

# Unpacking the Literature on Stress and Resiliency: A Narrative Review Focused on Learners in the Operating Room



Richard Ng, MD, MSc, FRCSC,\* Saad Chahine, PhD,<sup>†,‡</sup> Brent Lanting, MD, MSc, FRCSC,<sup>‡</sup> and James Howard, MD, MSc, FRCSC<sup>‡</sup>

\*London Health Sciences Centre, Western University, Ontario, Canada; <sup>†</sup>Centre for Education Research and Innovation, Schulich School of Medicine & Dentistry, Western University, London, Ontario, Canada; and <sup>‡</sup>London Health Sciences Centre - University Hospital, Western University, London, Ontario, Canada

**PURPOSE:** The operating room is a high pressure environment for surgical trainees as they attempt to reach a high level of performance in the midst of a multitude of stressors. The purpose of this work was to examine the relationships between stress, coping, and psychological resilience and their effects on performance and learning in surgical training.

**METHODS:** A narrative review was carried out of the existing literature on stress, coping, and resilience in surgeons and surgical trainees. Multiple fields of study were examined including medical education, surgery, surgical safety, anesthesia, workplace ergonomics, and psychology.

**RESULTS:** Sources of intraoperative stress include fatigue, disruptions, interpersonal conflicts, time pressure, a complex case or high risk patient, surgical errors, and surgeon temperament. These stressors can negatively impact the performance of surgeons and trainees and may inhibit learning.

How a learner responds to stress in the operating room is highly variable and influenced by the context of the stress, the coping mechanisms available, and individual psychological resilience. Stress management techniques, such as mental rehearsal, are beneficial for reducing stress. Resilience is protective against stress and burnout, and resilience training is useful for reducing stress and improving mental health in physicians and medical students.

**CONCLUSIONS:** Surgical trainees experience significant stress in the operating room and their experience

of stress is modulated by cognitive and behavioral factors. Further research is required on the development of effective interventions to help trainees manage intraoperative stress, with the potential to improve surgical performance, learning, and patient safety. (J Surg Ed 76:343–353. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

**KEY WORDS:** Stress, Resiliency, Coping, Surgical Education

**COMPETENCIES:** Professionalism, Interpersonal and Communication Skills, Practice-Based Learning and Improvement

## INTRODUCTION

The operating room is a high pressure environment where errors can have significant consequences. Surgeons and surgical trainees experience marked stress during surgery,<sup>1,2</sup> with potentially adverse effects on performance and learning.<sup>3,4</sup> Researchers have previously measured intraoperative stress in surgeons.<sup>5</sup> Resilience is protective against stress and anxiety in athletes, medical students, and trauma surgeons.<sup>6-8</sup> Resilience training interventions have been shown to reduce stress and improve quality of life in physicians.<sup>9</sup>

However, little is known about stress coping strategies and the influence of resilience in surgical trainees. This narrative review explores the literature on the dynamic relationships between individual stress, coping strategies, and resilience in the operating room. A greater understanding of the interactions between stress, performance, learning, and resiliency will provide directions for further study and solutions

*Correspondence:* Inquiries to Saad Chahine, PhD Center for Education Research and Innovation, Western University, Health Sciences Addition Room 110, London, Ontario, Canada, N6A 5C1; tel:+1-519-661-2111 x 89044; e-mail: [saad.chahine@schulich.uwo.ca](mailto:saad.chahine@schulich.uwo.ca)

<sup>†</sup> ORCID: <https://orcid.org/0000-0003-0488-773X>

to remedy the adverse effects of stress on surgical trainees.

## METHODS

This paper presents a framework to understand stress and coping in the operating room in surgical trainees, particularly in relation to individual resilience. Our purpose is to summarize and synthesize the literature across several fields including medical education, surgery, surgical safety, and psychology. This narrative review<sup>10</sup> is nonexhaustive and explores the relationships between stress, performance, learning, coping mechanisms, and resilience, with a focus on learners in the operating room. By drawing on concepts from multiple disciplines, we have synthesized a discussion of stress and resiliency in surgical training. A 3-step process was used to develop and refine the literature and concepts present. Initially, the authors (RN and SC) met and identified research fields upon which the review would focus, including medical education, surgery, surgical safety, anesthesia, workplace ergonomics, and psychology. PubMed and Google Scholar were then used to identify significant literature relating to stress in these fields. Second, RN and SC discussed the recurring concepts in the literature, and a more in-depth search was performed including a review of the references of relevant sources. Emphasis was placed upon articles focused on surgical education. Finally, the articles identified were examined and thematic groupings were developed based on consensus with the research team.

## RESULTS

The majority of literature on stress in surgical education is focused on the causes of stress and its effects on performance and learning. However, there has been a recent emergence of study on how different individuals cope with stress and are affected by stress. This literature examines how different personal characteristics such as resilience, perseverance, and grit affect individual responses to stress, but the bulk of the study in medical training has focused on resilience. To allow for a more functional discussion of this broad body of literature, we identified 3 interlinked themes through a consensus process: (1) Stress, stressors, performance, and learning, (2) Coping with intraoperative stress, and (3) Resilience and individual responses to stress. An examination of these 3 major themes will open a greater understanding of the perspectives of surgical trainees and how to improve intraoperative performance and learning.

