolved over many years, but organizational cultures that emphasize deference and power differences between healthcare workers may be unsafe, given the increasing complexity and technological sophistication, particularly in cardiac surgery. Increasing data on the impact of culture on patient safety highlight the need for a reevaluation of the current educational and training paradigm toward more collaborative and interdisciplinary approaches.

**Safety Culture Versus Safety Climate**

An organization’s safety culture refers to those collective behaviors and values that influence its ability to identify and mitigate hazards and systemic conditions that contribute to
error. Safety culture has been stated to be “the product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization’s health and safety management.”

Although senior leadership is critical in establishing a safety-oriented culture, it is the frontline providers who must be fully engaged in creating a climate of QI and safety.

In contrast, organizational climate refers to the commitment with which individuals or groups carry out an organization’s vision and to what degree they adhere to established policies and procedures. Zohar refers to safety climate as “… shared perceptions with regard to safety policies, procedures, and practices.” Climate is often defined as “the way we do business around here.” Safety culture tends to be more ethereal, whereas safety climate is more conducive to measurement, particularly within a functional unit.

Although safety culture and climate are typically a function of the larger organization, small functional units such as the OR often have a unique culture and climate that are distinct from, albeit influenced by, the larger organization. In the OR environment, assessments of safety culture and climate using a variety of instruments such as questionnaires and surveys have raised a number of interesting and potentially actionable observations. One study in a non–cardiac surgery setting identified marked differences between surgeons and nurses in the degree of familiarity with other team members, a factor known to impact patient safety.

In another study, nurses expressed more negative responses than physicians concerning their work unit’s support of and attention to safety. It is important to recognize that such findings may not be generalizable and that culture measurement tools have inherent limitations and applicability.

Although a strong safety culture is thought to save lives, the relationship between culture and clinical performance is complex and nuanced. Acting on findings from attitude surveys, combined with team-skills training sessions, has improved indices of emotional climate, teamwork, and threats to patient outcomes.

Some authors have argued, however, that safety culture and actual performance are conceptually and practically different. Moreover, although measurable improvements in safety attitudes can be elicited after interventions, it is unclear whether these effects are sustainable or translate into better patient outcomes.

In the area of cardiac surgery, only a few observational studies have assessed the impact of organizational characteristics on potential outcomes. used a questionnaire to assess leadership, organizational structure, and safety climate, in addition to confidence assertion, information sharing, stress and fatigue, teamwork, work values, and error and procedural compliance. Respondents reported that established procedures and protocols frequently were not followed, and only 43% of the respondents reported feeling comfortable speaking up. Similar results have been reported in pediatric cardiac surgery. The unique milieu of the cardiac OR includes heavy reliance on technology, with the added dimension of CPB and perfusionists. This highly complex environment is ideal for the study and design of interventions to improve team culture.

Behaviors That Undermine a Culture of Safety

Rigid Hierarchical Culture

Organizations with a predominantly hierarchical culture are generally oriented toward and place a high premium on stability. These organizations are characterized by uniformity, rigid coordination, internal efficiency, and a close adherence to rules and regulations. These characteristics are not inherently bad; in surgery, as in the military, a close adherence to rules and regulation and clear lines of authority are critical to effective performance. However, when these characteristics lead to significant power distance, status asymmetry, and disruptive behavior, safety will be compromised, with team members reluctant to challenge authority or to speak up when errors are recognized. A centralized approach to management often results in frontline providers feeling less empowered to speak up or take action when confronted with safety issues. Hospitals and surgical teams with a rigid hierarchical culture have been shown to have inferior scores on performance measures and safety climate measures. Targeted interventions, as highlighted by Singer and colleagues, include team training that emphasizes the collective shunning of unprofessional behavior and a commitment to continuous QI.

