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Review

The influence of stress responses on surgical performance and outcomes: Literature review and the development of the surgical stress effects (SSE) framework

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ABSTRACT

Background: Surgical adverse events persist despite several decades of system-based quality improvement efforts, suggesting the need for alternative strategies. Qualitative studies suggest stress-induced negative intraoperative interpersonal dynamics might contribute to performance errors and undesirable patient outcomes. Understanding the impact of intraoperative stressors may be critical to reducing adverse events and improving outcomes.

Data sources: We searched MEDLINE, psycINFO, EMBASE, Business Source Premier, and CINAHL databases (1996–2016) to assess the relationship between negative (emotional and behavioral) responses to acute intraoperative stressors and provider performance or patient surgical outcomes.

Results/Conclusions: Drawing on theory and evidence from reviewed studies, we present the Surgical Stress Effects (SSE) framework. This illustrates how emotional and behavioral responses to stressors can influence individual surgical provider (e.g. surgeon, nurse) performance, team performance, and patient outcomes. It also demonstrates how uncompensated intraoperative threats and errors can lead to adverse events, highlighting evidence gaps for future research efforts.

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1. Background

Over half of all adverse medical events involve surgical patients.[1] The majority of these are intraoperative, and many are potentially preventable.[2,3] Surgery's complexity makes it challenging to study, thus limiting our understanding of the moderators of intraoperative stress and its downstream influence on performance and outcomes. National surgical improvement efforts (e.g. National Surgical Quality Improvement Program or NSQIP) have focused monitoring and intervention strategies on preoperative rather than intraoperative risks.

Surgical performance can be affected by varying provider and team characteristics, changing environmental/technological factors, unpredictable intraoperative surgical findings, and fluctuating team dynamics. Unexpected or crisis situations can lead to substantial stress for the surgical team. Negative interpersonal interactions, disruptive surgeon behaviors, and tense or hostile environments are common in the operating room (OR) and attributable to work-related stress.[4–6] Unfortunately, as stress can degrade performance, surgical teams find themselves unusually vulnerable to performance errors in crises, when performance is most critical.[7–9] Understanding how behavioral responses to OR stressors can influence surgical performance may be critical to reducing adverse surgical events and improving outcomes.

Few studies have explored how individual emotional and behavioral responses to stressors influence team dynamics and intraoperative performance. Riskin et al. proposed that one reason why only marginal improvements in patient safety have been achieved despite two decades of effort is because improvement efforts have focused on system change while largely neglecting interpersonal dynamics.[10] To address this gap, we conducted a literature review guided by the central hypothesis that intraoperative stressors lead to emotional (e.g. frustration, anger) and behavioral responses (e.g. disruption) of individual providers that may impact patient outcomes through their influence on intraoperative surgical team performance. In this manuscript, we review prior research on the consequences of behavioral responses to stressors in the OR, and present a conceptual framework for how these responses may affect intraoperative surgeon and team performance and patient outcomes. We then propose high yield avenues for future research.

Our integrated Surgical Stress Effects (SSE) framework demonstrates how organizational, environmental, patient, and provider/team factors all contribute to stress and negatively influence the performance of team and individuals. Our approach is novel, as we integrate theories from different disciplines to better understand the relationships among stressors, the emotional/behavioral responses of team members, and intraoperative performance/outcomes. This framework is relevant to both preventing errors/adverse events and optimizing care, and may inform future interventions to improve intraoperative performance and outcomes. Below we provide conceptual definitions of the components of this integrated framework and review the evidence supporting the posited associations between these components.

1.1. Surgical stress effects (SSE) framework: theoretical considerations

Our conceptualization of the determinants of surgical performance and outcomes was informed by insights from the Job Demands and Resources (JDR) theory from occupational health/organizational psychology, the Component Process Model from affective psychology, and the Threat and Error Model from human factors engineering, and is illustrated in Fig. 1.

According to the JDR Theory, individual performance is a function of job demands (e.g. case difficulty, time pressure, technology requirements) and available resources (e.g. individual, team, social, organizational), shown in Fig. 1, Box D. Performance (Fig. 1, Boxes F and G) is optimal when resources match or exceed the physical, cognitive, and emotional demands of the job. When demands outstrip resources, chronic occupational stress is induced, performance quality is degraded, and errors increase.[11,12] Although the JDR theory has been applied in an assessment of surgeon work engagement and work ability,[13] prior studies have not applied this theory to acute stress and intraoperative performance. However, the JDR theory is particularly salient in the intraoperative context because it highlights that job resources in this context not only rely on the skills of the surgeon (Fig. 1, Box A) but also on other surgical team members (Box A), the organization (Box B), and the environment (Box C).

