Human Factors and Human Nature in Cardiothoracic Surgery

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At 7:34 A.M. on September 11, 1974, Eastern Air Lines Flight 212 from Charleston, SC, crashed in an open field 3.3 miles short of runway 36 at Douglas Municipal Airport in Charlotte, NC [1]. There was little or no wind, and the visibility was limited due to patchy dense ground fog. Of the 82 people on board, 11 survived. Notably, 5 flights preceded Flight 212 onto runway 36 without difficulty that morning.

Partly based on the cockpit voice recorder, the National Transportation Safety Board determined that the likely cause of the crash was “the flight crew’s lack of altitude awareness at critical points during the approach due to poor cockpit discipline in that the crew did not follow prescribed procedures” [1]. Specific issues with discipline and prescribed procedures were as follows: “During the descent, until about 2 minutes and 30 seconds prior to the sound of impact, the flight crew engaged in conversations . . . (that) covered a number of subjects, from politics to used cars, and both crew members expressed strong views and mild aggravation concerning the subjects discussed. The Safety Board believes that these conversations were distractive and reflected a casual mood and lax cockpit atmosphere, which continued throughout the remainder of the approach and which contributed to the accident” [1]. In 1981, in response to aviation accidents, the Federal Aviation Administration imposed the “Sterile Cockpit Rule,” which states that pilots are to refrain from nonessential activities or conversations that could distract or interfere with their duties during critical phases of flight and operations below 10,000 feet [2].

Surgical errors and adverse events include wrong or delayed operations and judgment lapses that lead to incorrect procedures [3–7]. It is estimated that 54% of the adverse events in patients undergoing operations surgery are preventable [7]. In patients undergoing coronary artery bypass grafting, for whom the risk-adjusted mortality rate ranges from 1.3% to 3.1%, approximately one-third of associated deaths may be preventable, with most occurring in the operating room and intensive care unit [6]. Surgical outcomes are often attributed primarily to the technical skills of the surgeon: when errors are made, the surgeon’s competence is questioned [3, 4, 8–10]. The notion that the surgeon is often held solely accountable is evidenced in the basis for surgeon rankings in public reporting.

Narratives of catastrophic events in the aviation industry are commonly used to illustrate the importance of human factors in accident causation and near misses. In surgery, such an approach has emphasized that errors are the result of the characteristics of the individual surgeon combined with the dynamics imposed by the existing work system [5–7, 9–12]. The nontechnical skills of all members involved in the care of patients, such as communication and leadership, are critical components of teamwork, and breakdowns in these components lead to disruptions and adverse events.

Patient safety programs have targeted potential failure points within the system, such as those relating to the physical environment of the operating room, teamwork, tools and technology, tasks and workload, electronic medical records, and organizational processes [7, 9, 10–16]. Despite the publication of the Institute of Medicine report “To err is human” in 1999 and the World Health Organization (WHO) guidelines in 2008 identifying multiple practices to improve surgical safety, the pace of safety improvement has remained relatively slow [17–19].

Notwithstanding the Sterile Cockpit directive, mistakes continue to occur during takeoff and landing of aircraft [20, 21]. To illustrate, in October 2009, 28 years after the Sterile Cockpit Rule, the pilots of Northwest Flight 188 overflew their destination by 150 miles because they were using their laptop computers for personal activities [20, 21]. In another instance, a pilot was texting after the aircraft pushed back from the gate and before the takeoff sequence. As a consequence of these and other lapses, the Federal Aviation Administration issued an advisory in 2010 to crew members that cockpit distraction, including the use of personal electronic devices (PEDs) for unrelated activities, “constitutes a safety risk” and that the operators and directors of operations needed “to create a safety culture that clearly establishes guidance, expectations and requirements to control cockpit distractions, including use of PEDs, during flight operations” [20, 21].

The question is why, even in the high-risk aviation industry and in view of the Sterile Cockpit Rule, do judgment errors (eg, use of distractive devices) continue to occur? Similarly, in the health care environment, it has been posited that many explanatory factors for errors “remain to be uncovered” [3, 22]. Although analyzing

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work systems represents an important approach to human factors, one must not forget that human factors are inextricably linked to human nature, the study of which in other domains may provide insights into future interventions. This review is thus focused on individual-centered factors that affect patient outcomes. Along with factors in work systems identified above, we propose that surgeon-centered factors are based on at least three strategies: minimizing external distractions, improving interpersonal communication and teamwork, and mitigating work-related stress [3, 5, 9, 10].

