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Resiliency in the Operating Room: Exploring Trainee Stress During Surgery and the Role of Individual Resilience

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Abstract

Surgical trainees experience significant intraoperative stress, which can negatively impact performance and learning. Psychological resilience suggests why some individuals excel despite severe stress. This study explores the relationship between trainee resilience and intraoperative stress. A novel instrument was developed to assess Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR). Focus groups and a literature review identified eight domains of intraoperative stress. STRESSOR was used in a survey of orthopaedic residents in Canada and surgical trainees at Western University. Resiliency was assessed using the 10-item Connor-Davidson Resiliency Scale. 171 responses were received for a 38 percent response rate. The STRESSOR instrument had strong reliability and construct validity using confirmatory factor analysis. Increasing resilience correlated with lower intraoperative stress. Trainees with higher stress or lower resilience were more likely to have considered leaving residency. Resiliency training may reduce intraoperative stress, potentially improving surgical performance and learning while reducing resident attrition.

Keywords

Stress, Intraoperative Stress, Resilience, Resident Attrition, Surgical education, Medical education

Co-Authorship Statement

Chapter 1	Richard Ng – Author, Literature Review Saad Chahine – Refinement of Literature Review, Manuscript Preparation James Howard – Manuscript Preparation Brent Lanting – Manuscript Preparation
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Chapter 1

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

1.1 Introduction

The operating room is a high pressure environment where errors can have significant consequences. Surgical trainees experience marked stress during surgery, with potentially adverse effects on performance and learning. While researchers have measured intraoperative stress in surgeons, little is known about stress coping strategies and the influence of psychological resilience in surgical trainees. The purpose of this narrative review is to explore 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 provide practical solutions to remedy the adverse effects of stress on performance and learning in surgical trainees.

This narrative review will highlight major studies and synthesize the literature across a variety of disciplines including psychology, surgery, and medical education. We have identified four interlinked concepts: 1. Stress in the operating room, 2. The effects of stress on performance and learning, 3. Coping mechanisms, and 4. Resiliency. An examination of these four major themes will open a greater understanding of the perspectives of surgical trainees and how to improve intraoperative performance and learning.

1.2 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 review is non-exhaustive 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 three-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. In the second step, RN and SC met to discuss the recurring concepts in the literature, and a more in-depth search was performed including a review of the references of relevant sources. A greater emphasis was placed upon articles focused on surgical education. In the third step, the articles identified were examined and thematic groupings and relationships between themes were refined to develop this narrative review.

1.3 Stress, Stressors, Performance, and Learning

1.3.1 Stress

In order to understand the relationship between individual stress, coping strategies, and resilience in the operating room, we first must 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.[1] These demands, whether real or imagined, are conditions or events which are termed as stressors when they induce a stress response.[2] The human body attempts to maintain physiological homeostasis in response to constantly changing internal and external stressors, a response which was termed the "general adaptation syndrome" by Selye in 1950.[3] This response is mediated by the autonomic nervous system and hypothalamic-pituitary-adrenal axis and involves molecular, physiological, cognitive, and behavioral changes.[3] Selye also recognised that

individual responses to stress can be highly variable and defined the distinction between positive "eustress" versus negative "distress".[4]

The emotional response to stress was further explored by Lazarus, who described the experience of stress as being highly dependent on one's cognitive appraisal of a potential stressor.[5] Situations may be assessed as stressful based on a *primary appraisal* of whether there is any potential risk, and then classified as harm/loss, threat, or challenge based on a *secondary appraisal* of one's situation and perceived capabilities or resources. An individual's effort to reconcile taxing perceived demands with available resources is the process of coping.[6] 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).[7] Therefore, stress is a dynamic process which is influenced by personal and situational characteristics including one's emotions, self-esteem, and resilience.[8] Individuals may experience markedly different emotional experiences of stress, even if the stressors in a situation appear externally identical.

1.3.2 Stressors in the Operating Room

The task of performing surgery is demanding and stressful, requiring sustained attention to detail while performing intricate tasks.[9] 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 two studies through qualitative interviews of surgeons and surgical trainees. Wetzel et al.[10] carried out qualitative semi-structured interviews of consultant surgeons and surgeons in training in London, UK and identified themes for the causes of intraoperative stress and stress responses. Anton et al.[11] 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.[11] Respondents in both studies highlighted that stress in can have a detrimental impact on surgical performance, including adverse effects on technical and non-technical skills in the operating room.

1.3.3 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 1-1**).[2,9,10,12] It was adapted by Nixon in 1976 to be termed the Human Function Curve.[13] This intuitive visual highlights that a moderate amount of stress is beneficial to achieving optimal performance (eustress), but excess stress is detrimental to performance (distress).

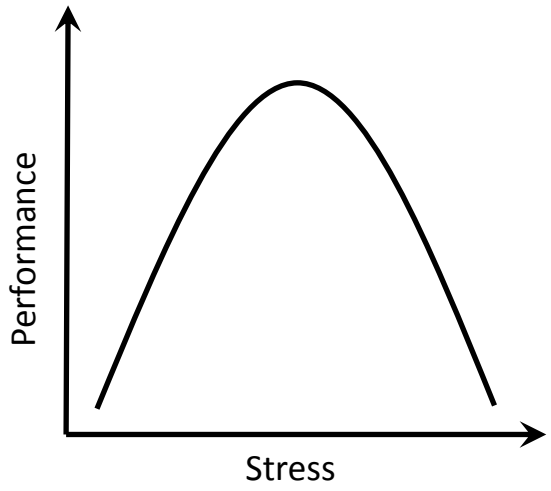

Figure 1-1: Yerkes-Dodson Law. Adapted from Yerkes and Dodson, 1908.[11]

Subjectively, surgeons have noted that small amounts of stress can be beneficial in aiding concentration and focus.[14] Moderate stress levels associated with an in-training examination have also been associated with improved technical performance in surgical

residents.[15] However, surgeons self-report that high levels of stress are detrimental to performance, with impaired dexterity, judgment, decision making, and communication.[10,11,14] Moreover, surgeons have admitted that mistakes are more likely to occur during high stress, and 40 percent of surgeons reported witnessing an intraoperative complication directly related to surgeon stress.[11]