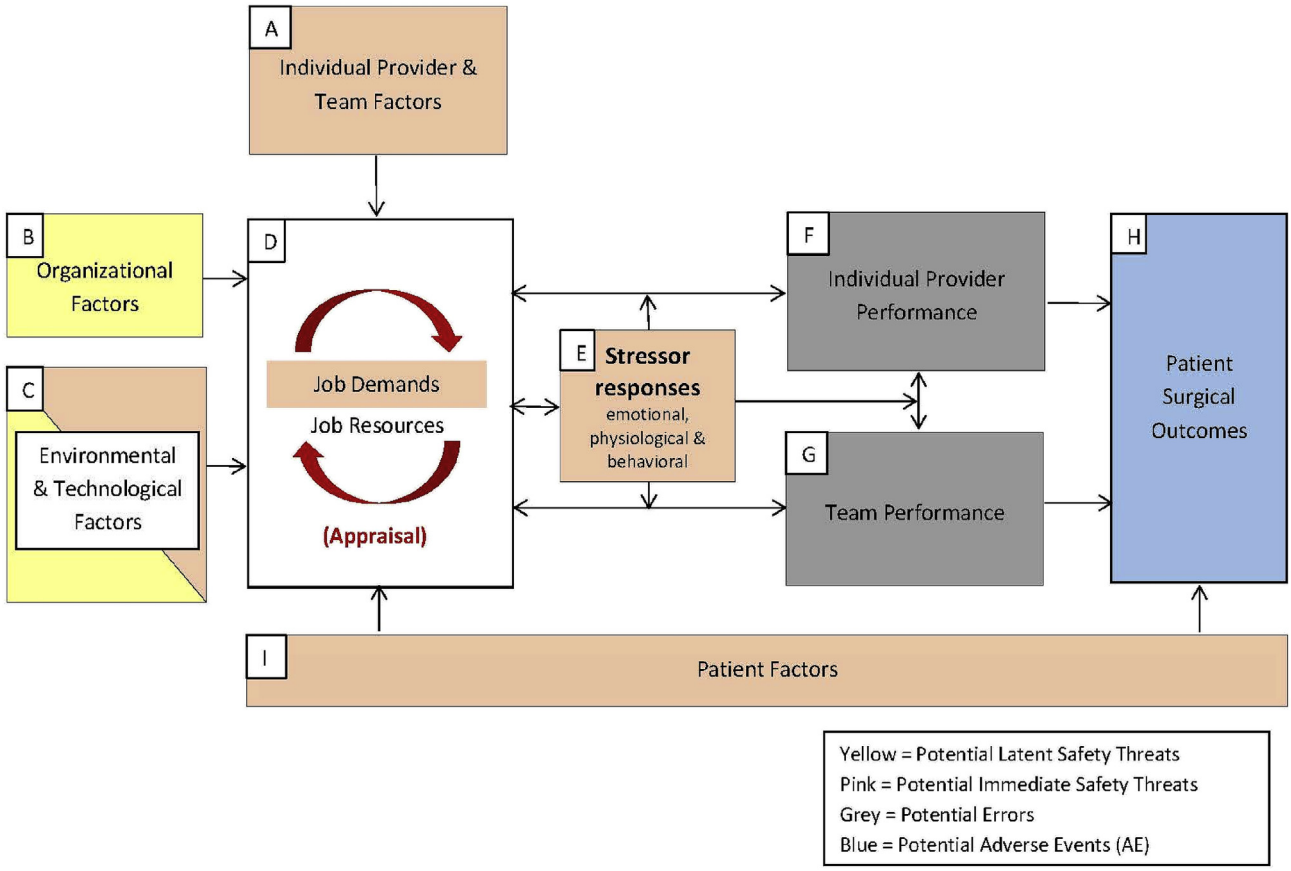

Fig. 1. Surgical stress effects framework.

The Component Process Model is a psychological theory of emotion, which posits emotions result from an interplay of five sub-systems: 1) conscious and sub-conscious cognitive appraisals of stimuli, 2) physiological arousal, 3) motor expression ("body language"), 4) subjective feeling, and 5) motivation or action tendencies (which increase the likelihood of emotion-specific behaviors)[14] see Fig. 1, Box E. Appraisal (Fig. 1, Box D cycle) refers to assessments of an environmental stimulus for its personal relevance as well as the individual's ability to cope with the stimulus.[14,15] Appraisal can be conceptualized as iterative in nature, comprised of feedback loops with ongoing re-appraisal.[16] The basic Component Process Model architecture dovetails well with JDR theory while introducing two additional relevant variables: the presence of the individual's stress/emotional response to selected appraisals (Fig. 1, Box E) and the iterative (ongoing) nature of appraisal over time as stimuli change (Fig. 1, Box D cycle).

According to the Threat and Error Model, organizational, task, environmental, team, provider, and patient factors all can contribute to adverse events and other undesirable outcomes through combinations of latent (hidden) and immediate safety threats.[17] Safety threats set the stage for human error to occur, and unmitigated error leads to patient harm.[18] Latent safety threats (yellow in Fig. 1) are systemic factors embedded in the environment or organizational structure and processes. These include institutional culture, scheduling, and policies that can create a setting conducive to error.[19] Immediate safety threats (pink in Fig. 1) include task factors (e.g. procedure difficulty), work environment (e.g. equipment availability, distractions), team factors (e.g. minimal experience working together, history of conflict), provider factors (e.g. lack of surgical experience, coping skills), and patient characteristics (e.g. clinical acuity, difficult anatomy). Immediate threats can lead to human errors (grey in Fig. 1) such as physical task mistakes, cognitive blunders, or poor communication. When no compensation occurs for such errors, adverse event(s) can occur (blue in Fig. 1).[20]

2. Methods/Data sources

We reviewed the literature and summarized the empirical support for the relationship between negative (emotional and behavioral) responses to acute intraoperative stressors and provider performance or patient surgical outcomes. To identify relevant articles, we searched the MEDLINE, psycINFO, EMBASE, Business Source Premier, and CINAHL databases for English language studies with key words relating to stress, performance, and surgical outcomes published between 1996 and May 2016 (Refer to Appendix A for search strategy). We examined the abstracts of papers that met the initial search criteria to identify observational and experimental studies specifying the impact of provider stress, emotion, and/or their associated behaviors (e.g. conflict, disruptive behavior) on either patient surgical outcomes or individual/team intraoperative performance. We excluded non-empirical papers (i.e. conceptual papers, opinion pieces) as well as studies assessing stress responses of patients, reports of provider stress outside the OR, and studies of chronic provider stress. We analyzed pertinent full-length articles, and then used the snowball method to identify additional relevant articles from the article references retrieved in the initial search. Additionally, we utilized a forward search strategy among identified articles, allowing assessment of articles citing that work. Where there was no available evidence specific to the

OR, we expanded our search to find the best evidence from other similar high-acuity contexts (e.g. aviation). Although our framework acknowledges the potential influence of many contributory factors on surgical performance and outcomes, our literature search focuses on how stress responses influence performance and outcomes. Therefore, we only describe organizational, patient, provider and team factors that are considered either potentially stress-sensitive, potential direct antecedents of stress, or potential moderators of the appraisal process. Due to the voluminous literature addressing contributing factors, when describing these relationships, we often cite relevant review articles rather than original research.