Minimizing External Distractions

Few would argue that minimizing distractions in the operating room is ideal. However, until there is a complete understanding of its importance by all intraoperative personnel, it will remain an elusive goal. To date, one focus has been to minimize clutter and congestion in the operating room to improve surgical work flow [9, 10, 23]. With increased awareness, many surgical teams have successfully established a highly functional physical environment. Nonetheless, work flow and communication in the operating room may be improved such as by optimizing the setup and location of the cardiopulmonary bypass circuit [24].

Another important source of distraction in the operating room is the problem of noise—specifically, sudden, unexpected noise—which may increase the level of stress among the providers and impede the flow of the operation [9, 10, 25–27]. To decrease noise and distraction in the operating room, some have suggested limiting the number of visitors, optimizing the alarms systems, restricting the use of pagers, and discouraging conversations unrelated to the procedure [5, 9, 10].

Although conceptually straightforward, the practicality of implementing these proposals may not be. For instance, turning off the telephone ring tone or the intravenous pump alarm is not always possible based on the perceived needs of the operating room staff and the anesthesiology team. Eliminating distractions during critical periods of an operation (akin to the Sterile Cockpit Rule) is challenging given that these periods are dynamic and may not be apparent to those not closely monitoring the procedure [28]. Limiting the number of observers, though well intentioned, may lead to the perception that the surgeon is ill tempered and not interested in medical education. Finally, because prospective data on the direct effect of sudden noise on patient outcomes are lacking, the staff may not fully appreciate the beneficial effect of noise reduction in the operating room.

From the perspective of social psychology, intermittent and unpredictable noise increases a person's feeling of stress and decreases his ability to concentrate and perform complex tasks [29, 30]. Although there is evidence that some adaptation to noise occurs over time, individuals in noisy environments never fully adapt and continue to evidence impaired cognitive function. Study subjects who can anticipate and have some degree of control over the noise are less distressed by it [29, 30]. The need to reduce the negative effect of noise and the limited ability of the surgical team to adapt must be acknowledged and respected. The surgeon, anesthesiologist, and other operating room personnel should be encouraged to develop specific tactics to mitigate the frequency and effect of noise and other distractions.

Improving Interpersonal Communication

Studies of human factors have emphasized the importance of teamwork and communication, the effectiveness of which is often evident among familiar team members [5, 9, 10, 14]. "Primary" surgical teams, defined as those in which most team members are routinely matched together, have a lower number of surgical flow disruptions and errors compared with "secondary" surgical teams, where members have little familiarity with each other [14]. Because team stability improves awareness of the progression of the case, temporary or permanent staff changes may compromise the shared knowledge of intraoperative events.

Despite issues with resource allocation, many centers have made efforts to minimize staff changes during cardiothoracic surgical procedures and to have specific personnel assigned to a team to maintain optimal teamwork. However, expecting primary surgical team members to operate as a unit without some personnel changes among nursing and anesthesiology staff is not always possible or sustainable because of workload concerns and organizational culture. When personnel changes do occur during the course of an operation, they should involve structured, robust "hand-off" practices to preserve the continuity and flow of the procedure.

The Joint Commission report between 2014 and 2015 indicated that failure in communication and human factors were the two leading root causes of sentinel events that resulted in operative and postoperative complications [31]. Teamwork failures in cardiac operations are commonly attributed to communication issues, leading to a lack of role clarity among team members, resource waste, tension, procedural violations, and errors [5, 14, 31]. To date, many team effectiveness models have been developed to enhance team performance and communication, but there is no consensus about which approach is optimal [5, 13, 32, 33]. One proposal to improve communication and to reduce the possibility of error is to use standardized time-outs, checklists, and preoperative briefings [18, 34–37].

Unlike briefings, which are discussions guided by a structured but open-ended format, checklists and time-outs (mandated by the Joint Commission) typically are close-ended, with specific information called out and verified [5, 38]. Implementation of the WHO "Surgical Safety Checklist" has been associated with reduced rates of death from 1.5% to 0.8% and complications from 11% to 7% among patients undergoing noncardiac operations [34]. The WHO checklist includes standardized time-outs, specifically before induction of anesthesia, before skin incision, and before the patient leaves the operating room [18].