## STRESS, STRESSORS, PERFORMANCE, AND LEARNING

### Stress

To begin, we must first define what stress is and understand its effects on performance and learning. Stress has been defined as the body's response to physical or psychological demands.<sup>11</sup> The conditions or events that are associated with these demands (whether real or imagined) are known as stressors.<sup>12</sup> The human body attempts to maintain physiological homeostasis in response to constantly changing internal and external stressors, named as the "general adaptation syndrome" by Selye in 1950.<sup>13</sup> This response is mediated by the autonomic nervous system and the hypothalamic-pituitary-adrenal axis and involves molecular, physiological, cognitive, and behavioral changes.<sup>13</sup> Selye also recognized that individual responses to stress can be variable and distinguished between positive "eustress" versus negative "distress".<sup>14</sup>

The emotional response to stress was further explored by Lazarus, who described the experience of stress as being highly dependent on the cognitive appraisal of a potential stressor.<sup>15</sup> Situations may be assessed as stressful based on a *primary appraisal* of whether there is any potential risk, and then classified as harm and/or loss, threat, or challenge based on a *secondary appraisal* of one's situation and perceived capabilities or resources. An individual's effort to reconcile demands with available resources is the process of coping.<sup>16</sup> The emotional experience of stress is influenced by the cognitive appraisal of a demand and the coping response, leading to why some stressors are seen positively (as a challenge), while others are seen negatively (as a threat or harm).<sup>17</sup> Therefore, stress is a dynamic process which is influenced by personal and situational characteristics including one's emotions, self-esteem, and resilience.<sup>18</sup> Individuals may experience markedly different emotional experiences of stress, even if the stressors in a situation appear externally identical.

### Stressors in the Operating Room

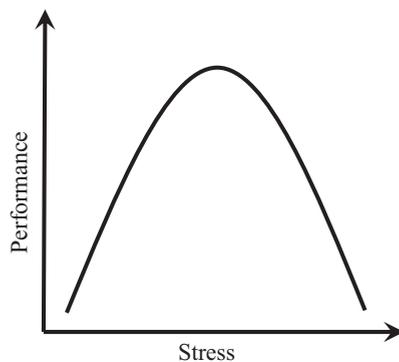
The task of performing surgery is demanding and stressful, requiring sustained attention to detail while performing intricate tasks.<sup>19</sup> Surgical trainees face the challenge of caring for patients while learning technical and non-technical skills in an environment that can be intimidating. The effective management of intraoperative stress is important for developing surgical competence and ensuring patient safety. The causes of stress in the operating room have been previously examined in 2 studies through qualitative interviews of surgeons and surgical trainees. Wetzel et al.<sup>20</sup> carried out qualitative

semistructured interviews of consultant surgeons and surgeons in training in London, United Kingdom and identified themes for the causes of intraoperative stress and stress responses. Anton et al.<sup>21</sup> surveyed surgeons and residents at a single centre about stressors and stress coping strategies in the operating room. Both of these studies highlighted that the intraoperative stressors may be divided into general categories including fatigue, disruptions, teamwork issues, time pressure, a complex surgery, a high risk patient, or surgical complications. As well, surgical residents and fellows self-reported that “issues with attending surgeon” were a significant source of stress in the operating room.<sup>21</sup> Respondents in both studies highlighted that stress in can have a detrimental impact on surgical performance, including adverse effects on technical and nontechnical skills in the operating room.

## Performance

There has been extensive study on the effects of stress on performance in the workplace. Stress at moderate levels can encourage peak performance but high levels of stress lead to impaired performance as demands outweigh the perceived resources to cope. This inverted-U-shape relationship between stress and performance is known as the Yerkes-Dodson Law (Figure)<sup>12,22</sup> and was adapted to the Human Function Curve by Nixon.<sup>23</sup> This intuitive visual highlights that moderate stress maximizes performance, but excess stress is detrimental.

Subjectively, surgeons have noted that small amounts of stress can be beneficial in aiding concentration and focus.<sup>24</sup> Moderate stress levels during an in-training examination have also been associated with improved technical performance in surgical residents.<sup>25</sup> However, surgeons self-report that high levels of stress are detrimental to performance and impair dexterity, judgment, decision making, and communication.<sup>20,21,24</sup> Moreover, surgeons have admitted that mistakes are more likely during high stress, and 40 percent of surgeons reported



**FIGURE.** Yerkes-Dodson Law. Adapted from Yerkes and Dodson, 1908.<sup>21</sup>

witnessing an intraoperative complication directly related to surgeon stress.<sup>21</sup>

Arora et al’s systematic review of the literature on the impact of stress on surgical performance in 2010<sup>19</sup> highlighted many studies correlating impaired performance with the presence of stressors such as fatigue, disruptions, time pressure, and teamwork issues. Tests of sleep-deprived residents and surgeons have shown marked decrease in cognition, memory, and simulated surgical performance.<sup>26-29</sup> Multiple studies have demonstrated that intraoperative disruptions are associated with worse intraoperative performance, increased time for task completion,<sup>30-34</sup> and higher error rates<sup>30,32,35</sup> in simulation settings and observed surgeries.<sup>36</sup> Time pressure has been demonstrated to be the greatest source of subjective stress during a simulated laparoscopic task,<sup>37,38</sup> increasing the rate of both skill-based and knowledge-based errors.<sup>39</sup> In the dynamic and high-risk environment of the operating room, poor communication between team members can compromise patient safety<sup>40</sup> and has been linked to higher rates of surgical error,<sup>41</sup> complication, and mortality.<sup>40,42</sup> Similarly, disruptive behavior amongst surgeons is associated with increased surgical errors<sup>43</sup> and a negative impact on patient safety.<sup>44</sup>

Although specific stressors have deleterious effects, there is limited literature concurrently assessing stress and surgical performance.<sup>19</sup> Surgeons report that stress impairs technical performance, including “feeling shaky, clumsy, and less dexterous.”<sup>20</sup> In laparoscopic surgery, elevated stress and impaired stress coping strategies are linked to less economy of motion and more technical errors.<sup>4,45</sup> Critical attending-trainee interaction impairs simulated laparoscopic performance and increase stress.<sup>46</sup>

Surgeons have reported that stress affects nontechnical performance, with stressful situations impairing communication and decision-making in the operating room.<sup>20,24</sup> Leblanc highlighted the effect of stress on nontechnical performance including the negative impacts on attention, working memory, memory retrieval, decision making, and group performance.<sup>3</sup> Stress depletes an individual’s attentional resources,<sup>47</sup> increasing focus toward threat-related information.<sup>48</sup> Therefore, high-stress situations divert attention toward the source of stress, which impedes performance if the stressor is *peripheral* to the task at hand (distracting).<sup>49</sup> Similarly, Starcke and Brand’s review<sup>50</sup> showed that elevated stress negatively affects decision making by increasing the use of automatic responses and impairing high-level cognition. This results in a greater focus on short-term rewards and a neglect of long-term risks. Therefore, increased stress has significant adverse effects on technical and nontechnical performance in the operating room.