Arora et al's systematic review of the literature on the impact of stress on surgical performance in 2010[9] highlighted many studies correlating impaired performance with the presence of stressors such as fatigue[16–19], disruptions[20–26], time pressure[27], and teamwork issues[28–31]. Tests of sleep-deprived residents and surgeons have shown marked decrease in cognition, memory, and simulated surgical performance[16–19]. Multiple studies have demonstrated that intraoperative disruptions are associated with worse intraoperative performance, including increased time for task completion[20–24] and higher error rates[20,22,25] in simulation settings as well as observed surgeries[26]. Time pressure has been demonstrated to be the greatest source of subjective stress during a simulated laparoscopic task[32,33], increasing the rate of both skill-based and knowledge-based errors.[27] In the dynamic and high-risk environment of the operating room, poor communication between team members can compromise patient safety[30] and has been linked to higher rates of surgical error[28], complication, and mortality.[29,30] Similarly, disruptive behaviour amongst surgeons is associated with increased surgical errors[31] and a negative impact on patient safety.[34]

Although specific stressors have been shown to have deleterious effects, there is limited literature concurrently assessing stress and surgical performance.[9] Surgeons report that stress impairs technical performance, including "feeling shaky, clumsy, less dexterous".[10] In laparoscopic surgery, elevated measures of stress and impaired stress coping strategies have both been linked to less economy of motion and more technical errors.[35,36] Critical attending-trainee interaction has been shown to impair simulated laparoscopic tasks and increase stress as measured by the State-Trait Anxiety Inventory (STAI), salivary cortisol, and mean arterial pressure.[37]

The effects of stress on non-technical performance have been studied by surveying surgeons, with multiple studies reporting that stressful situations can impair communication and decision-making in the operating room.[10,14] Leblanc has highlighted the effect of stress on non-technical performance including the negative impacts on attention, working memory, memory retrieval, decision making, and group performance.[38] Stress depletes an individual's attentional resources[39], resulting in an increased focus towards threat-related information and less attention to other areas.[40] Therefore, in high-stress situations attention is diverted towards addressing the source of stress, which impedes performance if the stressor is *peripheral* to the task at hand (distracting).[41] Similarly, Starcke and Brand reviewed the psychology research that has consistently shown that elevated stress negatively affects decision making.[42] This results in an increased use of automatic responses and an impairment of higher-level cognitive performance, with a greater focus on short-term rewards and a neglect of long-term risks. Therefore, elevated stress has significant adverse impacts on technical and non-technical performance in the operating room.

1.3.4 Learning

The impact of stress on learning has been studied both within and outside of medicine. Stress has been shown to impair working memory and memory retrieval, which can impair the recall of information or skills.[43,44] In contrast, stress and elevated cortisol levels are associated with *increased* memory formation and consolidation.[45] This is particularly true of emotionally laden information such as highly pleasurable or unpleasant experiences.[46] However, excessively high levels of acute stress or chronically high stress levels have both been shown to be detrimental to learning.[47,48]

The influence of stress on learning is highly contextual. Learning is increased if the stress is experienced *within the context* of the learning episode and if the learning is related to coping with the stressor. In contrast, learning is inhibited when the stress is not within the context of the memory - when stress is experienced before or after the learning experience or if the stress is not related to the material being learned.[48–50] Therefore,

learning can be enhanced with contextual stress, but *distracting* stress will increase memory of the distraction instead of the material to be learned. This demonstrates that a resident in the operating room who is being berated for making an error is more likely to remember the more emotionally laden and threatening stressor (being berated) than the 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.[51] 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 eight weeks later, demonstrating retention of stress adaptations.[52] 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.[53]

This supports the concept that learners may benefit from experiencing *contextual* stress while training in the operating room, but stress which is non-contextual or excessively high 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.

1.4 Coping with Intraoperative Stress

When surgeons and surgical trainees are surveyed on stress management techniques that they use intraoperatively, responses include refocusing on the task, deliberate relaxation, increased communication, mental rehearsal, pausing or slowing down, and reviewing a mental "game plan".[11] Unhealthy responses have also been highlighted, including

swearing, yelling, and decreased communication with team members. The process of these responses has been broken into the stages of reassessment, decision making, preparation, team communication, and solving the problem in Wetzel's study of surgeon responses to stressful situations.[10] 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.[54,55]

1.4.1 Mental Practice for Stress Reduction

One intervention which has been studied for stress reduction is mental practice, which is the systematic and detailed mental rehearsal of surgical steps without actually performing them. Also known as mental training or mental rehearsal, mental practice has been shown to be beneficial for reducing stress in surgeons. Stress was objectively measured in Wetzel's study in 2011, which included education on stress management techniques as well as planning and mental practice for a simulated surgery. This study found that surgeons who received the stress training and mental practice package had significantly decreased stress as measured by heart rate variability while also demonstrating significantly better teamwork skills and coping mechanisms than the control group.[56] Mental practice was also shown to be effective for stress reduction in Arora's 2011 study on novice surgeons performing simulated laparoscopic cholecystectomies. This randomized control study showed improved technical performance and decreased in subjective stress, heart rate, and salivary cortisol in the intervention group.[57,58]

1.4.2 Other Stress Reduction Methods

Beyond mental practice, there have been a broad range of research on attempts to reduce stress in medical trainees. Interventions that have been studied in medical students include self-hypnosis, meditation, mindfulness training, progressive muscle relaxation, and focus or support groups on stress management.[59] A Cochrane review of interventions to decrease stress in health care workers identified that cognitive-behavioural training, mental relaxation training, and physical relaxation training all have moderate effects on

reducing stress, but noted a need for randomized studies.[60] A recent systematic review of stress management training in medical students identified the efficacy of discussion groups and mindfulness training (training individuals to be more aware of their thoughts and feelings), but higher-quality studies are still required.[61] In surgeons and surgical residents, research has examined diaphragmatic breathing, relaxation training, and stress management teaching sessions.[56,62–65] These interventions have shown benefit for subjectively reducing stress, but only some of the studies used validated questionnaires to measure participants' perceived stress. Nevertheless, surgeons have consistently reported a desire for greater stress management training,[11,14] suggesting a need for further study in this area.