Checklists also can be useful in guiding crisis management scenarios such as failed intubation, pulseless electrical activity, air embolus, and malignant hyperthermia [5, 38]. In cardiac surgery, development and implementation of a hemostasis checklist based on the most common sites of bleeding and focusing on surgical techniques can reduce reoperation for bleeding [39]. The effect of surgical safety checklists on patient outcomes, however, is likely to vary with the effectiveness of each institution's implementation process (Table 1) [35, 36, 40]. Coordinated efforts to explain why the checklist is being implemented and facilitated education regarding its use are necessary to achieve "buy-in" among surgical staff. In the absence of such "buy-in" and understanding, staff may not use the checklists as intended, leading to frustration, lack of interest, and eventual abandonment [37, 40].

Preoperative briefings are intended to establish a dialog and provide an opportunity for all operating room personnel to confirm and exchange information, identify concerns, and anticipate problems that may arise [5, 41, 42]. A short, structured briefing decreases the frequency of flow disruptions, enhances knowledge of the case, and limits miscommunications among staff even when instituted within a familiar team [14, 41, 43]. By decreasing interruptions and distractions, briefings can potentially shorten overall procedure times [43, 44]. In essence, the overarching goal of briefings is to communicate the critical components of a procedure by requiring a dedicated period of time to exchange information and clarify important issues.

Despite the demonstrated benefits of checklists and briefing protocols, their use in surgery has not been widespread ostensibly as a result of the lack of protocol standardization, the need for development and customization, individual attitudes or resistance to change, perceived reduced autonomy, and organizational barriers [13, 37, 40, 41, 45, 46]. Acknowledging the benefits of checklists, surgeons nonetheless report lower levels of comfort, team efficiency, and communication, suggesting that adapting to checklists or briefings may be uncomfortable initially [45].

A behavioral explanation for the resistance to implementation may be found in social psychology studies, which confirm not only the tendency to maintain the status quo but also the observation that each person is fairly accurate in his perception of others, but his self-perception (eg, in virtues, skills or other traits) is distorted in that he thinks he is better than others; that is, he considers himself above average [29, 47–50]. This divergence in assessment stems from a person's unwillingness to consult objective data when predicting his own behavior but readily uses this information when predicting the behavior of others [47].

Thus, one can understand why members of the surgical team may vary in their assessment of their own and their colleagues' teamwork and communication skills [13, 41, 46, 51–53]. For instance, self-reported perceptions of communication and teamwork skills by surgeons are alarmingly discordant with reports from anesthesiologists and other operating room staff [51, 53]. Notably, surgeons, anesthesiologists, and nursing staff perceive themselves as team players, but 51% of nurses do not see the surgeon as a team player, and 72% of nurses are not content with communication and teamwork in the operating room [51]. Surgeons rate their level of teamwork participation with nurses as high to very high 87% of the time in contradistinction to the perception of nurses, who rate surgeons as high or very high only 48% of the time [42] (Fig 1).

Because physicians typically overrate their nontechnical skills and downplay the effects of disruptions, they may regard the imposition of checklists or guidelines as unnecessary, as limiting their ability to provide individualized care, or as an affront to their intelligence [5, 13, 41, 46, 51, 52]. In addition, studies of self-serving bias, such as with "naïve realism," show that each person believes that he sees the world as it really is and believes that the facts, as he sees them, are evident to everyone, leading him to conclude that all others should agree with him [29, 50]. Those not in agreement with him are considered to be wrong and biased.

Naïve realism in surgery may be reflected in the differences in opinion among providers about what

Table 1. Explaining Why and Showing How to Implement a Surgical Safety Checklist[a]

Action	Implementation Leaders	Surgical Staff
Explaining why	Describe magnitude of changes seen in WHO pilot study Highlight values that align institution with checklist Build on past success with patient safety projects Model multidisciplinary participation	Understand rationale for checklist implementation (WHO results, institutional values) Appreciate ongoing patient safety efforts Recognize own role in patient safety Value multidisciplinary collaboration
Showing how	Welcome and respond to staff input Demonstrate best practices through tailored education and pilot testing (multidisciplinary participation including test introduction, checklist complete before incision, avoid reliance on memory) Provide real-time coaching and feedback Anticipate long-term need for training, observation, encouragement, and quality control	Understand that their opinions and experiences are valued Master and commit to best practices Benefit from real time coaching Welcome long-term support

[a] Reproduced with permission. Modified from Conley et al. Effective surgical safety checklist implementation. J Am Coll Surg 2011;212:873–9.