## Learning

Stress impacts learning by decreasing working memory and memory retrieval, which can impair the recall of information or skills.<sup>51,52</sup> In contrast, stress and elevated cortisol levels are associated with *increased* memory formation and consolidation.<sup>53</sup> This is particularly true of emotionally laden information such as highly pleasurable or unpleasant experiences.<sup>54</sup> However, excessively high levels of acute stress or chronically high stress levels have both been shown to be detrimental to learning.<sup>55,56</sup>

The influence of stress on learning is highly contextual. Stress *within the context* of the learning episode increases learning related to coping with the stressor. However, learning is inhibited by high stress before or after the learning experience or stress that is not related to the material being learned.<sup>56-58</sup> Therefore, learning can be enhanced with *contextual* stress, but *distracting* stress will increase memory of the distraction instead of the material to be learned. A resident who is berated for making an error is more likely to remember the emotional and threatening stressor (being berated) than learning from the error.

Learning under appropriate stress increases memory consolidation and promotes the development of stress adaptations, a process known as *stress inoculation*. Individuals who train under moderate stress learn to perform better under stress through the development of coping mechanisms, with decreased physiologic response to stressors and more accurate expectations of performance.<sup>59</sup> Crewther et al. demonstrated that novices learning simulated laparoscopic tasks experienced less stress (both objectively and subjectively) as they became more skilled and experienced. This reduced stress was still evident when subjects were retested 8 weeks later, demonstrating retention of stress adaptations.<sup>60</sup> As well, gradually increasing the intensity of stress as learners progress in phases from an unstressed conditions to low-fidelity training to high-fidelity training has been shown to be beneficial to the development of stress adaptations.<sup>61</sup>

This supports the concept that learners may benefit from experiencing *contextual* stress while training in the operating room, but noncontextual or excessively high stress is distracting and impairs learning. Teaching residents to operate under appropriate conditions can improve their ability to function under similar stresses in the future through the development of stress adaptations and coping techniques.

## COPING WITH INTRAOPERATIVE STRESS

When surgeons and surgical trainees are surveyed on intraoperative stress management techniques, responses

include deliberate relaxation, increased communication, mental rehearsal, pausing or slowing down, and reviewing a mental “game plan.”<sup>21</sup> Unhealthy responses include swearing, yelling, and decreased team communication. Wetzel’s study of surgeons in stressful situations divided stress responses into the stages of reassessment, decision making, preparation, team communication, and solving the problem.<sup>20</sup> The “performance under pressure” aspect of coping with stress during surgery has been compared to athletics, where sports psychology has discussed the importance of training in concentration, arousal control, and mental practice.<sup>62,63</sup>

## Mental Practice for Stress Reduction

Mental practice (also known as mental training or mental rehearsal) is the systematic and detailed imaginary rehearsal of surgical steps without actually performing them. Mental practice has been shown to reduce stress in surgeons. In 2011, Wetzel found that surgeons who received education on stress management and mental practice had less intraoperative stress as measured by heart rate variability.<sup>64</sup> A randomized control study also showed that mental practice improved performance and decreased stress in novice surgeons performing simulated laparoscopic cholecystectomies.<sup>65,66</sup>

## Other Stress Reduction Methods

Beyond mental practice, there has been a broad range of research on attempts to reduce stress in medical trainees. Interventions studied in medical students include self-hypnosis, meditation, mindfulness training, progressive muscle relaxation, and focus or support groups on stress management.<sup>67</sup> A Cochrane review of stress reduction interventions in health care workers identified that cognitive-behavioral training, mental relaxation training, and physical relaxation training all have moderate effects on reducing stress, but noted a need for randomized studies.<sup>68</sup> A recent systematic review of stress management training in medical students identified that mindfulness training and discussion groups have been efficacious, but higher-quality studies are still required.<sup>69</sup> In surgeons and surgical residents, research has examined diaphragmatic breathing, relaxation training, and stress management teaching sessions.<sup>64,70-73</sup> These interventions have shown benefit for subjectively reducing stress, but only some of the studies used validated stress assessment scales. Nevertheless, surgeons have consistently reported a desire for greater stress management training,<sup>21,24</sup> suggesting a need for further study in this area.

## RESILIENCE AND INDIVIDUAL RESPONSES TO STRESS

### What is Resilience?

The variation between individual responses to stress may be explained by studying psychological resilience. Resilience focuses on healthy adaptation to severe stress and is defined as the “dynamic capability which can allow people to thrive on challenges given appropriate social and personal contexts.”<sup>74</sup> Resilient individuals “bounce back, cope successfully, and function above the norm in spite of significant stress or adversity,”<sup>75</sup> meeting challenges with optimism and flexibility.<sup>76</sup> Resilience has been conceptualized as a trait, a process, or an outcome.<sup>18</sup> As a trait, resilience has been studied as the characteristics and factors that provide an individual with the ability to cope with stress.<sup>77</sup> As a process, resiliency research has examined *how* individuals thrive in the face of adversity,<sup>78</sup> and recognizes it as a dynamic process with interacting protective and risk factors. Finally, resilience has been also defined by its outcome—“An individual’s stability or quick recovery (or even growth) under significant adverse conditions.”<sup>79</sup> These different perspectives of resilience share common characteristics: Resilience is characterized by exposure to stress or adversity and a positive recovery or development in spite this exposure. Resiliency is a multidimensional construct modulated by internal factors such as self-efficacy, an internal locus of control, and emotional stability,<sup>18,80-82</sup> as well as external attributes including supportive relationships and family cohesion.<sup>83,84</sup> Resilience has been studied across a variety of populations<sup>85</sup> and has been shown to be modifiable and to vary over time.<sup>77,81,86</sup>