3. Results and discussion

The search strategy produced limited literature addressing the impact of negative behavioral responses to intraoperative stressors on surgical performance or patient outcomes. Findings in the non-surgical literature were therefore used to develop a conceptual framework we apply to surgery. The Surgical Stress Effects (SSE) framework presented below is consistent with both evidence from non-surgical settings as well as the limited data from the surgical context.

3.1. The components of the SSE framework (Fig. 1)

3.1.1. Outcomes

Desired patient outcomes (Fig. 1, Box H) include the absence of harm (e.g. patient adverse events) and presence of efficient, high-quality surgical care. Intraoperative performance (Fig. 1, Boxes F & G) requires execution of both technical (i.e. psychomotor skills used to accomplish procedures) and non-technical skills (i.e. cognitive and interpersonal skills such as communication, situational awareness, decision-making, teamwork, and leadership). Technical performance has long been assumed to influence surgical outcomes, although not until recently has this relationship been quantified.[21] The link between non-technical skills performance and patient surgical outcomes, while historically neglected, has been recognized in recent years.[22] Breakdowns in non-technical performance are common and can be associated with provider errors and adverse outcomes.[23]

3.1.2. Individual provider and team factors

The literature is replete with descriptions of the numerous attributes of surgical providers (Box A) that can affect both individual (e.g. technical skills and decision making) and team (e.g. communication skills) performance.[24,25] Some of these attributes are intrinsic to the individual (e.g. personality, inherent ability, risk tolerance) and quite stable, while others (e.g. technical and non-technical skills, surgical experience, attitudes) evolve slowly over time. Individual physiological and psychological states can change more rapidly (e.g. mood, fatigue, substance use, illness). Team factors, such as trust, familiarity with each other, and experience with the procedure also can influence performance. For the purpose of this review, we only discuss provider factors relevant to intraoperative emotional/behavioral responses to stressors and their impact on performance.

3.1.3. Patient factors

Patient factors (Box I), including comorbidities, immunologic status, surgical pathology severity, and individual anatomy/physiology can influence outcomes directly or through their impact on job demands.[26] For example, obese or disabled patients require additional effort to move and secure them on the operating table. Complex pathology increases the technical difficulty for surgeons and increases job demands on nurses who often must obtain additional supplies intraoperatively.

3.1.4. Organizational factors

Organizational factors (Box B) can influence performance and outcomes through an impact on job demands and resources (JDRs) and provider stress. Organizational factors include organizational culture, staffing/hiring practices, employee compensation, case scheduling practices, staff training/drills, intraoperative safety protocols, and policies regarding performance review and error reporting. Organizational culture refers to the beliefs, values, and behaviors shared by group members and is particularly important as it influences employee attitudes towards safety. Closely related constructs such as safety culture and safety climate are linked to safe behavior and positive patient outcomes.[27–29] In contrast, the unique organizational culture within the OR discourages questioning across the team's hierarchical layers.[30] The OR often lacks the psychological safety for team members to feel comfortable "speaking up" with concerns[31,32] which makes errors less likely to be recovered. Likely due to production pressure as well as the culture and isolation of the OR, conflict, raised voices, and even disruptive behavior may be tolerated more so than in the remainder of the hospital.[33] Poor case scheduling can increase job demands by limiting availability of equipment and specialized staff or by over-scheduling resulting in time pressure to finish long lists on time (latent safety threats).

3.1.5. Environmental and technological factors

The physical OR environment and technology (Box C) affect JDRs and are common sources of stress for surgeons. As surgery has become more dependent on technology, the incidence of error and delay due to equipment issues have increased. A recent review found 23.5% of errors noted in prospective observational studies of cardiac and general surgery were due to equipment problems.[34] Surgical technology also harbors potential latent hazards due to poor equipment design, physical arrangement, and lack of maintenance.[35] Environmental stressors such as noise, distractions, and interruptions are also common. Noise often exceeds recommended levels in the OR and has been shown to decrease team communication,[36] and non-surgical data suggests noise negatively affects technical performance.[37] Irrelevant conversation, staff flow, and pages/phone calls are sources of interruption and distraction with potential negative influences on intraoperative cognition and communication.[38]

3.1.6. Job demands, job resources, and JDR appraisal

Job demands (Box D) can be conceptualized as "what needs to be accomplished and how quickly," and cognitive, physical, and sociotechnical demands often fluctuate over the intraoperative period. They vary based on the provider's role within the OR[39] and can increase intraoperatively due to clinical deterioration of the patient, time pressure (e.g. patient acuity, scheduling), or distractions (e.g. pages, phone calls).[38,40] Job resources (Box D) are the individual, team, and work environment assets that are immediately available to meet the job demands. Traits and states of individual providers and teams can contribute to job resources, but this is context dependent. We consider a factor as a job resource when it is currently available to meet job demands. For example, providers may have the necessary communication skills and training (provider factor), but if they lack the proper attitude or motivation (another provider factor), their communication skills are unavailable as a job resource. The availability of job resources can also be dynamic, changing over the course of a surgical case. For example, a surgeon might have excellent psychomotor skills and performs well at the beginning of a long case, but their hands tremble when

fatigued, dehydrated, and hypoglycemic after 10 hours of surgery.

Individuals continuously assess currently available job resources and demands (see ongoing cycle within Box D). In the SSE framework we use the term appraisal to refer to this iterative assessment process. According to Blascovich et al., when resources are appraised as sufficient to meet increasing job demands, then a "challenge" state occurs, which can enhance performance.[41] If, however, resources are appraised as insufficient, then a "threat" state ensues. Appraisal of a situation as "threatening" (or job demands as very high) correlates with the degree of stress reported.[42,43] Thus in our framework, when individuals perceive job demands exceed resources, they feel threatened and experience subjective "stress" (Box E).