Professionalism and Disruptive Behaviors

High-quality and safe patient care depends on teamwork, communication, and a collaborative work environment. Professionalism is maintained through the interplay of individual behavior and organizational structure. The culture of health care has historically tolerated disruptive and intimidating behaviors in exchange for a high level of skills and expertise. As the delivery of health services shifts from individual practitioners to team-based and multidisciplinary approaches, organizations that do not embrace interprofessional training and communication and that fail to eliminate maladaptive behaviors will be incapable of achieving highly reliable levels of safety and sustained outcomes.

Surgical errors must be understood in the context of the culture of the surgical team. In a study of surgical teams, found that teams that exhibited fewer teamwork behaviors, particularly information sharing during the intraoperative phase and debriefing during the handoff phase, were at higher risk for patient death and complications. Another study found that teamwork factors alone accounted for 45% of the variance in the technical errors committed by cardiac surgeons. Finally, found an association between a perturbed emotional climate and poorer thoracic surgical team performance.

The literature continues to link disruptive behaviors to errors and even to mortality. In a study of the effects of workplace intimidation on medication practices, 7% of respondents reported being involved in a medication error in which intimidation played a role. In cardiac surgery, data are scarce, but indicated that there was a “high predilection for disruptive behaviors to occur in high-stress areas with a greater potential for patient harm.” In a survey of hospital physicians and nurses, reported witnessing disruptive behavior among physicians and 65% reported witnessing disruptive behavior among nurses at their hospitals.
Respondents reported that general surgery was the specialty in which disruptive events occurred most often (28%), with cardiovascular surgery at 13%. This behavior cuts across all disciplines. In a perioperative study, 75% of respondents reported having witnessed disruptive behaviors in attending surgeons, 64% in anesthesiologists, 59% in nurses, 43% in surgical residents, and 35% in anesthesia residents. Additionally, 46% of respondents claimed they were aware of potential adverse events that could have occurred from disruptive behavior, and 19% reported that they had specifically witnessed an adverse event caused by disruptive behavior. More than 80% of the perioperative personnel reported loss of concentration, reduced communication/collaboration, and impaired relationships with other team members as a result of disruptive behavior. Finally, investigators have reported that frontline staff believes that these behaviors affect patient safety and outcomes.\textsuperscript{367,369,370}

In 2009, The Joint Commission implemented leadership standards that required the “creation and maintenance of a culture of safety and quality throughout the hospital,” including having a disruptive behavior policy in place and a formal process to manage unacceptable behaviors.\textsuperscript{371,372} These disruptive behaviors are specifically defined: “Intimidating and disruptive behaviors include overt actions such as verbal outbursts and physical threats, as well as passive activities such as refusing to perform assigned tasks or quietly exhibiting uncooperative attitudes during routine activities…. Such behaviors include reluctance or refusal to answer questions or return phone calls or pages; condescending language or voice intonation; and impatience with questions. Overt and passive behaviors undermine team effectiveness and can compromise the safety of patients.” Recently, The Joint Commission has revised the definitions to “behaviors that undermine a culture of safety.”\textsuperscript{373}

There is considerable overlap between disruptive behaviors and workplace bullying. In one view, bullying is seen as the most extreme example of disruptive behavior. The Workplace Institute\textsuperscript{74} defines bullying as “repeated, health-harming mistreatment that takes 1 or more of the following forms: a) verbal abuse; b) offensive conduct/behaviors (including non-verbal) which are threatening, humiliating, or intimidating; and c) work interference—Sabotage—which prevents work from getting done.”

As a high-stress, high-intensity, complex environment, the perioperative setting is particularly susceptible to the insidious introduction of disruptive or bullying behavior. The environment is tense, procedures do (and must) move quickly, and precision is expected. In particular, the bullying of nurses and other personnel in the OR may be caused in part by the inherent stress of performing surgery, high patient acuity, shortage of perioperative professionals, overtime, on-call demands, and the fact that any one surgical subspecialty can be quite isolated.\textsuperscript{375} Disruptive behaviors are perpetuated by a physician-dominated hierarchical culture and a perceived “code of silence.”\textsuperscript{376} The inability to speak up for fear of retribution creates an environment in which small errors may accumulate to contribute to a major event. Bullying behavior erodes teamwork and the development of a safety culture.