### Resilience in Medicine

Resilience in physicians, surgeons, and trainees has been previously studied. Higher resilience is associated with lower burnout in general practice registrars<sup>87</sup> and decreased stress in Canadian medical students.<sup>7</sup> Internal medicine residents with low resilience are more likely to describe stress interfering with their relationships and have worse stress coping skills.<sup>88</sup> Increased resilience is protective against post-traumatic stress in surgeons managing trauma patients.<sup>8</sup> Of note, a recent study of American general surgery trainees showed that higher resilience is associated with lower stress and burnout.<sup>89</sup>

### Resilience Training

The conceptualization of resilience as a dynamic process has led to interventions to increase resilience. Factors targeted for improvement have included self-efficacy, cognitive flexibility, emotional regulation, social skills,

and physical health habits.<sup>90-92</sup> The interventions studied have varied from mindfulness training to multimodal cognitive behavioral therapy, delivered via online training, one-to-one training, or group sessions over a duration ranging from a single 90-minute session to sessions over 12 weeks. Despite the permutations across content, delivery, and duration of resiliency training interventions, a recent meta-analysis showed that resilience training is beneficial for increasing resilience, decreasing stress, and reducing depression.<sup>91</sup> Moreover, a systematic review of resilience training in the workplace showed that resilience training can improve resilience, self-efficacy, and reduce stress, depression, and anxiety. Of particular note is the Penn Resiliency Program (PRP), which is based on cognitive behavioral therapy and has been extensively studied in a variety of contexts.<sup>93</sup> A meta-analysis of 17 studies showed that the PRP is effective at significantly decreasing depressive symptoms.<sup>94</sup>

Interventions for increasing resilience have been examined in physicians and medical students. Zwack and Schweitzer highlighted useful practices and attitudes for enhancing physician resilience including putting aside time for leisure, cultivating healthy relationships with colleagues and family, and maintaining realistic expectations.<sup>95</sup> Resilience training interventions for physicians including facilitated discussion groups and web-based cognitive behavioral training have been effective.<sup>96</sup> A 90-minute one-on-one program at the Mayo Clinic reduced stress and anxiety and improved resilience and quality of life in physicians and radiologists.<sup>9,97</sup> Medical trainees also benefit from increased resilience, and it has been suggested that resilience should be taught to medical students.<sup>74</sup> A study of residents in family medicine, psychiatry, and anesthesia showed a trend towards decreased depression and anxiety in female and junior residents after mindfulness-based resiliency training.<sup>98</sup> The PRP has been shown to benefit Chinese medical students, increasing resilience, positive emotion, and cognitive appraisal scores over a control group.<sup>99</sup>

## DISCUSSION

Surgical trainees face significant stress that can impact their performance and learning. Resilience provides a lens into understanding the different stress responses that trainees experience in the operating room. As an individual faces a stressor, whether they perceive it negatively (as a threat) or positively (as a challenge) depends on their own cognitive and emotional responses to the stress and their perceived coping resources. Individuals with increased resiliency are more likely to respond positively and persist by having healthy stress adaptations, social supports, and a belief that they can control the

outcome (greater internal locus of control). Increased resilience in surgeons has been associated with lower secondary traumatic stress and improved work performance.<sup>8,100</sup> Compared to other physicians, surgeons and surgical residents have been shown to be a psychologically distinct population, with higher levels of aggression, extraversion and conscientiousness, and lower levels of neuroticism.<sup>101-106</sup> Zeppa et al. found in 1984 that medical students who choose a surgical residency have higher self-esteem and more internal locus of control than their nonsurgical colleagues.<sup>107</sup> This suggests that choosing surgery as a career may self-select for more resilient individuals, as the demands of a surgical residency require strong stress coping skills. However, there has been little research on resilience in surgical trainees and how it impacts their experiences of stress. Given the high rates of attrition in surgical residency programs<sup>108</sup> and that up to 75 percent of residents are experiencing significant burnout,<sup>109</sup> increasing trainee resiliency may be invaluable for improving resident selection, education, and mental health.

As a narrative review, we have sought to highlight major studies and synthesize the literature on stress and resiliency in learners in the operating room. However, this is not a comprehensive or systematic review. Moreover, the topic of group performance under stress has not been addressed in depth in this paper. For a further examination of group performance during surgery, we suggest the previous works by Leblanc<sup>3</sup> and by Rogers and Lingard.<sup>110</sup>

## CONCLUSIONS

In conclusion, surgical trainees experience significant stress while learning to operate. Stressors include fatigue, disruptions, teamwork issues, time pressures, a complex surgery or high risk patient, surgical complications, and conflict with the attending surgeon. Stress can adversely impact on technical and nontechnical performance during surgery. Learning can also be negatively affected by stress, but training residents under appropriate and contextual stress promotes the development of healthy stress adaptations. Studies on stress management techniques, including mental practice, have demonstrated for reduced stress and improved performance.

Overall, the experience of stress is modulated by cognitive and behavioral factors, including the physical and emotional context of the stress, the severity of the stress, and the coping resources available. How individuals perceive and cope with stress is influenced by their psychological resilience, and resilience training has demonstrated significant benefits in physicians and medical students. Further research is needed to explore the

relationship between resilience and the experience of stress in surgical trainees. This would guide the development of effective interventions to help trainees manage intraoperative stress, with the potential of improving surgical performance, learning, and patient safety.