3.2. Stressors, emotions, and stress responses

Our conceptual framework posits that behaviors resulting from stress/negative emotions can impact surgeon and team performance. The term "stress" has varied meanings in different academic disciplines, ranging from literal physical pressure, to a pattern of physiological changes, to subjective emotional perception. Herein, we use the term "stressor" to refer to environmental, personal, and organizational changes that elicit negative emotions or feelings of "stress" in healthcare providers. We use the term "stress," as commonly used in lay conversation, to refer to a subjective (negative) emotional experience following an appraisal of job resources as inadequate to meet job demands. Stress often occurs in response to stimuli that are unpredictable and/or uncontrollable.[44] Studies of stress in surgery have also used various other terminologies such as "mental strain," "crisis management," "mental workload," and "emotional state."[45] OR stressors can also elicit other related emotions (e.g. anxiety, worry, anger, frustration) that can potentially compromise performance,[9] and we will consider these along with "stress." We use the term "stress response behaviors" to refer to observable behaviors provoked by subjective (negative) emotional experiences.

Both observational and qualitative studies in surgery have found that intraoperative surgical stressors include: technical complexity/complications, emergencies, noise interruptions, equipment failure, poor physical ergonomics/pain, time constraints, teamwork problems, and interpersonal issues.[9,36,40,46,47] Such stressors can negatively impact performance of individuals and teams[24,48,49] as illustrated in our SSE framework.

3.2.1. Stress and provider physiology

Stress is coupled tightly to an individual's physiology, since stress causes physiological changes and physiological changes can cause psychological stress. Emotional stress is associated with a predictable physiologic stressor response (arousal) that involves the sympathetic adrenomedullary system and the hypothalamic pituitary-adrenal axis. This 'stress response,' generates catecholamine release, increasing heart rate, blood pressure, respiration, perspiration, and muscle tension.[50,51] In addition, temporal physiological changes common in surgeons during long or demanding cases (e.g. fatigue, hypoglycemia) can be considered "internal" physiological stressors with potential adverse influence on performance quality.

Sleep deprivation is associated with poor psychomotor performance in non-medical settings,[52] but its impact on technical surgical performance is mixed and related research typically focuses on trainees.[53] Lack of sleep can impact cognition in various ways, diminishing attention, concentration, motivation, and reaction times.[54] Sleep deprivation studies outside of medicine have shown that fatigue has the most pronounced impact on mood, followed by cognition, and then motor performance.[55] The impact of surgeon fatigue on patient outcomes is inconsistent but several studies suggest a negative impact.[49] Surprisingly, the majority of nurses and surgeons are convinced they perform effectively even when fatigued.[56] Dehydration has been shown to impact cognitive performance and mood in physicians and nurses in the outpatient setting.[57] However, the impact of surgeon hydration on intraoperative performance has not been studied. The pace and nature of the work of surgeons and surgical trainees often leads to poor fluid intake and missed meals, in contrast to other surgical team members who take intraoperative breaks. In the non-surgical literature, blood glucose levels are correlated with cognitive performance, including memory, attention, decision-making, reaction time, verbal fluency, and auditory processing.[58] Hypoglycemia has been associated with anger, aggressiveness, and irritability,[59] which could negatively impact intraoperative interpersonal interactions. Experimental induction of frustration leads to more negative responses in fasting subjects.[60] The influence of fasting on mood and brain function are significantly more pronounced when individuals are expending cognitive effort.[61] Whether blood glucose impacts surgeon performance (technical and/or non-technical) under stress during long cases has not been studied.

3.2.2. Stress and individual technical (psychomotor) performance

Personal (e.g. fatigue), psychological (e.g. anxiety), workload related (e.g. time pressure), and environmental (e.g. heat, noise) stressors negatively impact both perceptual and psychomotor tasks in the non-surgical literature.[62] Perceptual and motor performance are more resilient to the impact of stress than is cognitive performance (see cognition discussion below).[62] Fortunately for surgeons, the performance of well-learned tasks (from procedural memory) are the most impervious to the impact of stress, as they are more automatic requiring fewer cognitive resources.[63]

From the limited surgical literature, intraoperative stressors appear to negatively impact technical/psychomotor performance. Assessment of surgeons performing laparoscopic transfer tasks in a simulator noted that experimental "stressors" (i.e. time-pressure, noise, and multitasking) were associated with poorer performance (both skill and knowledge errors) but participants' perceived stress was not measured.[64] In medical students, multitasking impacted performance, while time pressure did not.[65] In this study, both self-reported anxiety and physiological measures of stress were measured but neither correlated with performance or with each other, highlighting the challenges of stress research in surgical settings.[65] Wetzel et al. found that technical performance of simulated carotid endarterectomy was degraded by stressors (e.g. task complexity, time pressure, patient acuity, inexperienced assistant, multitasking).[48] The ability to cope with stress appears to moderate its impact on performance.[48,66] It is not fully understood how stressors impact individual and team intraoperative performance as well as whether there are additional factors moderating those relationships.

3.2.3. Stress and individual non-technical performance

Carthey et al. found that surgeons with better non-technical (cognitive and interpersonal) skills made fewer errors and had lower mortality and complication rates, even when controlling for patient risk factors.[67] Unfortunately, the limited evidence available suggests that intraoperative stress can impair non-technical performance.[45] Many non-technical skills are cognitive. It is clear from the non-surgical literature that both excessive stress and strong negative emotions diminish working memory, attention, judgment/decision-making, and perceptual-motor function.[62,68,69] Working memory is a limited resource shared by various tasks, and therefore is vulnerable to stress due to its limited capacity.[62] The non-surgical literature suggests that anxiety and worry adversely impact memory

by consuming working memory capacity.[62]

Another way that stress affects cognition is through its impact on attention. When stressed, individuals narrow or "tunnel" their breadth of attention, attending to fewer environmental cues.[62] This can benefit performance when irrelevant information is ignored; however during complicated or ambiguous tasks, neglecting germane information can threaten performance.[51] Conversely, there is some evidence that stress can increase distraction from irrelevant sources and impair selective attention to more important stimuli.[70]

Stressors that reduce attention (e.g. interruptions, distractions) are common in the OR, and include equipment issues, noise, irrelevant conversation, staff flow, and interruptions (e.g. pages/phone calls).[71–73] Distractions can reduce performance quality and efficiency, although experience buffers this effect.[46,64,66,74,75] While the majority of distracting stressors during surgery are external (from the environment or team members), distractions can also be internal. Surgeons interviewed about stressful intraoperative situations recalled being distracted by worrying about the medicolegal implications of their actions, as well as how they would justify their actions post-operatively.[9] Some individuals are distracted by their own physiological stress response (e.g. tachycardia).[51] Finally, given the high rates of musculoskeletal disorders associated with performing surgery, surgeons can be distracted by their own physical discomfort[76] and personal needs during long procedures (e.g. hunger, full bladder).