The reluctance by healthcare organizations to address disruptive behaviors may stem from multiple factors. Rosenstein\textsuperscript{376} recommends a 10-step process (Table 2) to help organizations succeed in promoting a culture of patient safety. Recognition of an existing problem is the first step, with leadership committed to assessing the professional environment through validated tools to identify the prevalence of disruptive behavior. Collaborative leadership efforts can raise the level of awareness and accountability by providing education and training. Agreed-upon policies and procedures must include safe, non-punitive mechanisms for reporting disruptive behaviors. Thus, organizations and their individual employees can better commit to patient safety and quality.\textsuperscript{376}

For more than a decade, the Vanderbilt Medical Center has focused on promoting professionalism through identifying, measuring, and addressing unprofessional behaviors.\textsuperscript{360,377} These efforts include 6 core principles: (1) Dedicated leadership, (2) a model or framework for guiding intervention, (3) institutional policies, (4) surveillance tools, (5) training, and (6) accountability.\textsuperscript{360} Positive results included reduced malpractice claims, improved patient safety and quality, better team communications, reduced reinforcement of negative behaviors, and behavior change among physicians.\textsuperscript{377} No studies specifically speak to the impact of such programs in cardiac surgery.

**The “Hero Culture” as a Vulnerability**

Further complicating the hierarchical structure that allows unchallenged disruptive behavior, the “hero culture” of the exhausted surgical team is revered in the media, where the self-sacrificing surgeon and team members go beyond the point of exhaustion to serve patient needs. This image belies the impact of fatigue on performance. Although the studies were performed in noncardiac units, 2 separate reports documented the effect of prolonged working hours and associated sleep deprivation on attention failures\textsuperscript{378} and the incidence of serious medical errors committed by interns working in ICUs.\textsuperscript{79} Subsequently, other investigators showed that sleep

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**Table 2. The 10-Step Process to Promoting a Culture of Safety\textsuperscript{378}**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
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<tbody>
<tr>
<td>1.</td>
<td>Organizational culture</td>
</tr>
<tr>
<td>a.</td>
<td>Leadership commitment, assessment, structure</td>
</tr>
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<td>2.</td>
<td>Clinical champions</td>
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<tr>
<td>3.</td>
<td>Recognition and awareness</td>
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<tr>
<td>a.</td>
<td>Education</td>
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<tr>
<td>4.</td>
<td>Structured education/training</td>
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<tr>
<td>a.</td>
<td>Diversity, sensitivity, stress management</td>
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<tr>
<td>b.</td>
<td>Conflict management, assertiveness</td>
</tr>
<tr>
<td>5.</td>
<td>Collaboration/communication tools</td>
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<tr>
<td>6.</td>
<td>Relationship building</td>
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<tr>
<td>7.</td>
<td>Policies and procedures</td>
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<td>8.</td>
<td>Reporting mechanisms</td>
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<tr>
<td>9.</td>
<td>Intervention</td>
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<tr>
<td>a.</td>
<td>Pre: assess safety culture before implementation of intervention</td>
</tr>
<tr>
<td>b.</td>
<td>Current: assess safety culture during implementation of intervention</td>
</tr>
<tr>
<td>c.</td>
<td>Post: assess safety culture after implementation of intervention</td>
</tr>
<tr>
<td>10.</td>
<td>Reinforcement of patient safety initiatives</td>
</tr>
</tbody>
</table>

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deprivation increases the risk of accidental self-inflicted injuries and the risk of medical residents (trainees) having car accidents during their daily commute. Growing concern that fatigue and extended working hours can contribute to poor performance and outcomes has led to regulatory efforts to mitigate its effects. However, the studies did not measure intermediate outcomes such as incidence of errors or of error capture and recovery, and the results may speak more to team resiliency in recovering from errors than to lack of an effect. A survey of perfusionists found that 15% were performing CPB after being awake for up to 36 hours, and 50% described experiencing microsleep during bypass. Two of 3 reported committing fatigue-related minor errors, and 6.7% admitted to serious perfusion-related accidents ascribed to fatigue.