Previous presentations:

1. MSc in Surgery Colloquium Presentation, Western University, London, ON, Canada – June 8, 2017
2. Department of Surgery Research Day, Western University, London, ON, Canada – June 23, 2017
3. MSc in Surgery Thesis Defense, Western University, London, ON, Canada – July 24, 2017

## REFERENCES

1. Jones KI, Amawi F, Bhalla A, Peacock O, Williams JP, Lund JN. Assessing surgeon stress when operating using heart rate variability and the state trait anxiety inventory: will surgery be the death of us. *Colorectal Dis.* 2015;17:335-341. <https://doi.org/10.1111/codi.12844>.
2. Balch CM, Freischlag JA, Shanafelt TD. Stress and burnout among surgeons: understanding and managing the syndrome and avoiding the adverse consequences. *Arch Surg.* 2009;144:371-376.
3. LeBlanc VR. The Effects of Acute Stress on Performance: Implications for Health Professions Education. *Acad Med.* 2009;84:S25-S33. <https://doi.org/10.1097/ACM.0b013e3181b37b8f>. (Supplement).
4. Arora S, Sevdalis N, Aggarwal R, Sirimanna P, Darzi A, Kneebone R. Stress impairs psychomotor performance in novice laparoscopic surgeons. *Surg Endosc.* 2010;24:2588-2593. <https://doi.org/10.1007/s00464-010-1013-2>.
5. Rieger A, Stoll R, Kreuzfeld S, Behrens K, Weippert M. Heart rate and heart rate variability as indirect markers of surgeons' intraoperative stress. *Int Arch Occup Environ Health.* 2014;87:165-174. <https://doi.org/10.1007/s00420-013-0847-z>.
6. Gonzalez SP, Moore EWG, Newton M, Galli NA. Validity and reliability of the Connor-Davidson Resilience Scale (CD-RISC) in competitive sport. *Psychol Sport Exerc.* 2016;23:31-39.
7. Rahimi B, Baetz M, Bowen R, Balbuena L. Resilience, stress, and coping among Canadian medical students. *Can Med Educ J.* 2014;5:e5-e12.
8. Warren AM, Jones AL, Shafi S, Roden-Foreman K, Bennett MM, Foreman ML. Does caring for trauma

- patients lead to psychological stress in surgeons? *J Trauma Acute Care Surg.* 2013;75:179-184. <https://doi.org/10.1097/TA.0b013e3182984a7d>.
9. Sood A, Prasad K, Schroeder D, Varkey P. Stress management and resilience training among Department of Medicine faculty: a pilot randomized clinical trial. *J Gen Intern Med.* 2011;26:858-861.
  10. Grant MJ, Booth A. A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Inf Libr J.* 2009;26(2):91-108.
  11. Selye H. The evolution of the stress concept. *Am Sci.* 1973;61:692-699.
  12. Arora S, Sevdalis N, Athanasiou T, Debas H, Darzi A. Surgical performance under stress: conceptual and methodological issues. *Key Topics in Surgical Research and Methodology.* Berlin, Heidelberg: Springer Berlin Heidelberg; 2010; 141-150.
  13. Selye H. Stress and the general adaptation syndrome. *Br Med J.* 1950;1:1383.
  14. Selye H. Forty years of stress research: principal remaining problems and misconceptions. *Can Med Assoc J.* 1976;115:53.
  15. Lazarus RS, Folkman S. *Stress, Appraisal, and Coping.* Springer Publishing Company; 1984.
  16. Lazarus RS. Coping theory and research: past, present, and future. *Psychosom Med.* 1993;55:234-247.
  17. Lazarus RS. From psychological stress to the emotions: A history of changing outlooks. *Annu Rev Psychol.* 1993;44:1-22.
  18. Fletcher D, Sarkar M. Psychological resilience: a review and critique of definitions, concepts, and theory. *Eur Psychol.* 2013;18:12.
  19. Arora S, Sevdalis N, Nestel D, Woloshynowych M, Darzi A, Kneebone R. The impact of stress on surgical performance: a systematic review of the literature. *Surgery.* 2010;147:318-330e6.
  20. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. *Am J Surg.* 2006;191:5-10.
  21. Anton NE, Montero PN, Howley LD, Brown C, Stefanidis D. What stress coping strategies are surgeons relying upon during surgery. *Am J Surg.* 2015;210:846-851.
  22. Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. *J Comp Neurol Psychol.* 1908;18:459-482.
  23. Nixon PG. The human function curve. With special reference to cardiovascular disorders: part I. *The Practitioner.* 1976;217:765.
  24. Arora S, Sevdalis N, Nestel D, Tierney T, Woloshynowych M, Kneebone R. Managing intraoperative stress: what do surgeons want from a crisis training program. *Am J Surg.* 2009;197:537-543.
  25. LeBlanc V, Woodrow SI, Sidhu R, Dubrowski A. Examination stress leads to improvements on fundamental technical skills for surgery. *Am J Surg.* 2008;196:114-119.
  26. O'Brien MJ, O'Toole RV, Newell MZ, et al. Does sleep deprivation impair orthopaedic surgeons' cognitive and psychomotor performance. *J Bone Jt Surg Am.* 2012;94.
  27. Olasky J, Chellali A, Sankaranarayanan G, et al. Effects of sleep hours and fatigue on performance in laparoscopic surgery simulators. *Surg Endosc.* 2014;28:2564-2568.
  28. Samkoff J, Jacques CH. A review of studies concerning effects of sleep deprivation and fatigue on residents' performance.pdf. *Acad Med.* 1991;66:687-693.
  29. Weinger M, Ancoli-Israel S. Sleep deprivation and clinical performance. *J Am Med Assoc.* 2002;287:955-957.
  30. Siu K-C, Suh IH, Mukherjee M, Oleynikov D, Stergiou N. The impact of environmental noise on robot-assisted laparoscopic surgical performance. *Surgery.* 2010;147:107-113.
  31. Suh IH, Chien J-H, Mukherjee M, Park S-H, Oleynikov D, Siu K-C. The negative effect of distraction on performance of robot-assisted surgical skills in medical students and residents. *Int J Med Robot.* 2010;6:377-381.
  32. Ployter JR, Buzink SN, Rutkowski A-F, Jakimowicz JJ. Do absorption and realistic distraction influence performance of component task surgical procedure. *Surg Endosc.* 2009;24:902-907.
  33. Goodell KH, Cao CGL, Schwaitzberg SD. Effects of cognitive distraction on performance of laparoscopic surgical tasks. *J Laparoendosc Adv Surg Tech.* 2006;16:94-98.
  34. Ghazanfar MA, Cook M, Tang B, Tait I, Alijani A. The effect of divided attention on novices and experts in laparoscopic task performance. *Surg Endosc.* 2015;29:614-619.