1.5 Resilience and Individual Responses to Stress

1.5.1 Psychological Resilience

Are some individuals more adept at stress coping strategies or are others more affected by stress? The variation between individual responses to stress may be explained by studying psychological resilience. Resilience focuses on healthy adaptation in the face of severe stress and is defined as the "dynamic capability which can allow people to thrive on challenges given appropriate social and personal contexts"[66]. Resilient individuals "bounce back, cope successfully, and function above the norm in spite of significant stress or adversity"[67], meeting challenges with optimism and flexibility.[68] The literature on resilience has conceptualized it as a trait, a process, or as an outcome.[8] As a trait, resiliency has been studied as the characteristics and factors that provide an individual with the ability to cope with stress.[69] As a process, resiliency research has examined *how* individuals thrive in the face of adversity[70], 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."[71] These different perspectives of resilience all 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 multi-dimensional construct that is dynamic and modulated by personal and environmental factors.[8,72–74] These factors include internal attributes such as self-efficacy, an internal locus of control, and emotional stability, as well as external attributes including supportive relationships and family cohesion.[75,76] Resilience has been studied across a variety of populations[77] and has been shown to be modifiable and to vary over time.[69,73,78]

1.5.2 Resilience Training

The conceptualization of resilience as a dynamic process has led to interventions to try to increase resilience. Factors targeted for improvement have included self-efficacy, cognitive flexibility, emotional regulation, social skills, and physical health habits.[79–81] 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.[80] 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.[82] A meta-analysis of 17 studies showed that the PRP is effective at significantly decreasing depressive symptoms.[83] The PRP has since been adapted into the US Army Master Resilience Training Course,[84] which has shown benefit for improving self-reported resilience and psychological help in brigade combat teams and National Guard soldiers.[85]

Interventions for increasing resilience have been examined in physicians and medical students. In family physicians, the themes of positive attitudes, balance in personal and professional arenas, effective practice management, and personal supports have been shown to increase physician resilience.[86] 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.[87]

Resilience training interventions for physicians including facilitated discussion groups and web-based cognitive behavioural training have been shown to be effective.[88] A 90-minute one-on-one program at the Mayo Clinic showed benefit for improving resilience, stress, anxiety, and overall quality of life in physicians and radiologists.[89,90] Medical trainees also benefit from increased resilience, and it has been suggested that resilience should be selected for and taught to medical students[66]. 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.[91] The PRP has been shown to benefit Chinese medical students, increasing resilience, positive emotion, and cognitive appraisal scores over a control group.[92]

1.6 Discussion

Stress is ubiquitous in the operating room, and surgical trainees face significant stressors that can impact their performance and learning. Resilience can provide a lens into understanding the different responses to stress that trainees experience in the operating room. As an individual faces a stressor, whether they consider 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 to stress and persist despite adversity 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.[93,94] 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.[95–100] 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 non-surgical colleagues.[101] 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[102] and that up to 75 percent of residents are experiencing significant burnout,[103] 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[38] and by Rogers and Lingard.[104]

1.7 Conclusion

In conclusion, surgical trainees experience significant stress while learning to operate from a variety of sources including fatigue, disruptions, teamwork issues, time pressures, a complex surgery or high risk patient, surgical complications, and conflict with their attending surgeon. This stress can have a significant adverse impact on technical and non-technical skills during surgery with potential negative effects on patient safety. Learning can also be negatively affected by stress, but training residents under appropriate and contextual stress can promote the development of healthy stress adaptations. Studies on stress management techniques including mental practice have shown benefit for reducing stress and improving 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 significantly influenced by their psychological resilience, and resilience training has demonstrated significant benefits in physicians and medical students. Further research is needed on 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 to improve surgical performance, learning, and patient safety.

1.8 References

1. Selye H. The Evolution of the Stress Concept. *Am Sci*. 1973;61(6):692-699.

2. Arora S, Sevdalis N. Surgical Performance Under Stress: Conceptual and Methodological Issues. In: Athanasiou T, Debas H, Darzi A, eds. Key Topics in Surgical Research and Methodology. Berlin, Heidelberg: Springer Berlin Heidelberg; 2010:141-150.

3. Selye H. Stress and the general adaptation syndrome. *Br Med J*. 1950;1(4667):1383.

4. Selye H. Forty years of stress research: principal remaining problems and misconceptions. Can Med Assoc J. 1976;115(1):53.

5. Lazarus RS, Folkman S. Stress, Appraisal, and Coping. Springer Publishing Company; 1984.

1. Selye H. The Evolution of the Stress Concept: The originator of the concept traces its development from the discovery in 1936 of the alarm reaction to modern therapeutic applications of syntoxic and catatoxic hormones. Am Sci. 1973;61(6):692-699.

2. Arora S, Sevdalis N. Surgical Performance Under Stress: Conceptual and Methodological Issues. In: Athanasiou T, Debas H, Darzi A, eds. Key Topics in Surgical Research and Methodology. Berlin, Heidelberg: Springer Berlin Heidelberg; 2010:141-150.

3. Selye H. Stress and the general adaptation syndrome. Br Med J. 1950;1(4667):1383.

4. Selye H. Forty years of stress research: principal remaining problems and misconceptions. Can Med Assoc J. 1976;115(1):53.

4. Lazarus RS, Folkman S. Stress, Appraisal, and Coping. Springer Publishing Company; 1984.

6. Lazarus RS. Coping theory and research: past, present, and future. Psychosom Med. 1993;55(3):234–247.

7. Lazarus RS. From psychological stress to the emotions: A history of changing outlooks. Annu Rev Psychol. 1993;44(1):1–22.

7. Fletcher D, Sarkar M. Psychological resilience. Eur Psychol. 2013.

8. 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(3):318-330.e6.

9. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. Am J Surg. 2006;191(1):5-10.

11. 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(5):846–851.

12. Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. J Comp Neurol Psychol. 1908;18(5):459–482.

13. Nixon PG. The human function curve. With special reference to cardiovascular disorders: part I. The Practitioner. 1976;217(1301):765.

13. 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(4):537-543.

15. LeBlanc V, Woodrow SI, Sidhu R, Dubrowski A. Examination stress leads to improvements on fundamental technical skills for surgery. Am J Surg. 2008;196(1):114–119.

15. 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(21).

16. Olasky J, Chellali A, Sankaranarayanan G, et al. Effects of sleep hours and fatigue on performance in laparoscopic surgery simulators. Surg Endosc. 2014;28(9):2564-2568.

18. 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.

19. Weinger M, Ancoli-Israel S. Sleep Deprivation and Clinical Performance. J Am Med Assoc. 2002;287(8):955-957.

19. 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(1):107-113.

20. 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(4):377-381.

21. Pluyter JR, Buzink SN, Rutkowski A-F, Jakimowicz JJ. Do absorption and realistic distraction influence performance of component task surgical procedure? Surg Endosc. 2009;24(4):902-907.

22. Goodell KH, Cao CGL, Schwaitzberg SD. Effects of Cognitive Distraction on Performance of Laparoscopic Surgical Tasks. J Laparoendosc Adv Surg Tech. 2006;16(2):94-98.

23. 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(3):614-619.

25. 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(11):1026–1030.

26. 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(5):658-665. doi:10.1016/j.surg.2007.07.034.

27. 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(9):1481-1484. doi:10.1007/s00464-002-9224-9.

28. Catchpole K, Mishra A, Handa A, McCulloch P. Teamwork and Error in the Operating Room: Analysis of Skills and Roles. Ann Surg. 2008;247(4):699-706. doi:10.1097/SLA.0b013e3181642ec8.