WHO = World Health Organization.

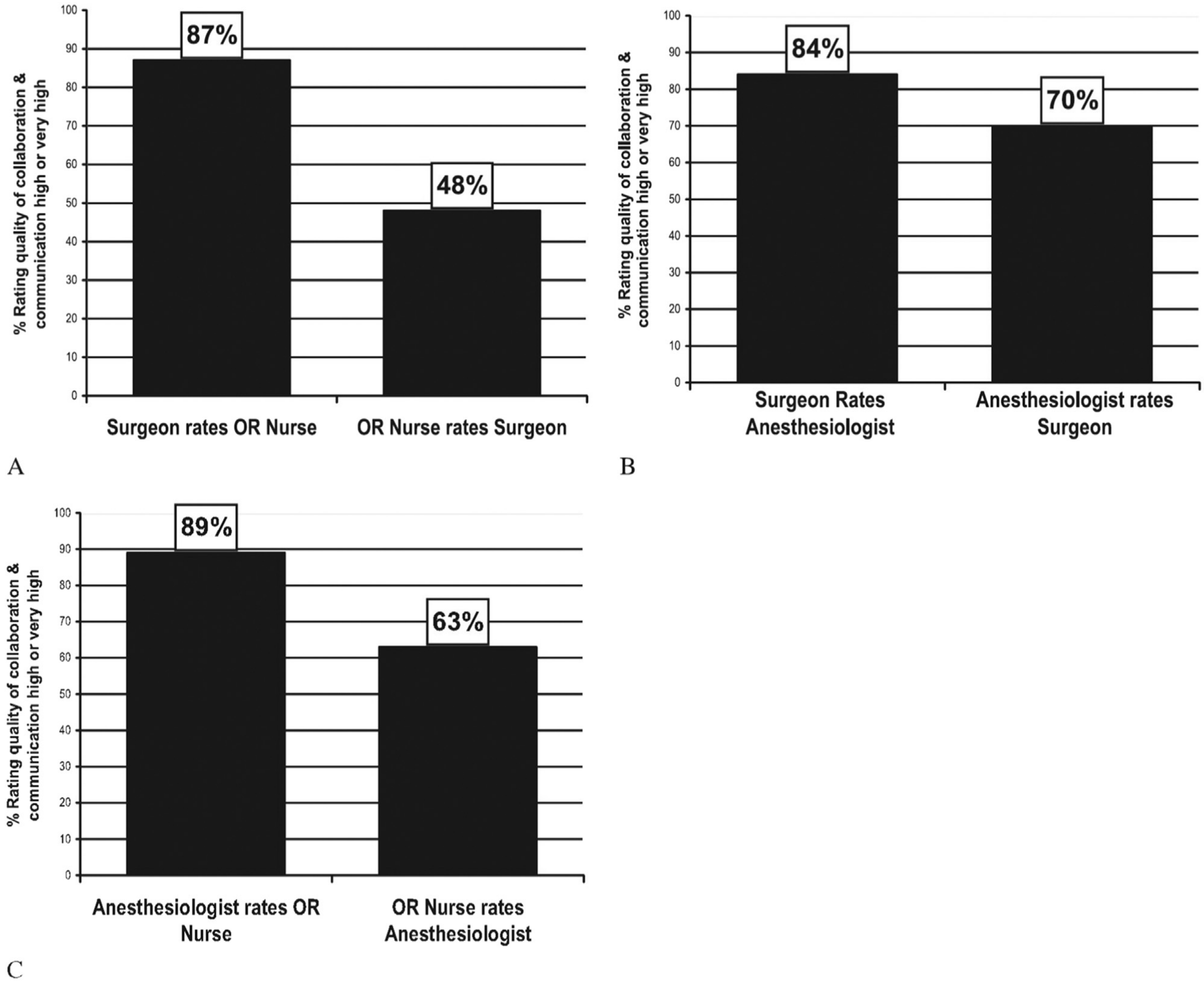

Fig 1. Differences in teamwork perceptions (A) between surgeons and operating room (OR) nurses, (B) between surgeons and anesthesiologists, and (C) between anesthesiologists and OR nurses. (Reproduced with permission. From Makary MA, et al. Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. J Am Coll Surg 2006;202:746–52.)