**Cultivating a Culture of Safety**

A great deal of the literature regarding changing an organization’s culture is reported at the hospital level, not the cardiac OR level. Interventions to improve quality and safety in the OR are still in their infancy; convincing data demonstrating that these interventions result in sustained improvements in the safety climate of these high-hazard environments are still lacking. As described previously, interventions to improve communication in the cardiac ORs, such as checklists, briefings, and teamwork training, are typically associated with improvements in safety attitudes of OR personnel, as well as patient safety. Attempts to impact an entire organization’s safety attitudes underscore the vexing nature and intractability of the culture problem.

Functional units have been shown to be amenable to structural, if not strategic, interventions. The Comprehensive Unit-Based Safety Program (CUSP) is a safety culture program that has been tested, albeit in ICUs, not the OR. CUSP was the safety culture improvement intervention in the Keystone project, an improvement collaborative to reduce catheter-based infection in 100 ICUs. CUSP is a 5-step iterative process that includes educating staff on the science of safety, identifying defects, involving senior executives to work with staff to prioritize safety hazards and provide resources, learning from 1 defect per month, and implementing teamwork and improvement tools with intermittent quantitative assessments of culture. CUSP is integrated into the organization’s strategic plan but defers to frontline workers, giving them autonomy to identify and rectify safety hazards. Use of the CUSP approach together with specific checklists resulted in a virtual elimination of catheter infections, a significant decrease in ventilator-associated pneumonia, and significant improvements in teamwork climates.

**Benefits of Organizational Focus on Quality**

The experiences at Bristol and Winnipeg that led to the deaths of several pediatric cardiac surgery patients highlight the need for robust QI and quality assurance programs. In both cases, the institutions were inadequately equipped to either identify or address problems, and warnings went unheeded. The investigating authorities recommended radical changes, such as institutional prioritization of quality control systems, incorporation of feedback from all stakeholders (including patients and families), and establishment of a culture that encourages all clinicians to speak up and be heard. The authors noted that such an effort should be led by a centralized quality department to detect issues and monitor progress after interventions.

**Single-Center Improvements**

As a result of the tight coupling that exists along the continuum of care, most QI initiatives in cardiac surgery are not focused exclusively on the OR. Comprehensive approaches used in the management of cardiac surgery patients include Total Quality Management, Institute for Healthcare Improvement Breakthrough Collaboratives, ProvenCare, Operational Excellence, and others. The success of these efforts depends on the extent to which each model fulfills the elements of team trust, data integrity, clinical leadership, institutional commitment, and infrastructure for QI.

Doran and colleagues observed the use of the rapid-cycle improvement model (ie, Institute for Healthcare Improvement Breakthrough Series) in a community adult cardiac surgery program. They found significant improvements in hospital length of stay, time on the ventilator, patient satisfaction, and cost. Stanford and colleagues published results of a Total Quality Management System, including surgeon-led implementation of perioperative checklists, nursing supervision to track progress, mortality and morbidity conferences focused on “fix the problem, not the blame,” and mandated multidisciplinary consultation. These interventions significantly reduced the operative mortality of CABG patients.

A single-center QI program (ProvenCare; Geisinger Health System, Danville, PA) asked cardiac surgeons to develop a 40-element care bundle for elective CABG patients. Care elements were evidence based and hard-wired into the care process to ensure consistent implementation. The care process was continually altered to improve implementation. Blood product use, ICU readmissions, and hospital readmissions decreased. Although the ProvenCare model has received considerable interest in controlling costs for health plans, its effectiveness and consistency also provide a model for continuous quality management with profound implications for safety culture.

A process-oriented multidisciplinary approach (POMA) at a cardiac surgery program in Leeds, England, brought all care providers together preoperatively to evaluate and prepare the patient for CABG surgery. In a comparison of patients who underwent CABG before (n=262) and after (n=248) POMA was implemented, improvements in average length of stay, median procedural cost, and the incidences of atrial fibrillation and respiratory infections were noted.