29. Mazzocco K, Petitti DB, Fong KT, et al. Surgical team behaviors and patient outcomes. Am J Surg. 2009;197(5):678-685. doi:10.1016/j.amjsurg.2008.03.002.

30. Rosenstein AH, O'Daniel M. Impact and implications of disruptive behavior in the perioperative arena. J Am Coll Surg. 2006;203(1):96–105.

31. Cochran A, Elder WB. Effects of disruptive surgeon behavior in the operating room. Am J Surg. 2015;209(1):65-70. doi:10.1016/j.amjsurg.2014.09.017.

32. 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(9):1961-1969. doi:10.1007/s00268-011-1141-4.

33. 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(6):776-782. doi:10.1016/j.surg.2010.12.005.

34. 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(21). doi:10.2106/JBJS.J.01933.

35. Arora S, Sevdalis N, Aggarwal R, Sirimanna P, Darzi A, Kneebone R. Stress impairs psychomotor performance in novice laparoscopic surgeons. Surg Endosc. 2010;24(10):2588-2593. doi:10.1007/s00464-010-1013-2.

36. 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(12):1554–1559.

37. 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(9):897-903. doi:10.3109/0142159X.2015.1114597.

38. LeBlanc VR. The Effects of Acute Stress on Performance: Implications for Health Professions Education: Acad Med. 2009;84(Supplement):S25-S33. doi:10.1097/ACM.0b013e3181b37b8f.

39. Chajut E, Algom D. Selective attention improves under stress: implications for theories of social cognition. J Pers Soc Psychol. 2003;85(2):231.

40. MacLeod C, Rutherford EM. Anxiety and the selective processing of emotional information: Mediating roles of awareness, trait and state variables, and personal relevance of stimu. Behav Res Ther. 1992;30(5):479–491.

41. 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(4):439–444.

42. Starcke K, Brand M. Decision making under stress: a selective review. Neurosci Biobehav Rev. 2012;36(4):1228–1248.

43. 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. doi:10.1016/j.nlm.2014.01.015.

44. Kuhlmann S. Impaired Memory Retrieval after Psychosocial Stress in Healthy Young Men. J Neurosci. 2005;25(11):2977-2982. doi:10.1523/JNEUROSCI.5139-04.2005.

45. Wolf OT. The influence of stress hormones on emotional memory: relevance for psychopathology. Acta Psychol (Amst). 2008;127(3):513–531.

46. Buchanan TW, Lovallo WR. Enhanced memory for emotional material following stress-level cortisol treatment in humans. Psychoneuroendocrinology. 2001;26(3):307–317.

47. Salehi B, Cordero MI, Sandi C. Learning under stress: the inverted-U-shape function revisited. Learn Mem. 2010;17(10):522–530.

48. Joëls M, Pu Z, Wiegert O, Oitzl MS, Krugers HJ. Learning under stress: how does it work? Trends Cogn Sci. 2006;10(4):152–158.

49. Schwabe L, Wolf OT. Learning under stress impairs memory formation. Neurobiol Learn Mem. 2010;93(2):183–188.

50. Schwabe L, Wolf OT, Oitzl MS. Memory formation under stress: quantity and quality. Neurosci Biobehav Rev. 2010;34(4):584–591.

51. Saunders T, Driskell JE, Johnston JH, Salas E. The Effect of Stress Inoculation Training on Anxiety and Performance. Educational Publishing Foundation; 1996. http://psycnet.apa.org/journals/ocp/1/2/170/. Accessed March 30, 2017.

52. 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(7):2961-2968. doi:10.1007/s00464-015-4584-0.

53. 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(18):1514–1529.

54. 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(2):262-269. doi:10.1016/j.jsurg.2013.07.002.

55. Gibney EJ. Performance skills for surgeons: lessons from sport. Am J Surg. 2012;204(4):543-544. doi:10.1016/j.amjsurg.2010.12.004.

56. Wetzel CM, George A, Hanna GB, et al. Stress Management Training for Surgeons—A Randomized, Controlled, Intervention Study: Ann Surg. 2011;253(3):488-494. doi:10.1097/SLA.0b013e318209a594.

57. Arora S, Aggarwal R, Moran A, et al. Mental Practice: Effective Stress Management Training for Novice Surgeons. J Am Coll Surg. 2011;212(2):225-233. doi:10.1016/j.jamcollsurg.2010.09.025.

58. Arora S, Aggarwal R, Sirimanna P, et al. Mental practice enhances surgical technical skills: a randomized controlled study. Ann Surg. 2011;253(2):265–270.

59. Shapiro SL, Shapiro DE, Schwartz GE. Stress management in medical education: a review of the literature. Acad Med. 2000;75(7):748–759.

60. Ruotsalainen JH, Verbeek JH, Mariné A, Serra C. Preventing occupational stress in healthcare workers. Cochrane Libr. 2015. http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD002892.pub5/pdf. Accessed January 26, 2017.

61. Shiralkar MT, Harris TB, Eddins-Folensbee FF, Coverdale JH. A systematic review of stress-management programs for medical students. Acad Psychiatry. 2013;37(3):158–164.

62. Christakis I, Pagkratis MT, Varvogli L, Darviri C, Chroussos 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(5):312. doi:10.4174/jkss.2012.82.5.312.

63. Causer J, Vickers JN, Snelgrove R, Arsenault G, Harvey A. Performing under pressure: Quiet eye training improves surgical knot-tying performance. Surgery. 2014;156(5):1089-1096. doi:10.1016/j.surg.2014.05.004.

64. Maher Z, Milner R, Cripe J, Gaughan J, Fish J, Goldberg AJ. Stress training for the surgical resident. Am J Surg. 2013;205(2):169-174. doi:10.1016/j.amjsurg.2012.10.007.

65. 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. doi:10.1016/j.surge.2016.08.003.

66. 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(4):349-356. doi:10.1111/j.1365-2923.2011.04188.x.

67. Tusaie K, Dyer J. Resilience: A historical review of the construct. Holist Nurs Pract. 2004;18(1):3–10.

68. Wagnild GM, Collins JA. Assessing resilience. J Psychosoc Nurs Ment Health Serv. 2009;47(12):28–33.

69. Connor KM, Davidson JRT. Development of a new resilience scale: The Connor-Davidson Resilience Scale (CD-RISC). Depress Anxiety. 2003;18(2):76-82. doi:10.1002/da.10113.

70. Luthar SS, Cicchetti D, Becker B. The Construct of Resilience: A Critical Evaluation and Guidelines for Future Work. Child Dev. 2000;71(3):543-562. doi:10.1111/1467-8624.00164.