35. Feuerbacher RL, Funk KH, Spight DH, Diggs BS, Hunter JG. Realistic distractions and interruptions that impair simulated surgical performance by novice surgeons. *Arch Surg*. 2012;147:1026–1030.
36. Wiegmann DA, ElBardissi AW, Dearani JA, Daly RC, Sundt III TM. Disruptions in surgical flow and their relationship to surgical errors: An exploratory investigation. *Surgery*. 2007;142:658–665. <https://doi.org/10.1016/j.surg.2007.07.034>.
37. Wilson MR, Poolton JM, Malhotra N, Ngo K, Bright E, Masters RSW. Development and validation of a surgical workload measure: the surgery task load index (SURG-TLX). *World J Surg*. 2011;35:1961–1969. <https://doi.org/10.1007/s00268-011-1141-4>.
38. Poolton JM, Wilson MR, Malhotra N, Ngo K, Masters RSW. A comparison of evaluation, time pressure, and multitasking as stressors of psychomotor operative performance. *Surgery*. 2011;149:776–782. <https://doi.org/10.1016/j.surg.2010.12.005>.
39. Moorthy K, Munz Y, Dosis A, Bann S, Darzi A. The effect of stress-inducing conditions on the performance of a laparoscopic task. *Surg Endosc Interv Tech*. 2003;17:1481–1484. <https://doi.org/10.1007/s00464-002-9224-9>.
40. Rosenstein AH, O'Daniel M. Impact and implications of disruptive behavior in the perioperative arena. *J Am Coll Surg*. 2006;203:96–105.
41. Catchpole K, Mishra A, Handa A, McCulloch P. Teamwork and Error in the Operating Room: Analysis of Skills and Roles. *Ann Surg*. 2008;247:699–706. <https://doi.org/10.1097/SLA.0b013e3181642ec8>.
42. Mazzocco K, Petitti DB, Fong KT, et al. Surgical team behaviors and patient outcomes. *Am J Surg*. 2009;197:678–685. <https://doi.org/10.1016/j.amjsurg.2008.03.002>.
43. Cochran A, Elder WB. Effects of disruptive surgeon behavior in the operating room. *Am J Surg*. 2015;209:65–70. <https://doi.org/10.1016/j.amjsurg.2014.09.017>.
44. Patel P, Robinson BS, Novicoff WM, Dunnington GL, Brenner MJ, Saleh KJ. The disruptive orthopaedic surgeon: implications for patient safety and malpractice liability. *J Bone Jt Surg Am*. 2011;93. <https://doi.org/10.2106/JBJS.J.01933>.
45. Hassan I, Weyers P, Maschuw K, et al. Negative stress-coping strategies among novices in surgery correlate with poor virtual laparoscopic performance. *Br J Surg*. 2006;93:1554–1559.
46. Flinn JT, Miller A, Pyatka N, Brewer J, Schneider T, Cao CGL. The effect of stress on learning in surgical skill acquisition. *Med Teach*. 2016;38:897–903. <https://doi.org/10.3109/0142159X.2015.1114597>.
47. Chajut E, Algom D. Selective attention improves under stress: implications for theories of social cognition. *J Pers Soc Psychol*. 2003;85:231.
48. MacLeod C, Rutherford EM. Anxiety and the selective processing of emotional information: mediating roles of awareness, trait and state variables, and personal relevance of stimuli. *Behav Res Ther*. 1992;30:479–491.
49. LeBlanc VR, MacDonald RD, McArthur B, King K, Lepine T. Paramedic performance in calculating drug dosages following stressful scenarios in a human patient simulator. *Prehosp Emerg Care*. 2005;9:439–444.
50. Starcke K, Brand M. Decision making under stress: a selective review. *Neurosci Biobehav Rev*. 2012;36:1228–1248.
51. Raio CM, Brignoni-Perez E, Goldman R, Phelps EA. Acute stress impairs the retrieval of extinction memory in humans. *Neurobiol Learn Mem*. 2014;112:212–221. <https://doi.org/10.1016/j.nlm.2014.01.015>.
52. Kuhlmann S. Impaired memory retrieval after psychosocial stress in healthy young men. *J Neurosci*. 2005;25:2977–2982. <https://doi.org/10.1523/JNEUROSCI.5139-04.2005>.
53. Wolf OT. The influence of stress hormones on emotional memory: relevance for psychopathology. *Acta Psychol (Amst)*. 2008;127:513–531.
54. Buchanan TW, Lovallo WR. Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology*. 2001;26:307–317.
55. Salehi B, Cordero MI, Sandi C. Learning under stress: the inverted-U-shape function revisited. *Learn Mem*. 2010;17:522–530.
56. Joëls M, Pu Z, Wiegert O, Oitzl MS, Krugers HJ. Learning under stress: how does it work. *Trends Cogn Sci*. 2006;10:152–158.
57. Schwabe L, Wolf OT. Learning under stress impairs memory formation. *Neurobiol Learn Mem*. 2010;93:183–188.