Uhlig et al described the implementation of formal multidisciplinary daily rounds on heart surgery patients that involved patients, family members, pharmacy personnel, nurses, social workers, physician assistants, and cardiac surgeons. This program markedly improved patient satisfaction and decreased mortality among CABG patients.

Finally, Culig et al described an “operational excellence” method derived from the Toyota Production System used in a...
new community cardiac surgery program. Shifting of the culture from a strict, hierarchical, “defects are punished” mentality to a collaborative “problems are blessings” mentality was accomplished through disciplined 10-minute daily meetings, which included a formal problem-solving process. The display of relevant, real-time data on public boards was used to track ongoing progress. Over 2 years, the risk-adjusted CABG complication rate was 60% less than that observed for the regional population.

A culture of safety and trust is a cornerstone of effective quality and safety improvements. Rather than a punitive culture of “blame and shame,” a “just culture” mentality provides conditions and behaviors necessary to develop trust. Clinical leaders with training in the science of improvement can strengthen workplace trust with consistent behavior in identifying and working to resolve work defects. Such leadership behavior demonstrates an institutional commitment to QI and provides a QI infrastructure.

**Multicenter Collaborative Improvements**

Over the years, multicenter collaborative efforts in cardiac surgery have improved quality and safety in cardiac surgery in large part by sharing of site-specific and surgeon-specific data and best practices. This model in cardiac surgery originated in 1987 with the formation of the Northern New England Cardiovascular Disease Study Group. Five hospitals and their cardiovascular teams started collecting and sharing patient demographic, process, and outcome data and developed risk-adjustment methodology for creation of predictive models. Site visits between hospitals and frequent face-to-face meetings focused on standardization, ongoing improvement, and shared learning. Use of this model has led to improvement in overall mortality, mortality in women, and reexploration for bleeding.

On the basis of this success, other multicenter collaborative efforts have developed. In 1996, a group of cardiac surgeons initiated the Virginia Cardiac Surgery Quality Initiative, which encompasses 17 hospitals and 10 cardiology and thoracic surgery groups. Focused projects resulted in statewide reductions in the incidence of perioperative atrial fibrillation, improved glycemic control, and decreased blood transfusion. The Michigan Society of Thoracic and Cardiovascular Surgeons formed a quality initiative with the goal of decreasing variation around best practices. Now funded by a health plan, their focus on interventions and data sharing has increased use of the left internal mammary artery in CABG surgery, and decreased the incidence of prolonged controlled ventilation. Other collaborative efforts in adult CABG patients include the Alabama Coronary Artery Bypass Grafting Project, Washington Clinical Outcomes Program, California Local/Regional Cardiac Surgery Database, and Minnesota Local/Regional Cardiac Surgery Database.

Some studies have questioned the general effectiveness of QI collaboration. Lack of funding, data fatigue, and the competitive pressures among surgeons may limit collaborations to a finite lifespan. Future research to examine the usefulness of external data sharing and interorganizational learning may identify those properties and characteristics that maximize performance among all participants. The extensive availability of information technologies and quality control tools with refinements designed for the healthcare environment will aid groups in deploying interventions that will result in continuous outcomes improvement.

**Future Research**

Multidisciplinary prospective studies regarding predisposition to error may be the next phase in the evolution of understanding of human error in the cardiac surgical setting. This human factors research includes study of the larger organization, the workspace, the necessary clinical and technical processes, human interaction with equipment, and particularly human interaction with one another (communication and teamwork). Investigators with clinical expertise (surgeons, nurses, anesthesiologists, and perfusionists) and nonclinical expertise (human factors engineers and systems analysts) must collaborate to perform this research. To gain a better understanding of safety and performance in the cardiac OR, and to provide a QI infrastructure.