71. Leipold B, Greve W. Resilience: A conceptual bridge between coping and development. Eur Psychol. 2009;14(1):40–50.

72. McCubbin L. Challenges to the Definition of Resilience. 2001. http://eric.ed.gov/?id=ED458498. Accessed January 24, 2017.

73. Windle G. What is resilience? A review and concept analysis. Rev Clin Gerontol. 2011;21(2):152–169.

74. Pooley JA, Cohen L. Resilience: A definition in context. Aust Community Psychol. 2010;22(1):30–37.

75. Friborg O. Validation of [a] Scale to Measure Resilience in Adults. Department of Psychology, Faculty og social Sciences, University of Tromsø; 2005. https://www.researchgate.net/profile/Oddgeir_Friborg/publication/261096803_Validation_of_a_scale_to_measure_resilience_in_adults/links/0a85e5332d4a29af62000000.pdf. Accessed October 19, 2016.

76. Kilic SA, Dorstyn DS, Guiver NG. Examining factors that contribute to the process of resilience following spinal cord injury. Spinal Cord. 2013;51(7):553–557.

77. Shastri PC. Resilience: Building immunity in psychiatry. Indian J Psychiatry. 2013;55(3):224-234. doi:10.4103/0019-5545.117134.

78. Ong AD, Bergeman CS, Boker SM. Resilience comes of age: Defining features in later adulthood. J Pers. 2009;77(6):1777–1804.

79. 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(3):533–562.

80. 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(10):e111420.

81. Southwick SM, Charney DS. The science of resilience: implications for the prevention and treatment of depression. Science. 2012;338(6103):79–82.

82. Seligman ME, Ernst RM, Gillham J, Reivich K, Linkins M. Positive education: Positive psychology and classroom interventions. Oxf Rev Educ. 2009;35(3):293–311.

83. 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(6):1042.

84. Reivich KJ, Seligman ME, McBride S. Master resilience training in the US Army. Am Psychol. 2011;66(1):25.

85. Lester PB, Harms PD, Herian MN, Krasikova DV, Beal SJ. The Comprehensive Soldier Fitness Program Evaluation. Report 3: Longitudinal Analysis of the Impact of Master Resilience Training on Self-Reported Resilience and Psychological Health Data. DTIC Document; 2011. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA553635. Accessed January 25, 2017.

86. Jensen PM, Trollope-Kumar K, Waters H, Everson J. Building physician resilience. Can Fam Physician. 2008;54(5):722–729.

87. 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(3):382-389. doi:10.1097/ACM.0b013e318281696b.

88. 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(1):9-12. doi:10.1007/s40596-015-0475-x.

89. 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(8):858–861.

90. 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(6):358–363.

91. 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. doi:10.2147/AMEP.S88580.

92. 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.

93. 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(1):179-184. doi:10.1097/TA.0b013e3182984a7d.

94. 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(2):317–325.

95. 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(5):901–907.

96. 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(12):83.

97. McGreevy J, Wiebe D. A preliminary measurement of the surgical personality. Am J Surg. 2002;184(2):121–125.

98. 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(3):182–186.

99. 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(10):1293–1297.

100. Hoffman BM, Coons MJ, Kuo PC. Personality differences between surgery residents, nonsurgery residents, and medical students. Surgery. 2010;148(2):187–193.

101. Linn BS, Zeppa R. Does surgery attract students who are more resistant to stress? Ann Surg. 1984;200(5):638.

102. 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(3):265–272.

103. IsHak WW, Lederer S, Mandili C, et al. Burnout During Residency Training: A Literature Review. J Grad Med Educ. 2009;1(2):236-242. doi:10.4300/JGME-D-09-00054.1.

104. Rogers DA, Lingard L. Surgeons Managing Conflict: A Framework for Understanding the Challenge. J Am Coll Surg. 2006;203(4):568-574. doi:10.1016/j.jamcollsurg.2006.06.012.

Chapter 2

2 Research Design

2.1 Description of Research Questions and Methodology

As demonstrated in the review of literature seen in **Chapter 1**, there is a gap in the literature regarding intraoperative stress and resilience in surgical trainees. The operating room is an environment where stress is ubiquitous,[1] and excess stress can have adverse effects on performance in surgeons.[2] High levels of stress can impair decision making,[3,4] communication,[5,6] and technical performance.[7,8] In trainees, acute stress can negatively impact learning by impairing memory retrieval and by distracting from the material to be learned.[9] However, in the face of the high stress that learners face in the operating room, some individuals thrive while others wilt. Resilience provides a perspective for understanding how some individuals are able to "bounce back, cope successfully, and function above the norm in spite of significant stress or adversity."[10] From this, we hypothesize that increasing resilience is protective against stress in the operating room. The relationship between intraoperative stress and resilience in surgical trainees has not been previously explored in the published literature.

Attrition during surgical residency is common, with reported rates of attrition reported from 18-26 percent.[11–13] This poses a challenge to surgical training programs and program directors, as resident attrition creates an unexpected labor shortage while impacting the harmony and morale of the residency program.[14] As well, the resident who resigns must cope with the challenge of finding another career path and also sacrifices the time spent on the program they are leaving from. The high stress that trainees face during surgery may contribute to burnout and attrition. Chronic job stress has been linked to burnout,[15,16] which is common in surgical residency.[17,18] Burnout is also linked to lower job satisfaction and greater attrition.[19] Trainees with higher resilience are less likely to report burnout,[20] while surgical residents who have higher grit (a measure of perseverance) are less likely to consider leaving residency.[21] As well, surgical resident

attrition has been improved by changing the resident selection process to favor candidates who have better stress management.[13] We hypothesize that individuals who are more resilient or less stressed are also likely to leave their residency training program.

Therefore our research questions for this project are:

1. What is the variation in experiences of intraoperative stress and stress coping mechanisms in surgical trainees?
2. What is the variation in resilience in surgical trainees?
3. What is the relationship between stress and resilience in this population?
4. How does this relationship vary by gender, age, and year of training?
5. What is the relationship between resiliency, stress, and trainee attrition?

We chose to answer these questions through a survey of surgical trainees in order to capture a wide range of responses across different surgical specialties and training programs across Canada. In the development of this survey, a need was identified for an instrument to assess intraoperative stress. Intraoperative stress in trainees has been previously measured subjectively and objectively through the State Trait Anxiety Index (STAI), heart rate, and salivary cortisol levels.[7,22] These studies examined stress during the conditions of a simulated laparoscopic task, but not during actual surgeries. Other studies have surveyed surgeons and residents by asking subjects to rate the severity of pre-specified stressors[23] or through qualitative interviews.[5] However, no validated instrument for intraoperative stress exists, particularly for surgical trainees. Therefore we set out to develop an instrument to assess Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR) so that it could be used to compare trainee stress against psychological resilience through a survey.