constitutes effective communication and in the adoption of protocols such as briefings and checklists. A survey of a United Kingdom practice found that 39% of surgeons stated they always performed briefings but only 4% of their nurses agreed [46]. The tendency of physicians to misperceive their communication and leadership skills may lead to a view that no improvement is needed [41, 49, 51], which in turn creates a major obstacle when attempting to introduce new paradigms to improve patient safety. Because people are generally unaware of their biases, educating them on their effect may help to some degree [54]. Minimizing complexity and grounding protocols in the realities of the specific workplace environment (accounting for the clinical needs and providers' biases) are important considerations in designing checklists and briefing protocols [37, 55]. Methods to overcome provider resistance and optimize dissemination involve active leadership, deliberate enrollment, training and coaching, and ongoing feedback [37, 40, 41, 46, 56]. As with protocols developed for team training and crew resource management, the use of checklists and briefings must be monitored to ensure that their use is sustained and that they ultimately improve outcomes [13, 31, 33, 57, 58].

Another possible explanation for surgeons not participating in preoperative briefing may be based on their desire to minimize distractive thinking; that is, the surgeon may not want to focus on "what can go wrong" immediately before the procedure. In describing the "ironic process" of mental intrusions, Wegner [59] notes that when participants are asked to try not to think of something, the moment they stop trying to suppress the thought (e.g., when they are stressed), the very thing they do not want to think about comes forward [29]. In preparing for a procedure, it is common for a surgeon to mentally image each correct step. However, by discussing potential errors immediately before the operation, he will need to suppress their intrusive nature during the procedure. As a result of the ironic process, the surgeon will not be able to overcome his ability to suppress the thoughts of potential errors during a subsequent stressful period and will become distracted by them. At some centers, discussions between the surgeon and anesthesiologist regarding challenging patients may occur at a time removed from the start of the procedure. Thus, standardizing such an earlier approach (ie, the day before) among the surgical staff should be considered, recognizing the potential logistical issues with staff availability.

Mitigating Work-Related Stress

Increased physical and mental workload can lead to stress and fatigue and reduce the level of cognitive function [60, 61]. Although physical workload is reflected in task duration and the strength required for the task, mental workload incorporates elements of complexity, time pressures, and perceived risks. Work breaks to combat physical and mental fatigue during operations may be effective but require intraoperative hand-offs [62]. For the cardiothoracic surgeon, work breaks to lessen the workload during surgical procedures are often not possible given the exigencies of cardiopulmonary bypass and patient-related and logistical considerations.

The ability of a surgeon to adjust to changes is vital to ensuring a safe and successful operation; barriers to mitigate errors due to system factors are based on his or her cognitive flexibility, adaptability, and resiliency [9, 10, 16, 25]. Flexibility refers to the ability to consider multiple potential causes and generate effective therapies when dealing with an unstable patient. Adaptability is being able to change strategies in the setting of new, unexpected information and disruptions to flow. A surgeon's resilience is evidenced by his capacity to remain calm after ineffective attempts to remedy the problem and his belief that the problem is solvable.

Surgical excellence is not error-free performance, but rather effective management (involving error detection, error tolerance, and error recovery) of hazards that emerge during an operation [11, 15]. Of the major intraoperative events in cardiac operations reported by deLeval and colleagues [15], 78% are compensated for or remedied by the surgical team without any observable effect on the patient. Thus, it is imperative to determine why some surgeons are more flexible, adaptable, and resilient and whether these characteristics are dynamic and can be enhanced.

Surgical errors that are technical in nature or due to judgment lapses seem inherently less affected by improved work systems because an individual makes the decisions and performs the operation [8]. To date, one area in the study of human factors that is not well appreciated is the mental state of the surgeon [3, 8]. According to a survey conducted by Shanafelt and colleagues [3], approximately 9% of surgeons report that they made a major medical error in the previous 3 months. Only 15% of those reporting an error attribute the error to a system failure, but more than 70% attribute the error to an individual factor that includes lapse in judgment, stress and burnout, and lapse in concentration. Importantly, committing a recent error is associated with the domains of burnout (emotional exhaustion, depersonalization, and loss of a sense of personal accomplishment) and symptoms of depression [3, 63]. It may be that the association between distress and errors is bidirectional, with a self-perpetuating cycle of distress and errors [3, 8, 64]. In contrast to the general impression that physical fatigue is associated with error, committing a surgical error appears not to be related to number of hours worked per week or number of nights on call per week, consistent with previous findings demonstrating no clear relationship between fatigue and patient outcome among residents and practicing surgeons [3, 65, 66]. In addition to current strategies to reduce the frequency of medical errors, physicians are likely to benefit from educational and other support programs that may help them to be more proactive in error prevention and reduce self-blame when errors occur.