**Summary Statements**

1. Most studies of patient safety in cardiac surgery are reactive (retrospective studies that seek to identify trends) rather than prospective studies to test interventions to reduce human error or improve safety.
2. The Joint Commission has implemented standards requiring “creation and maintenance of a culture of safety” and quality throughout the hospital, including having a disruptive behavior policy in place and a formal process to manage unacceptable behaviors.
3. Poor teamwork behaviors and a tense emotional climate are linked to surgical team errors and patient outcomes.
4. Local and regional QI initiatives in cardiac surgical settings specifically have resulted in improvements in blood product use, time on the ventilator, hospital length of stay, ICU readmissions, hospital readmissions, mortality, patient satisfaction, and cost.
5. Multicenter collaborative QI efforts in cardiac surgery specifically to share demographic, process, and outcomes data, as well as site visits between hospitals, have resulted in regional standardization of best practices and improvements in overall mortality, mortality in women, use of blood transfusions, prolonged ventilator support, glycemic control, and increased use of internal mammary arteries.

**Conclusions**

Cardiac surgery is a high-risk endeavor that requires an intense focus on patient safety, but sustainability requires a culture of safety. The research in this area is nascent but informative. Hospitals and research groups are testing interventions designed to improve teamwork and communication, and other interventions intended to reduce disruptive behaviors and fatigue. Placing patient safety first will ultimately lead to greater patient satisfaction and better clinical outcomes.
Recommendations for Future Action and Research: A “Call to Action” for Patient Safety

WHO has made the reduction of surgical errors one of its primary goals. WHO published guidelines in 2008 that identified multiple recommended practices to ensure the safety of surgical patients.42 However, errors persist. Traditional approaches to reducing human error, typically driven by hospital or professional society quality assurance committees, have established precedents that make significant improvements in patient safety difficult. A few interventions are supported by currently available, albeit limited evidence, as noted in each topic area above. Priority for implementation of these interventions would almost certainly improve patient safety. Furthermore, a concerted effort to expand the scientific study of human error as a unique area of clinical research could provide opportunities to improve patient safety in the cardiac OR, as well as other surgical and interventional settings (eg, the cardiac catheterization suite). Specific areas of study would certainly include (1) research to better understand communication failures and breakdowns in teamwork; (2) the best way to implement and reinforce interventions to improve communication and teamwork (eg, teamwork training, briefings and debriefings, and simulation); (3) interventions to promote professionalism and safety culture; and (4) OR ergonomics, including ideal space and layout to minimize flow disruptions and personnel traffic. Ideally, both provider outcomes such as behavior change and communication skills and patient outcomes such as morbidity (eg, infections) and costs would be measured.

Opportunities to Facilitate Translation of Current Knowledge Regarding Communication and Teamwork Into Clinical Practice

Table 3 displays the American College of Cardiology Foundation and American Heart Association scheme for the classification of recommendations and level of evidence. The writing group’s conclusions and recommendations using this classification scheme are listed below.
Communication failures are common and have been implicated as a cause of error and adverse outcomes in both general and cardiac surgery.† Research in aviation and the military has demonstrated that team training can facilitate improved coordination and enhanced performance. Substantial data do exist in surgical settings regarding the impact of training in nontechnical communication skills; for example, checklists, briefings and debriefings, other structured communication tools and protocols, team training, and simulation training.‡ However, except for the standardized time-out process, which is required by The Joint Commission, widespread adoption of standardized critical interaction by use of protocols has not occurred in cardiac or other ORs. Furthermore, in a few longer-term studies of team training, it appears that improvements are not easily sustained.164,197,198