The development of the STRESSOR instrument required an examination of the causes of stress as experienced by trainees. A sequential mixed methods design[24] beginning with focus groups with orthopaedic residents at Western University. These were conducted by an independent interviewer and the discussion was recorded and transcribed. Using thematic analysis,[25] the transcripts were analyzed to identify common themes from line-

by-line coding and iterative review. The themes found in the transcripts were divided into distinct domains of stress. A focused literature review was then carried out to situate and refine the domains of stress identified from the focus groups in the existing literature. Question items to form the STRESSOR instrument were then created to match each domain of stress. These items consisted of statements that subjects scored on a five-point Likert scale. The items were refined iteratively through multiple meetings with the research team over four months. Finally, STRESSOR was pilot tested on four residents in different training programs across Canada and final edits were made for clarity and brevity. Details on the development of the STRESSOR instrument are discussed in **Chapter 3**.

The STRESSOR instrument was then incorporated into a survey which included demographic questions, questions regarding the sources of stress and stress coping mechanisms, an instrument to assess resiliency, the STRESSOR instrument, and a single question about subject attitudes about leaving their training program. The resiliency instrument used for this study was the ten-item Connor Davidson Resiliency Scale (CD-RISC-10) scale. This scale is commonly used for resiliency research and was chosen for its concise length and prior studies demonstrating its responsiveness and validity.[26–28] The survey was then distributed to two cohorts – all orthopaedic residents in Canada in English-language training programs, and all surgical residents and clinical fellows at Western University. Subjects were invited by email to participate after permission was obtained from their program director. The survey was made available for two months through Qualtrics, an online survey system.

The results of the survey were used to first assess the psychometric properties of the newly developed STRESSOR instrument. The reliability of the STRESSOR instrument was analyzed using IBM SPSS Statistics 24 (IBM Corp., 2016) to calculate Cronbach's alpha for the instrument and for each domain of stress. Question items were removed from the STRESSOR instrument to improve reliability, and construct validity was then

assessed with confirmatory factor analysis using EQS 6.1 (Multivariate Software, Inc., 2012). The results of the reliability and validity testing are discussed in **Chapter 3**.

The adjusted STRESSOR instrument and the other survey results were then used to answer the questions introduced at the beginning of this research project. The sources of stress as reported by subjects based on *most frequent* and *most severe* were analyzed, as well as the most common stress coping mechanisms reported. The resilience of subjects was studied based on the CD-RISC-10 scores. The relationship between STRESSOR scores and CD-RISC-10 scores was examined, and univariate and multivariate analysis used to study the influence of age, gender, and age of training. Lastly, trainee perceptions about attrition were examined by a single question item asking if they had seriously considered leaving their residency training program because of intraoperative stress. The relationships between stress, resilience, and trainee perceptions about leaving were investigated. The methods and results of these analyses are discussed in **Chapter 4**. Lastly, the conclusions of this research project and future directions for study on the topics of intraoperative stress, resilience, and trainee attrition are presented **Chapter 5**.

2.2 References

1. Arora S, Hull L, Sevdalis N, et al. Factors compromising safety in surgery: stressful events in the operating room. *Am J Surg*. 2010;199(1):60-65. doi:10.1016/j.amjsurg.2009.07.036.

2. 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(3):318-330.e6. doi:10.1016/j.surg.2009.10.007.

3. Starcke K, Brand M. Decision making under stress: a selective review. *Neurosci Biobehav Rev*. 2012;36(4):1228–1248.

4. Xiao Y, Mackenzie CF, others. Decision making in dynamic environments: Fixation errors and their causes. In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol 39. SAGE Publications; 1995:469–473. http://pro.sagepub.com/content/39/9/469.short. Accessed November 1, 2016.

5. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. *Am J Surg*. 2006;191(1):5-10. doi:10.1016/j.amjsurg.2005.08.034.

6. 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(4):537–543.

7. Arora S, Sevdalis N, Aggarwal R, Sirimanna P, Darzi A, Kneebone R. Stress impairs psychomotor performance in novice laparoscopic surgeons. *Surg Endosc*. 2010;24(10):2588-2593. doi:10.1007/s00464-010-1013-2.

8. 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(12):1554–1559.

9. LeBlanc VR. The Effects of Acute Stress on Performance: Implications for Health Professions Education: *Acad Med*. 2009;84(Supplement):S25-S33. doi:10.1097/ACM.0b013e3181b37b8f.

10. Tusaie K, Dyer J. Resilience: A historical review of the construct. *Holist Nurs Pract*. 2004;18(1):3–10.

11. Gifford E, Galante J, Kaji AH, et al. Factors Associated With General Surgery Residents' Desire to Leave Residency Programs: A Multi-institutional Study. *JAMA Surg*. 2014;149(9):948. doi:10.1001/jamasurg.2014.935.

12. Adams S, Ginther DN, Neuls E, Hayes P. Attitudes and factors contributing to attrition in Canadian surgical specialty residency programs. *Can J Surg J Can Chir*. 2017;60(4):4616.

13. 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(3):265–272.

14. Longo WE. Attrition: our biggest continuing challenge. *Am J Surg*. 2007;194(5):567-575. doi:10.1016/j.amjsurg.2007.08.010.

15. Cordes CL, Dougherty TW. A review and an integration of research on job burnout. *Acad Manage Rev*. 1993;18(4):621–656.

16. McManus IC, Winder BC, Gordon D. The causal links between stress and burnout in a longitudinal study of UK doctors. *The Lancet*. 2002;359(9323):2089–2090.

17. Martini S, Arfken CL, Churchill MA, Balon R. Burnout comparison among residents in different medical specialties. *Acad Psychiatry*. 2004;28(3):240–242.

18. Prins JT, Gazendam-Donofrio SM, Tubben BJ, Van Der Heijden FM, Van De Wiel H, Hoekstra-Weebers JE. Burnout in medical residents: a review. *Med Educ*. 2007;41(8):788–800.

19. Maslach C, Schaufeli WB, Leiter MP. Job burnout. *Annu Rev Psychol*. 2001;52(1):397–422.

20. 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(1):2.

21. Salles A, Lin D, Liebert C, et al. Grit as a predictor of risk of attrition in surgical residency. *Am J Surg*. 2017;213(2):288-291. doi:10.1016/j.amjsurg.2016.10.012.

22. 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(6):776-782. doi:10.1016/j.surg.2010.12.005.

23. 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(5):846–851.