Situational awareness is another skill requiring attention and facilitates rapid responses to warning signals,[77] thus preventing intraoperative errors. When critical choices are made under time pressure, errors can occur due to a lack of situational awareness.[78] Doleman et al. found that when anesthesiologists were stressed, they had lower scores on the non-technical skills domains of situational awareness and decision making.[79]

Intraoperative decisions are critical during surgery, particularly when faced with the stress of anatomic anomalies or intraoperative patient decompensation. Retrospective review of surgical mortality reports in Scotland found that decision errors were much more common than technical mistakes.[80] Stress adversely influences how individuals make decisions.[69] Stress can lead to simpler decision-making strategies, including consideration of fewer alternatives, use of heuristics (i.e. mental short cuts based on experience), and failure to consider consequences.[62,69,81,82] Individuals under stress may continue to use ineffective strategies, known as cognitive lock-up, which can lead to fixation errors.[62] In other domains, various stressors can impair decision making including: noise (impacts social judgments), fatigue (worse in complex decisions), interruptions (worse in complex decisions with frequent irrelevant interruptions), workload, and time pressure.[62]

The influence of stress on decision-making is modulated by individual characteristics. In pilots and drivers, experience moderates the relationship between stress and poor decision-making.[83,84] The limited data available from the surgical context, although qualitative, is consistent with findings from other disciplines. Some surgeons describe how intraoperative stress negatively impacted their judgment and the quality and speed of decision-making, while others reported second-guessing earlier intraoperative decisions.[9]

3.2.4. Emotional stressor responses

The subjective experience of stress can be associated with various emotions, including fear, concern, annoyance, tension, frustration, and anger.[51,85] Much of the surgical literature evaluating subjective intraoperative stress utilizes a self-report metric validated for anxiety assessment, the State Trait Anxiety Inventory (STAI).[86,87] However, surgeons describe a wider range of emotional responses to intraoperative stressors, including anger, frustration, and irritation.[9] Negative emotions can decrease decision quality through the neglect of important information, poor assessment of outcome probabilities, and preference for high-risk, high-reward strategies without consideration of consequences.[88] Emotions can persist after their inciting conditions and negatively impact subsequent unrelated decisions.[89] Intraoperative observational studies often describe provider frustration stemming from patient or environmental stressors, including in cases where errors occurred.[90,91] Frustration and hostility in the OR are associated with poor team coordination,[92] and high surgeon frustration levels correlated with both short- and longer-term post-operative complications after hernia repair at VA hospitals.[93]

Emotion also can impact appraisal (Fig. 1 Box D cycle), in terms of risk perception and attribution of responsibility.[89] This supports the arrow in Fig. 1 from stressor response back to appraisal.

3.2.5. Stress and emotional contagion within teams

Emotional states can be "contagious," spread among group members, and influence performance.[94] Negative emotions (such as anger) are more contagious than positive ones.[95] Additionally, recent research suggests that contagion depends on the emotion's relevance and often flows from high to lower status individuals.[96] This work has implications for hierarchical OR teams, where surgeons are the "high status" individuals. so their emotions have the potential to "infect" the entire team. Unfortunately, qualitative work suggests that attending surgeons may be unaware of how their stress negatively influences the rest of the team.[6] Conversely, leaders who cope well with stress and support their subordinates decrease team stress and augment their performance.[62,97]

3.2.6. Stressors impact team performance

Stressors can induce behavioral stress responses that have the potential to adversely affect team performance. Team communication, cooperation, coordination, performance monitoring, shared leadership, and adaptability are critical for quality care in the OR, particularly in unexpected or stressful situations.[98–100] Poor teamwork, as measured by direct intraoperative observation of behavioral markers, is associated with an increase in 30-day mortality and complications.[101] Stressed team members, likely due to attentional narrowing, demonstrate reduced cooperation, impaired communication, lack of attention to interpersonal cues, and are less likely to help each other.[7] Exposure to high levels of stress also can degrade team performance due to a loss of team identity and shared mental models.[8]

Inexperienced surgeons reported in a qualitative study that during stressful situations they over-focused on the technical aspects of the problem and reduced communication within their team.[9] Anesthesiologist communication quality correlated with performance during a simulated anesthesia crisis.[102] Davenport et al. found that at the hospital level, staff self-reported levels of communication and collaboration correlated with risk adjusted 30-day post-operative morbidity but not mortality.[103] Unfortunately, poor communication can prevent surgeons from securing adequate team support, particularly in critical situations when it is needed most. As an illustrative example, poor intraoperative communication between the surgeon and circulating nurse can lead to delay in obtaining a clamp required to stop bleeding and repair a vessel. The result is not only longer operative time but also increased blood loss, with the risk of hypotension, transfusion, and patient morbidity.