Recommendations

1. Checklists and/or briefings should be implemented in every cardiac surgery case, and postoperative debriefings should be encouraged by leadership in cardiac ORs (Class I; Level of Evidence B).
2. Team training to improve communication, leadership, and situational awareness should be implemented in cardiac ORs and should involve all members of the cardiac operative team (Class I; Level of Evidence B).
3. Formal handoff protocols should be implemented during transfer of the care of cardiac surgical patients to new medical personnel (Class I; Level of Evidence B).
4. It is reasonable to conduct event scenario training for significant and rare nonroutine events (ie, emergency oxygenator change out) on a regular basis that involves the complete cardiac surgery team (Class IIa; Level of Evidence C).
5. It is reasonable to conduct future studies of teamwork and communication that (a) investigate optimal communication models (eg, briefings and structured communication protocols in the cardiac surgical OR); (b) investigate team-training models to determine the “best product” for use in the cardiac OR; (c) investigate impediments to implementation of formal teamwork in communication skills; (d) include long-term studies of the sustained impact of such training on provider outcomes (eg, attitudes regarding safety, compliance with best practices, and communication skills); (e) investigate efficacy of formal training in teamwork and communication skills in improving patient outcomes (eg, satisfaction, blood product use, infections, ICU readmissions, mortality, and costs); and (f) include establishment of an anonymous national multidisciplinary event-reporting system to obtain data about events and near-misses (Class IIa; Level of Evidence C).

Physical Environment Research Opportunities

Poor OR ergonomics are present in many, if not most, cardiac ORs. Hazards for both patients and staff exist, including infection in patients related to personnel traffic and airflow, risk of injury to staff caused by tripping over cords and equipment, and hazardous noise levels for everyone in the room because of alarms, music, and multiple simultaneous conversations.3 Optimal OR design to maintain efficient flow and restriction of the number of personnel may reduce hazards. Integration of information from various monitors and reduction of noise and alarm fatigue, by design of high-sensitivity and -specificity alerts, may improve patient safety.313,328

Safety Culture: Implementation of Policies Regarding Professionalism and Quality

In 2009, The Joint Commission implemented standards requiring the creation and maintenance of a culture of safety, including having a disruptive behavior policy in place and a formal process to manage unacceptable behaviors.371,372 Subspecialty units, including the cardiac operating team, may develop a unique culture with both positive and negative aspects.

Recommendations

1. Local institutional policies that define disruptive behavior in medical professionals in all hospital settings should be implemented immediately, with transparent and formal procedures for addressing unacceptable behaviors and interventions to eliminate such behaviors (Class I; Level of Evidence C).
2. We recommend that every institution commit to a culture of safety by establishing a robust quality assurance and QI program to (a) continuously identify system, unit, and individual safety hazards; (b) provide leadership and resources to eliminate identified hazards; and (c) encourage and value the input of all members of the cardiac surgery team in a nonpunitive atmosphere (Class I; Level of Evidence C).

Safety Culture: Research Opportunities

Only a few studies have assessed the impact of organizational culture on provider or patient outcomes.394,395,397 Currently available data provide limited evidence that patient outcomes (eg, satisfaction, blood product use, infections, ICU readmissions, mortality, and costs) may be improved with patient safety and QI initiatives. It is unknown whether improvements in safety-oriented provider attitudes and organizational culture are sustainable.

†References 13, 16, 18, 20–23, 58, 59, 72, 76–80.
§References 296, 304, 310, 311, 314, 316, 317, 321.
Recommendations

1. Scientific testing of interventions in the complex technology-oriented setting of the cardiac OR is reasonable, including interventions that (a) test existing tools and develop new tools designed to improve safety culture and climate; (b) provide ongoing assessment after intervention(s), to measure sustainability of improvements in safety culture; and (c) lead to establishment of multi-institutional large clinical trials to assess the efficacy of improvements in safety culture in reducing selected adverse patient outcomes (Class IIb; Level of Evidence C).

2. Design and funding of multidisciplinary prospective studies of human and systems factors that predispose to error in the cardiac OR is reasonable (Class IIb; Level of Evidence C).

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Disclosures

Writing Group Disclosures

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<th>Employment</th>
<th>Research Grant</th>
<th>Other Research Support</th>
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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be “significant” if (1) the person receives $10,000 or more during any 12-month period, or 5% or more of the person’s gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10,000 or more of the fair market value of the entity. A relationship is considered to be “modest” if it is less than “significant” under the preceding definition.

*Modest.
†Significant.

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*Modest.
†Significant.


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Patient Safety in the Cardiac Operating Room

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