24. Creswell JW. *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*. 2nd ed. Thousand Oaks, Calif: Sage Publications; 2003.

25. Watling CJ, Lingard L. Grounded theory in medical education research: AMEE Guide No. 70. *Med Teach*. 2012;34(10):850-861. doi:10.3109/0142159X.2012.704439.

26. Wang L, Shi Z, Zhang Y, Zhang Z. Psychometric properties of the 10-item Connor–Davidson Resilience Scale in Chinese earthquake victims. *Psychiatry Clin Neurosci*. 2010;64(5):499–504.

27. 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.

28. Madewell AN, Ponce-Garcia E. Assessing resilience in emerging adulthood: The Resilience Scale (RS), Connor–Davidson Resilience Scale (CD-RISC), and Scale of Protective Factors (SPF). *Personal Individ Differ*. 2016;97:249–255.

Chapter 3

3 Development of an Instrument to Assess Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR)

3.1 Introduction

The operating room is a high risk environment where surgical residents and fellows face significant stress with potentially detrimental impacts on surgical performance and learning. There is limited literature on the causes of intraoperative stress in surgical trainees. The purpose of our research is to explore the experiences of intraoperative stress in surgical trainees. Understanding this relationship will guide interventions to decrease stress, potentially improving resident performance and learning. This paper describes the development and validation of an instrument to assess Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR).

3.2 Background

Physical or psychological demands on an individual, whether real or imagined, are defined as stressors,[1] and stress is the body's response to these demands.[2] The physiologic stress response was described by Selye in 1950[3] and is mediated by the autonomic nervous system and hypothalamic-pituitary-adrenal axis through molecular, physiological, cognitive, and behavioural changes. However, the experience of stress is highly subjective, emotional, and dependent on how stressors are perceived. Lazarus described that a stressful situation may be appraised by an individual as harm/loss, threat, or challenge based one's assessment of the situation and the perceived capabilities or resources.[4] The process of reconciling the perceived demand (stressor) with the available resources is known as coping.[5] Thus the experience of stress is a dynamic process involving an individual's physiologic response, emotions, coping strategies, and

resilience.[6] This explains why a potentially stressful situation may be experienced markedly differently by different individuals, as the same stressors may be seen positively (as a challenge) by some, while others may see it negatively (as a threat or harm).[7]

Stress can have deleterious effects on performance and learning in the operating room. Subjectively, surgeons have self-reported that small amounts of stress can be beneficial in aiding concentration and focus,[8] but high levels of stress impair dexterity, judgment, decision making, and communication.[8–10] This is consistent with the Yerkes-Dodson Law,[1,9,11,12] which describes an inverted-U-shape relationship between stress and performance where moderate stress is associated with optimal performance but excess stress hinders performance. A systematic review of the literature on stress and surgical performance in 2010[11] highlighted that stressors such as fatigue,[13–16] disruptions,[17] time pressure,[18,19] and teamwork issues[20–22] are associated with impaired surgical performance. Furthermore, objective measures of stress including elevated salivary cortisol, heart rate, and mean arterial pressure have been linked to impaired performance at simulated laparoscopic tasks in trainees.[23,24] Stress also impairs non-technical performance in the operating room, including communication and decision-making.[8,9] Leblanc reviewed the negative impacts of stress on attention, memory, decision making, and group performance in medicine[25] and highlighted the importance of effective coping strategies and social supports for stress management. Clearly, elevated stress is not benign, and can have significant detrimental effects on technical and non-technical performance during surgery.

Stress can also impact learning in a myriad of ways. Stress impairs the recall of information or skills by impairing working memory and memory retrieval. Excessively high levels of acute or chronic stress can impede learning.[26,27] However, moderate stress and elevated cortisol levels are associated with *increased* memory formation and consolidation, particularly in emotional situations.[28,29] The influence of stress on learning appears to be contextual. Stress which is *within the context* of the learning experience

enhances memory formation, particularly if the information being learned is related to coping effectively with the stressor. In contrast, learning is inhibited by *non-contextual* stress – stress which is not related to the material being learned. Thus distracting stress increases memory of the distraction instead of the material to be learned.[27,30,31] Trainees may therefore benefit from moderate and contextual stress while training in the operating room, but stress which is non-contextual or excessively high will distract and impair learning. Furthermore, training under appropriate stress can promote *stress inoculation*, which is the development of coping mechanisms to manage stress and improve performance under stressful conditions.[32]

Our research questions for this study were:

1. How is stress in the operating room conceptualized by surgical trainees?
2. What literature exists to provide evidence to the conceptualization of stress by surgical trainees?
3. To what extent can a survey capture experiences of stress in the operating room in surgical trainees?
4. Do the results show evidence of reliability and construct validity?

This paper will discuss the development of an instrument to assess Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR), and the validation of this instrument. We plan to use this instrument to subsequently compare trainee stress with psychological resilience.

3.3 Methods

A four step process with a sequential mixed methods design[33] was used for the development of the STRESSOR instrument. We first conducted qualitative exploratory focus groups to gain an understanding of the major stressors faced by surgical trainees in the operating room. We then thematically analyzed the data from the focus groups using line-by-line coding and iterative review.[34] The second step involved a targeted literature

review where we situated the themes identified from the focus groups within the larger medical education literature. Sources of stress that trainees face in the operating room were then distilled into distinct domains of stress. In the third step, specific question items were created to match the domains identified from the focus groups and literature review. These items were reviewed multiple times extensively with the research team to refine the survey. Finally, the fourth step involved pilot testing the STRESSOR instrument with subjects from different specialty training programs across Canada and then electronic distribution of the survey.

3.3.1 Step 1: Exploratory Focus Groups

Multiple focus groups were held with orthopaedic residents at Western University. The focus groups were semi-structured interviews carried out by an independent interviewer (JB) who is not involved in resident teaching or evaluation. A total of 23 residents were interviewed in separate groups by Postgraduate year (PGY). Groups of novice (PGY-1), junior (PGY-2/3) and senior (PGY-4/5) residents were created to allow residents to speak freely about interactions between junior and senior residents. The interviewer attempted to center the discussion on causes of stress in the operating room, but encouraged the residents to speak freely about their thoughts and emotions. The interviews were recorded and transcribed with anonymous identifiers. The transcripts were systematically reviewed and stressors mentioned by residents were identified.

The authors used thematic analysis to systematically review the transcripts and identify stressors mentioned by residents. Line-by-line coding was used to develop descriptions for stressors, which were then categorized into common themes. The transcripts were iteratively reviewed until saturation was reached and all stressors were categorized into themes. The results of this analysis were reviewed with the independent interviewer to ensure content validity.