3.2.7. Behavioral stress responses: negative interactions within teams

Our conceptual framework illustrates how stressors induce

emotional and behavioral stress responses (Box E) that can adversely impact the performance of others (Boxes F, G). In a recent randomized control trial of simulated neonatal resuscitations, a colleague's rudeness degraded both diagnostic and procedural performance as well as information-sharing and help-seeking.[10] Surveys of perioperative nurses found exposure to verbal abuse in the past year is common (91%)[104] and associated with decreased concentration (84%), reduced team collaboration/communication (89%), and adverse events (19%).[5] A recent study noted that emotional abuse and emotional work demands were the strongest predictors of concentration problems among OR nurses.[105] A review in the nursing literature found that two thirds of studies link negative inter-professional relationships to increased patient mortality.[106] Dysfunctional behavior is noted more commonly in surgeons than any other healthcare providers.[5] Cochran and Elder interviewed OR staff and found that disruptive surgeon behavior shifts team focus away from the patient and increases surgical errors.[107] Villafranca et al. recently reviewed the antecedents of disruptive behavior and noted a combination of intrapersonal (e.g personality, psychological and physiological states), interpersonal (e.g hierarchy), and organizational (e.g.production pressure, supply shortages) factors,[33] which is consistent with our broader SSE framework.

Surgeons attribute hot tempers and dysfunctional behaviors, motivated by strong negative emotions, to the stress of their work.[6,9] However, such stress response behaviors (Box E) can increase job demands (Box D) for other team members, serving as "secondary stressors." Many non-surgeons feel that surgeon arrogance, intensity, and tendency to demean others leads to stress and frustration among other surgical team members.[5,108] Negative emotion as well as misattribution of blame and harsh language (e.g. profanity, threats, personal attacks) engender conflict between team members.[109–111] Poorly managed conflict is another source of secondary stress and distraction to team members[112] and can even result in harm to patients.[113] Some surgeons justify using forceful communication (including threats) in high-pressure settings in order to expedite achieving their short-term goals,[110] but such behavior tends to increase relationship conflict[109,110] and degrade team building.[109] Unfortunately, physicians often falsely view intimidating behaviors as justifiable expressions of frustration which are compartmentalized without adverse impacts on communication or patient safety.[114]

Negative interpersonal interactions often produce tense or hostile intraoperative environments. Observational studies find the majority of surgical cases contain "high tension events" which most commonly occur between surgeons and nurses.[4,115] Tension appears cumulative and potentially contagious.[115] In response to tension, team members may withhold information or refuse to collaborate.[116] Unfortunately, 68% of nurses and consultants and 86% of trainees acknowledged they were more likely to make errors in tense or hostile environments.[56] A randomized simulation study assessing "encouraging" vs. "discouraging" environments found that fewer surgical trainees were willing to speak up to prevent an intraoperative error when the environment discouraged questioning their attending,[117] confirming that effective intraoperative teamwork requires psychological safety.

3.3. Strategies for maximizing performance and outcomes

3.3.1. Coping with acute stress

Coping refers to the psychological effort used to manage stressful events. Individuals vary in their ability to cope with high workload and stressors. Some intrinsic characteristics, such as personality, correlate with stress perception and coping.[43] Wetzel et al. studied the influence of perceived stress and coping on teamwork performance during both crisis and non-crisis simulation scenarios. They found that during crises, teamwork is best preserved when the surgeon is experienced and reports minimal subjective stress.[48]

Stress coping strategies correlate with both technical and non-technical performance in simulated surgical settings.[48,66] In a randomized intervention trial, stress management training decreased levels of perceived stress and increased job satisfaction.[118] Emotion regulation is a common coping mechanism used in negative situations and can be accomplished using various strategies, such as reappraisal and expressive suppression.[119] Reappraisal involves a cognitive re-interpretation of a negative situation, so the situation no longer "feels" so negative.[120,121] Unfortunately, acute stress reduces cognitive reappraisal ability,[122] but whether this occurs in the OR is unknown. Another emotion regulation strategy is expressive suppression, where an individual actively resists the urge to act on emotional impulses. In the laboratory, suppression of behavioral expression of emotion adversely affects verbal[120] and spatial memory[123]; both are important to surgeon performance. As discussed previously, blood glucose is important for cognitive function, and glucose supplementation improves memory.[124] However, effortful self-control significantly reduces blood glucose and impairs not only subsequent attempts at behavioral self-control during a frustrating task but also decreases willingness to help others.[125] It is not known whether glucose levels moderate surgeons' emotional regulation abilities or whether it affects frustration tolerance during surgery.

3.3.2. Error compensation

Error prevention, detection and recovery are important in high risk settings such as the OR[126–128] According to our conceptual framework, a provider's performance (Fig. 1, Box F) might be an immediate threat/error (colored grey) which is then compensated by the team (Box G) thus preventing an adverse outcome (blue Box H). This is supported by an observational study in cardiac surgery where 40% of surgical errors were not immediately detected by the surgeon. Non-surgeon team members were almost three times more likely than surgeons to detect or mitigate such errors.[46] Teams with good non-technical skills prevent accumulation of minor failures that can escalate to more serious adverse events.[18,25] In pediatric cardiac surgery, successful error compensation by team members reduced the risk of death in the setting of life-threatening intraoperative errors.[127]

3.4. An illustrative scenario

As an illustration of our conceptual framework, consider an inexperienced surgeon performing a difficult aortic aneurysm repair. He requested specific instruments in advance. Yet at a critical moment, he asks for his vascular clamp and the clamp is not available. The surgeon is visibly frustrated (subjective emotion), his face turns red (blood pressure and pulse increase), and he shouts angrily at the circulating nurse (disruptive stress response behavior). His hands shake (decreased technical performance). While the surgeon focuses intently on controlling the bleeding with the available instruments (cognitive response to stress), he stops communicating with his colleagues (poor teamwork). He fails to notice that blood loss has been excessive (poor situational awareness) and that the patient may now need a blood transfusion (adverse impact on patient care). The circulating nurse, in the meantime, is distracted and angry that she was unfairly blamed for a mistake made by the previous nurse in the room. She initially fails to notice the suction container is rapidly filling with blood (lack of situational awareness) and when she does notice, she chooses not to mention it since she fears angering the surgeon further (poor

teamwork due to lack of psychological safety). The anesthesiologist is busy managing the unexpected hypotension but is also distracted by the surgeon's outburst. As a result, at the moment when the surgeon needs his team the most, his aggressive behavior and lack of communication have curtailed their ability and willingness to work together to achieve the best patient outcome. Unfortunately, as teams provide protection against errors (in terms of detection, response, and management),[99,127] any negative impact of the surgeon's stress responses on teamwork can decrease error compensation and increase the risk of adverse events.