58. Schwabe L, Wolf OT, Oitzl MS. Memory formation under stress: quantity and quality. *Neurosci Biobehav Rev.* 2010;34:584–591.
59. Saunders T, Driskell JE, Johnston JH, Salas E. The effect of stress inoculation training on anxiety and performance. *J Occup Health Psychol.* 1996;1:170–186.
60. Crewther BT, Shetty K, Jarchi D, et al. Skill acquisition and stress adaptations following laparoscopic surgery training and detraining in novice surgeons. *Surg Endosc.* 2016;30:2961–2968. <https://doi.org/10.1007/s00464-015-4584-0>.
61. Keinan G, Friedland N, Sarig-Naor V. Training for task performance under stress: the effectiveness of phased training methods. *J Appl Soc Psychol.* 1990;20:1514–1529.
62. Cocks M, Moulton C-A, Luu S, Cil T. What surgeons can learn from athletes: mental practice in sports and surgery. *J Surg Educ.* 2014;71:262–269. <https://doi.org/10.1016/j.jsurg.2013.07.002>.
63. Gibney EJ. Performance skills for surgeons: lessons from sport. *Am J Surg.* 2012;204:543–544. <https://doi.org/10.1016/j.amjsurg.2010.12.004>.
64. Wetzel CM, George A, Hanna GB, et al. Stress Management Training for Surgeons—A Randomized, Controlled, Intervention Study. *Ann Surg.* 2011;253:488–494. <https://doi.org/10.1097/SLA.0b013e318209a594>.
65. Arora S, Aggarwal R, Moran A, et al. Mental practice: effective stress management training for novice surgeons. *J Am Coll Surg.* 2011;212:225–233. <https://doi.org/10.1016/j.jamcollsurg.2010.09.025>.
66. Arora S, Aggarwal R, Sirimanna P, et al. Mental practice enhances surgical technical skills: a randomized controlled study. *Ann Surg.* 2011;253:265–270.
67. Shapiro SL, Shapiro DE, Schwartz GE. Stress management in medical education: a review of the literature. *Acad Med.* 2000;75:748–759.
68. Ruotsalainen JH, Verbeek JH, Mariné A, Serra C. Preventing occupational stress in healthcare workers. *Cochrane Database Syst Rev.* 2015;4. <http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD002892.pub5/pdf>. Accessed January 26, 2017.
69. Shiralkar MT, Harris TB, Eddins-Folensbee FF, Coverdale JH. A systematic review of stress-management programs for medical students. *Acad Psychiatry.* 2013;37:158–164.
70. Christakis I, Pagkratis MT, Varvogli L, Darviri C, Chrousos G. Measuring the stress of the surgeons in training and use of a novel interventional program to combat it. *J Korean Surg Soc.* 2012;82:312. <https://doi.org/10.4174/jkss.2012.82.5.312>.
71. Causer J, Vickers JN, Snelgrove R, Arsenault G, Harvey A. Performing under pressure: quiet eye training improves surgical knot-tying performance. *Surgery.* 2014;156:1089–1096. <https://doi.org/10.1016/j.surg.2014.05.004>.
72. Maher Z, Milner R, Cripe J, Gaughan J, Fish J, Goldberg AJ. Stress training for the surgical resident. *Am J Surg.* 2013;205:169–174. <https://doi.org/10.1016/j.amjsurg.2012.10.007>.
73. Wallace L, Raison N, Ghumman F, Moran A, Dasgupta P, Ahmed K. Cognitive training: how can it be adapted for surgical education. *The Surgeon.* September 2016. <https://doi.org/10.1016/j.surge.2016.08.003>.
74. Howe A, Smajdor A, Stöckl A. Towards an understanding of resilience and its relevance to medical training: Resilience and its relevance to medical training. *Med Educ.* 2012;46:349–356. <https://doi.org/10.1111/j.1365-2923.2011.04188.x>.
75. Tusaie K, Dyer J. Resilience: a historical review of the construct. *Holist Nurs Pract.* 2004;18:3–10.
76. Wagnild GM, Collins JA. Assessing resilience. *J Psychosoc Nurs Ment Health Serv.* 2009;47:28–33.
77. Connor KM, Davidson JRT. Development of a new resilience scale: the Connor-Davidson Resilience Scale (CD-RISC). *Depress Anxiety.* 2003;18:76–82. <https://doi.org/10.1002/da.10113>.
78. Luthar SS, Cicchetti D, Becker B. The construct of resilience: a critical evaluation and guidelines for future work. *Child Dev.* 2000;71:543–562. <https://doi.org/10.1111/1467-8624.00164>.
79. Leipold B, Greve W. Resilience: A conceptual bridge between coping and development. *Eur Psychol.* 2009;14:40–50.
80. McCubbin L. Challenges to the definition of resilience. Paper presented at the meeting of the American Psychological Association, San Francisco, CA. 2001. <http://eric.ed.gov/?id=ED458498>. Accessed January 24, 2017.
81. Windle G. What is resilience? A review and concept analysis. *Rev Clin Gerontol.* 2011;21:152–169.
82. Pooley JA, Cohen L. Resilience: A definition in context. *Aust Community Psychol.* 2010;22:30–37.