Physicians often feel inadequately supported by their health care organizations as they attempt to cope with mistakes and adverse events [64]. Errors can have a significant emotional effect on physicians, resulting in distress with long-lasting effects [3, 8, 63, 64]. Individualized feedback and other therapeutic interventions can potentially be effective in promoting positive behavioral changes [67]. In the absence of introspection and self-awareness, surgeons in high-risk, high-stress environments are susceptible to depression, substance abuse, and burnout [68]. Surgeons also need to reliably calibrate their level of distress; that is, when surgeons receive individualized feedback on their well-being compared with normative samples of physicians, they often are amenable to change, particularly in terms of promoting work-life balance and career satisfaction [67]. Paradoxically, younger surgeons are particularly at risk for burnout, possibly as a result of expectations regarding the balance of career, family, and personal development [3, 54, 69]. In addition, surgeons with recent work-home conflicts are more likely to have symptoms of burnout and alcohol dependency (Table 2) [54, 70, 71]. The occurrence and effect of burnout may be mitigated by

Table 2. Partial List of Contributing Causes to Physician Burnout[a]

Length of training and delayed gratification
Limited control over the provision of medical services
Long working hours and enormous workloads
Imbalance between career and family
Feeling isolated or loss of time to connect with colleagues
Financial issues (salary, budgets, managed care, etc)
Grief and guilt about patient death or unsatisfactory outcome
Insufficient protected research time and funding
Sex- and age-related issue
Inefficient and/or hostile workplace environment
Setting unrealistic goals or having them imposed on oneself

[a] Reproduced with permission. From Balch et al. Stress and burnout among surgeons: Understanding and managing the syndrome and avoiding the adverse consequences. Arch Surg 2009;144:371–6.

identifying personal and professional values and striving to achieve balance between one's personal and professional life, to enhance areas of work that are most personally meaningful (eg, research and continuing education activities), and to nurture self-awareness and personal wellness strategies [8, 54, 69, 71].

Important in assessing human factors and patient safety is acknowledging the effect that an institution and its culture has on a surgeon's sense of mental fatigue and distress [8]. For example, policies that result in perceived loss of control by a physician, an emphasis on production and not on patient safety, and a punitive peer review process can destroy the sense of professional satisfaction, reduce the level of engagement, and increase provider distress [8, 60, 72]. Combating a stressful workplace through a stress reduction program can improve hospital performance, resulting in fewer medication errors and malpractice claims [8, 73]. It is logical to propose that health care institutions, as part of their error reduction strategy, acknowledge the effect of stress on providers' well-being and detect areas that contribute to lower job satisfaction and increased levels of stress among its staff [8, 72]. Hospitals experiencing high levels of stress can consider solutions targeted toward those factors that contribute to provider stress and burnout.

Conclusions

Analyzing work systems represents an important approach to human factors; however, errors made by surgeons are often technical in nature or the result of lapses in judgment. Assessing surgeon-centered factors is based on at least three strategies: minimizing external distractions, improving interpersonal communication and teamwork, and mitigating work-related stress. External distractions and sudden unexpected noise may increase the level of stress and impede the flow of an operation. To facilitate better adaptation and a sense of control, understanding the level of tolerance that the surgical team has for distractions and encouraging the team to develop specific tactics to mitigate their occurrence is critical.

Many models have been identified that promote better teamwork performance and communication. Belief systems inherent in human thought may create obstacles when attempting to introduce strategies to improve teamwork and communication. Because physicians typically overrate their nontechnical skills, they may view the imposition of checklists or guidelines as unnecessary or as limiting their ability to provide patient care. Development and implementation of appropriate protocols must be grounded in the realities of the workplace with full commitment of those affected by their use. The ability of the surgeon to adjust to changes, in terms of flexibility, adaptability, and resiliency, is the safety barrier mitigating the effect of negative system factors. Of major medical errors, only a small fraction of surgeons attributes the error to a system issue, whereas the vast majority attributes the error to an individual factor that includes lapse in judgment, stress, and burnout. Addressing provider-centered factors, such as imbalance of work, family, and personal growth, can help to reestablish the surgeon's mental health. Understanding the effect of the institution and its culture on the providers' sense of mental fatigue and distress is critical to improve patient outcomes.

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