3.5. Limitations of this review

This review is necessarily limited in scope in several areas. Although chronic stress and burnout can negatively influence the mental and physical resources of the surgeon and team, this review focuses on acute stress as it is more tightly coupled with short term performance outcomes. We focus on the intraoperative period, while understanding that pre-existing patient co-morbidities, preoperative events, and post-operative care also have an important impact on patient outcomes. When discussing latent factors in the organization and environment, we have not addressed safety-promoting factors but have discussed only safety threats, given their relevance to negative stress in providers. There is minimal literature addressing the impact of acute stress responses on surgical performance and patient outcomes. The existing evidence supports our conceptual framework but also demonstrates a need for future quantitative research in this area. While attempting to be comprehensive, we may have missed studies not appearing in the indexed literature.

3.6. Next steps

Based on the available literature, it is not yet clear to what degree environmental, organization, and individual characteristics influence emotional and behavioral responses to intraoperative stress. The few empiric studies of surgeon stress and outcomes are small and often assess simulated surgery, utilizing trainees as subjects. Research addressing the relationship between intraoperative stress, emotions, and behavior is qualitative and/or uncontrolled.

Future research should test the assumptions of the SSE framework, in particular to determine whether surgeon behavioral stress responses have a quantifiable impact on team dynamics and performance. It will also be useful to evaluate which intraoperative stressors are most likely to result in dysfunctional behavioral stress responses during live surgery and whether surgeon hypoglycemia or dehydration influence their ability to cope with stressors. Our review and framework suggest several potential intervention targets to improve performance, including prevention of stressors (decreasing job demands, increasing job resources) as well as stress response modification of individuals (coping) and teams (compensation). In addition, since psychological stress leads to dynamic changes in physiology, ongoing monitoring of surgical teams has potential to identify provider stress allowing implementation of “real time” interventions targeting high risk ORs.

4. Conclusion

This conceptual framework illustrates how emotional and behavioral stress responses and their antecedents can influence surgeon and team performance and patient surgical outcomes. It provides a valuable aid for understanding the complexities of the operating room while guiding future research in this high stakes environment.

Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the U.S. Department of Veteran's Affairs or the United States Government.

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Appendix A

Medline search strategy (limited to English language and humans) 1996–Jan 2017

exp Specialties, Surgical/OR surgeon$.ti,ab. OR surgical.ti,ab. OR surgery.ti,ab.

AND

exp “Conflict (Psychology)”/OR conflict.ti,ab. OR Problem Behavior/OR exp Emotions/OR “disruptive behavior”.mp. OR exp Stress, Psychological/OR (Aggression/or Bullying/or Dominance-Subordination/) OR “stress”.ti,ab. OR “rudeness”.ti,ab.

AND

[Psychomotor Performance/OR performance.ti,ab. OR “non technical performance”.ti,ab. OR “non technical skills”.ti,ab. OR “situational awareness”.ti,ab. OR (information seeking behavior/or nonverbal communication/or teach-back communication/or verbal behavior/) OR *Communication/OR Interdisciplinary Communication/OR “teamwork”.ti,ab. OR “coordination”.ti,ab. OR “technical performance”.ti,ab. OR physician-nurse relations/

OR

“reoperation”.ab,ti. OR “complication$”.ab,ti. OR “surgical outcome$”.ab,ti. OR “surgical mortality”.ti,ab. OR “surgical morbidity”.ti,ab. OR mortality.ti,ab. OR morbidity.ti,ab. OR “surgical complication”.ti,ab. OR “surgical complications”.ti,ab. OR (patient harm/or patient safety/)OR “patient safety”.ti,ab. OR exp Intraoperative Complications/OR “sentinel event$”.ti,ab. OR “never event$”.ti,ab. OR “failure to rescue”.ti,ab. OR Iatrogenic Disease/OR “glitch count”.ti,ab. OR “non routine event$”.ti,ab. OR “near miss”.ti,ab.]

PsychInfo search strategy (limited to English language and humans) 1987–Jan 2017

exp Surgery OR surgeon$.ti,ab. OR surgical.ti,ab.

AND

exp Motor Performance/OR exp Perceptual Motor Processes/OR exp Performance/OR psychomotor performance.mp. OR “non technical performance”.ti,ab. OR “non technical skills”.ti,ab. OF “situational awareness”.ti,ab. OR exp Information Seeking/OR exp Nonverbal Communication/OR exp verbal communication/OR exp nonverbal communication/OR exp communication/OR exp oral communication/OR exp communication skills/OR interdisciplinary communication.mp. OR “teamwork”.ti,ab. OR “coordination”.ti,ab. OR “technical performance”.ti,ab.

OR

“reoperation”.ab,ti.OR “surgical complication”.ti,ab. OR “surgical complications”.ti,ab. OR “complication$”.ab,ti. OR “surgical outcom$”.ab,ti. OR “surgical mortality”.ab,ti. OR “surgical morbidity”.ti,ab. OR mortality.ti,ab. OR morbidity.ti,ab. OR exp Patient

Harm/OR exp Patient Safety/OR exp Intraoperative Complications/OR exp Medical Errors/OR "sentinel event$".ti,ab. OR "never event$".ti,ab. OR "failure to rescue".ti,ab. OR Iatrogenic Disease/OR "glitch count".ab,ti. OR "non routine event$".ti,ab. OR "near miss".ti,ab.

AND

exp conflict/OR conflict.ti,ab. OR exp Behavior Problems/OR exp negative emotions/or exp emotions/OR "disruptive behavior".ti,ab. OR exp stress/OR exp psychological stress/OR exp Stress Reactions/OR exp Aggressive Behavior/OR exp relational aggression/OR exp Aggressiveness/OR exp Bullying/OR exp dominance hierarchy/OR "stress".ti,ab.