83. Friberg O. Validation of [a] Scale to Measure Resilience in Adults. Department of Psychology, Faculty of Social Sciences. University of Tromsø; 2005. [https://www.researchgate.net/profile/Oddgeir\\_Friberg/publication/261096803\\_Validation\\_of\\_a\\_scale\\_to\\_measure\\_resilience\\_in\\_adults/links/0a85e5332d4a29af62000000.pdf](https://www.researchgate.net/profile/Oddgeir_Friberg/publication/261096803_Validation_of_a_scale_to_measure_resilience_in_adults/links/0a85e5332d4a29af62000000.pdf). Accessed October 19, 2016.
84. Kilic SA, Dorstyn DS, Guiver NG. Examining factors that contribute to the process of resilience following spinal cord injury. *Spinal Cord*. 2013;51:553-557.
85. Shastri PC. Resilience: building immunity in psychiatry. *Indian J Psychiatry*. 2013;55:224-234. <https://doi.org/10.4103/0019-5545.117134>.
86. Ong AD, Bergeman CS, Boker SM. Resilience comes of age: defining features in later adulthood. *J Pers*. 2009;77:1777-1804.
87. Cooke GP, Doust JA, Steele MC. A survey of resilience, burnout, and tolerance of uncertainty in Australian general practice registrars. *BMC Med Educ*. 2013;13:2.
88. Bird A-N, Pincavage AT. Initial characterization of internal medicine resident resilience and association with stress and burnout. *J Biomed Educ*. 2016;2016:1-4. <https://doi.org/10.1155/2016/3508638>.
89. Lebares CC, Guvva EV, Ascher NL, O'Sullivan PS, Harris HW, Epel ES. Burnout and stress among US surgery residents: psychological distress and resilience. *J Am Coll Surg*. October 2017. <https://doi.org/10.1016/j.jamcollsurg.2017.10.010>.
90. Robertson IT, Cooper CL, Sarkar M, Curran T. Resilience training in the workplace from 2003 to 2014: A systematic review. *J Occup Organ Psychol*. 2015;88:533-562.
91. Leppin AL, Bora PR, Tilburt JC, et al. The efficacy of resiliency training programs: a systematic review and meta-analysis of randomized trials. *PLoS One*. 2014;9:e111420.
92. Southwick SM, Charney DS. The science of resilience: implications for the prevention and treatment of depression. *Science*. 2012;338:79-82.
93. Seligman ME, Ernst RM, Gillham J, Reivich K, Linkins M. Positive education: Positive psychology and classroom interventions. *Oxf Rev Educ*. 2009;35:293-311.
94. Brunwasser SM, Gillham JE, Kim ES. A meta-analytic review of the Penn Resiliency Program's effect on depressive symptoms. *J Consult Clin Psychol*. 2009;77:1042.
95. Zwack J, Schweitzer J. If every fifth physician is affected by burnout, what about the other four? Resilience strategies of experienced physicians. *Acad Med*. 2013;88:382-389. <https://doi.org/10.1097/ACM.0b013e318281696b>.
96. Beresin EV, Milligan TA, Balon R, Coverdale JH, Louie AK, Roberts LW. Physician Wellbeing: A Critical Deficiency in Resilience Education and Training. *Acad Psychiatry*. 2016;40:9-12. <https://doi.org/10.1007/s40596-015-0475-x>.
97. Sood A, Sharma V, Schroeder DR, Gorman B. Stress Management and Resiliency Training (SMART) program among Department of Radiology faculty: a pilot randomized clinical trial. *EXPLORE J Sci Heal*. 2014;10:358-363.
98. Goldhagen B, Kingsolver K, Stinnett S, Rosdahl J. Stress and burnout in residents: impact of mindfulness-based resilience training. *Adv Med Educ Pract*. August 2015;525. <https://doi.org/10.2147/AMEP.S88580>.
99. Peng L, Li M, Zuo X, et al. Application of the Pennsylvania resilience training program on medical students. *Personal Individ Differ*. 2014;61:47-51.
100. Mache S, Danzer G, Klapp BF, Groneberg DA. Surgeons' work ability and performance in surgical care: relations between organisational predictors, work engagement and work ability. *Langenbecks Arch Surg*. 2013;398:317-325.
101. Warschkow R, Steffen T, Spillmann M, Kolb W, Lange J, Tarantino I. A comparative cross-sectional study of personality traits in internists and surgeons. *Surgery*. 2010;148:901-907.
102. Barlow T, Wight A, Barlow D. A cross-sectional study of aggression levels in physicians and orthopaedic surgeons: impact on specialty selection and training. *JRSM Short Rep*. 2012;3:83.
103. McGreevy J, Wiebe D. A preliminary measurement of the surgical personality. *Am J Surg*. 2002;184:121-125.
104. MacNeily AE, Alden L, Webber E, Afshar K. The surgical personality: comparisons between urologists, non-urologists and non-surgeons. *Can Urol Assoc J*. 2011;5:182-186.

105. McCulloch P, Kaul A, Wagstaff GF, Wheatcroft J. Tolerance of uncertainty, extroversion, neuroticism and attitudes to randomized controlled trials among surgeons and physicians. *Br J Surg*. 2005;92:1293-1297.
106. Hoffman BM, Coons MJ, Kuo PC. Personality differences between surgery residents, nonsurgery residents, and medical students. *Surgery*. 2010;148:187-193.
107. Linn BS, Zeppa R. Does surgery attract students who are more resistant to stress. *Ann Surg*. 1984;200:638.
108. Khoushhal Z, Hussain MA, Greco E, et al. Prevalence and causes of attrition among surgical residents: a systematic review and meta-analysis. *JAMA Surg*. 2017;152:265-272.
109. IsHak WW, Lederer S, Mandili C, et al. Burnout during residency training: a literature review. *J Grad Med Educ*. 2009;1:236-242. <https://doi.org/10.4300/JGME-D-09-00054.1>.
110. Rogers DA, Lingard L. Surgeons managing conflict: a framework for understanding the challenge. *J Am Coll Surg*. 2006;203:568-574. <https://doi.org/10.1016/j.jamcollsurg.2006.06.012>.