CINAHL search strategy (limited to English language and humans) 1937–Jan 2017

"Surgeons/PF" OR TI surgery OR AB surgery OR TI surgeon# OR AB surgeon#

AND

TI conflict OR AB conflict OR TI problem behavior OR AB problem behavior OR TI emotion# OR AB emotion# OR TI "disruptive behavior" OR AB "disruptive behavior" OR TI stress OR AB stress OR TI aggression OR AB aggression OR TI frustration OR AB frustration OR TI anger OR AB anger OR TI bullying OR AB bullying

AND

[psychomotor performance OR TI performance OR AB performance OR TI non technical performance OR AB non technical performance OR situational awareness OR non technical skills OR information seeking behavior OR TI "information seeking behavior" OR AB "information seeking behavior" OR TI non verbal communication OR AB non verbal communication OR TI verbal behavior OR AB verbal behavior OR TI communication OR AB communication OR TI teamwork OR AB teamwork OR TI coordination OR AB coordination OR TI technical performance OR AB technical performance

OR

TI reoperation OR AB reoperation OR TI complication# OR AB complication# OR TI surgical outcome# OR AB surgical outcome# OR TI surgical mortality OR AB surgical mortality OR TI surgical morbidity OR AB surgical morbidity OR TI morbidity OR AB morbidity OR TI mortality OR AB mortality OR TI patient harm OR AB patient harm OR TI patient safety OR AB patient safety OR TI intraoperative complication# OR AB intraoperative complication# OR TI sentinal event# OR AB sentinal event# OR TI never event# OR AB never event# OR TI failure to rescue OR AB failure to rescue OR TI iatrogenic OR AB iatrogenic OR TI glitch count OR AB glitch count OR TI non routine event# OR AB non routine event# OR TI near miss OR AB near miss]

NOT

"stress urinary incontinence".ti,ab OR "stress incontinence" OR "stress fracture$".ti,ab.OR "oxidative stress" or "stress echo$" OR "stress test$" or "post traumatic stress"

Embase search strategy (1996–Jan 2017, exclude Medline journals, limit to English and Human).

exp Surgery OR surgeon$.ti,ab. OR surgical.ti,ab.

AND

[exp Motor Performance/OR exp Perceptual Motor Processes/OR exp Performance/OR psychomotor performance.mp. OR "non technical performance".ti,ab. OR "non technical skills".ti,ab. OF "situational awareness".ti,ab. OR exp Information Seeking/OR exp Nonverbal Communication/OR exp verbal communication/OR exp nonverbal communication/OR exp communication/OR exp oral communication/OR exp communication skills/OR interdisciplinary communication.mp. OR "teamwork".ti,ab. OR "coordination".ti,ab. OR "technical performance".ti,ab.

OR

"reoperation".ab,ti.OR "surgical complication".ti,ab. OR "surgical complications".ti,ab. OR "complication$".ab,ti. OR "surgical outcom$".ab,ti. OR "surgical mortality".ab,ti. OR "surgical morbidity".ti,ab. OR mortality.ti,ab. OR morbidity.ti,ab. OR exp Patient Harm/OR exp Patient Safety/OR exp Intraoperative Complications/OR exp Medical Errors/OR "sentinel event$".ti,ab. OR "never event$".ti,ab. OR "failure to rescue".ti,ab. OR Iatrogenic Disease/OR "glitch count".ab,ti. OR "non routine event$".ti,ab. OR "near miss".ti,ab.]

AND

exp conflict/OR conflict.ti,ab. OR exp Behavior Problems/OR exp negative emotions/OR "disruptive behavior".ti,ab. OR exp STRESS/OR exp psychological stress/OR exp Stress Reactions/OR exp Aggressive Behavior/OR exp relational aggression/OR exp Aggressiveness/OR exp Bullying/OR exp dominance hierarchy/OR "stress".ti,ab.

NOT

Exp Urinary incontinence, Stress/OR "stress urinary incontinence".ti,ab OR "stress incontinence" or "stress fracture$".ti,ab.OR "oxidative stress" or "stress echo$" or "stress test$" or "post traumatic stress"

Business Source Premier search strategy (1998 to Jan 2017).

TI surgery OR AB surgery OR TI surgeon# OR AB surgeon#

AND

TI conflict OR AB conflict OR TI problem behavior OR AB problem behavior OR TI emotion# OR AB emotion# OR TI "disruptive behavior" OR AB "disruptive behavior" OR TI stress OR AB stress OR TI aggression OR AB aggression OR TI frustration OR AB frustration OR TI anger OR AB anger OR TI bullying OR AB bullying

AND

[psychomotor performance OR TI performance OR AB performance OR TI non technical performance OR AB non technical performance OR situational awareness OR non technical skills OR information seeking behavior OR TI "information seeking behavior" OR AB "information seeking behavior" OR TI non verbal communication OR AB non verbal communication OR TI verbal behavior OR AB verbal behavior OR TI communication OR AB communication OR TI teamwork OR AB teamwork OR TI coordination OR AB coordination OR TI technical performance OR AB technical performance

OR

TI reoperation OR AB reoperation OR TI complication# OR AB complication# OR TI surgical outcome# OR AB surgical outcome# OR TI surgical mortality OR AB surgical mortality OR TI surgical morbidity OR AB surgical morbidity OR TI morbidity OR AB morbidity OR TI mortality OR AB mortality OR TI patient harm OR AB patient harm OR TI patient safety OR AB patient safety OR TI intraoperative complication# OR AB intraoperative complication# OR TI sentinal event# OR AB sentinal event# OR TI never event# OR AB never event# OR TI failure to rescue OR AB failure to rescue OR TI iatrogenic OR AB iatrogenic OR TI glitch count OR AB glitch count OR TI non routine event# OR AB non routine event# OR TI near miss OR AB near miss]

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