3.3.2 Step 2: Targeted Literature Review

Next, a review of the literature was carried out to identify literature regarding stress in surgeons and surgical trainees with a focus on stress during surgery or in the operating room. The authors (RN and SC) identified research fields upon which the review would focus, including medical education, surgery, surgical safety, anesthesia, and psychology. Significant research relating to stress in these fields were then identified using PubMed and Google Scholar. The authors then met to discuss 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 and stress within the operating room. The themes identified from the focus groups were then situated within the context of pre-existing literature identified from this review. This allowed us to refine the causes of intraoperative stress in surgical trainees into distinct domains of stress.

3.3.3 Step 3: Item Development

The STRESSOR instrument was developed over four months in consultation with a clinical fellow (RN), two attending surgeons (JH, BL), an expert in survey development and medical education (SC), and the independent interviewer from the focus groups (JB). Survey items were created to match the domains of stress from the focus groups and literature review. Multiple iterations were edited during multiple meetings over four months until consensus was reached.

3.3.4 Step 4: Pilot Testing and Distribution

Once the STRESSOR instrument was finalized, it was incorporated into a survey on resident stress and resiliency for distribution. Institutional research ethics board approval was obtained from Western University. The draft survey was then piloted with four surgical residents in different specialties and training centres across Canada and alterations were made to ensure clarity and brevity. The survey was created electronically in Qualtrics, which allowed for randomization of question sequence and validation of

complete responses. The survey was then distributed to all surgical residents and clinical fellows at Western University and to all orthopaedic surgery residents across Canada with the permission of residency program directors and fellowship directors. Responses were anonymously collected online using Qualtrics. The results were analyzed for item reliability and validity using IBM SPSS Statistics 24 (IBM Corp., 2016) and EQS 6.1 (Multivariate Software, Inc., 2012).

3.4 Results

3.4.1 How is stress in the operating room conceptualized by surgical trainees?

Our focus groups and literature review identified eight domains of stress experienced by trainees in the operating room as shown in **Table 3-1**.

Table 3-1: Domains of Intraoperative Stress

High Risk Patient or Surgery
Surgical Complications
Disruptions
Time Pressure
Fatigue
Making an Error
Teamwork Issues
Attending Temperament

The common categories of intraoperative stress identified through the focus groups were:

- Disruptions
    - The pager was extensively mentioned as one of the greatest causes of stress.
        - "When you're operating and you're trying to focus on the case and the patient on the table and you've got your beeper going off in the background."
- Time Pressure

        - "When you are still learning how to do things obviously you don't have the proficiency and the ability to go that fast. And there can be a lot of pressure sometimes to go faster, go faster."
- Fatigue
        - "I've been in the OR post-call after having not slept and I'm like practically falling asleep while standing. And, that's really stressful."
- Making an error
        - "The fear of making a mistake and even worse, making it. If you make a mistake, it hurts."
- Interpersonal conflict
    - Between other members of the operating room team (eg/ between the attending and a junior learner)
        - "I guess something else that's a little more specific to seniors, would be that situation where you're operating with a junior that's taking a lot of heat. […] And you're stuck in the middle of that interaction. It's like being a third wheel on a bad day."
- The learning environment, including;
    - Anxiety about the attending surgeon's mood
        - "Some people are more temperamental and lose their mind more quickly and others are patient and calm, that's it. And you can tell the difference and you can feel the difference."
    - Fear of being shamed/yelled at by the attending
        - "You can't learn with yelling and abuse but you don't need yelling and abuse. It's not effective for most people."
    - Pressure to meet attending's expectations
        - "You don't want to disappoint your staff because he's taking time to give you an opportunity to do this so you don't want to let him down."

A review of the literature identified two papers which studied causes of trainee stress in the operating room. Wetzel et al. interviewed attending surgeons and residents in London, UK and identified themes for the causes of intraoperative stress.[9] Anton et al. surveyed surgeons and residents in Charlotte, NC, USA about stressors in the operating room.[10] The greatest causes of resident stress in these studies included fatigue, disruptions, teamwork issues, time pressures, and issues with the attending surgeon. Both of these studies also identified a complex surgery/high risk patient and surgical complications as significant stressors.

Although the published literature does not distinguish clearly between surgical complications or adverse events and making an actual error, residents in the focus groups specifically emphasized fear of making an error as a significant source of stress. Since these are conceptually distinct entities, we have chosen to separate surgical complications and making an error as separate domains of intraoperative stress in trainees.

3.4.2 What literature exists to provide evidence to the conceptualization of stress by surgical trainees?

3.4.2.1 High Risk Patient or Surgery

Surgeons self-report that complex cases and high risk patients are some of the highest causes of intraoperative stress.[10] In a study of oral surgery procedures, more difficult surgeries were correlated with a greater increase in biomarkers of stress including heart rate, systolic blood pressure, and salivary cortisol. A study of simulated laparoscopic tasks showed that increasing task difficulty was correlated with increased peak pupil size, indicating an increased physiological stress response to complex surgical steps in surgical trainees.[86] Experience seems to moderate the effects of task difficulty, as experienced surgeons had a reduced increase in physiologic stress when increasingly difficult surgical procedures were encountered.[87,88]

3.4.2.2 Intraoperative Disruptions

The performance of surgery requires close attention and focus, and distractions or interruptions can cause disastrous complications such as bleeding or injury to viscera.[51] Unfortunately, disruptions during surgery are frequent and pervasive,[52–54] including case-irrelevant communication, pagers/phone calls, music, procedural issues, and equipment problems[51]. Disruptions are associated with worse intraoperative performance, including increased time for task completion[55–59] and higher error rates[55,57,60] in simulated and observed surgeries.[17] Therefore it is unsurprising that these disruptions are associated with higher stress and mental workload in surgeons.[61,62] Similarly, frequent paging has been shown to be disruptive to resident work and education.[63–65] Distractions are detrimental to simulated surgical performance in residents, but greater experience at working under distracting conditions can be protective,[56,66,67] suggesting that trainees can learn to focus despite disruptions.

3.4.2.3 Time Pressure

The pressure to complete more work in less time is common in surgery, particularly as institutions and health authorities are increasingly concerned about the expense of running an operating room, which has been estimated to be as high as $62/minute.[76] Time pressure has been identified as a significant source of intraoperative stress among surgeons and surgical trainees.[9,11,72] Time pressure increases the rate of technical and knowledge-based errors during simulated laparoscopic tasks[18,19,77] while negatively impacting team communication[78] and decision making skills.[79] In a study of surgeon decision-making, time pressure increases the use of intuitive or recognition-primed strategies over analytical strategies, allowing for rapid response from previous experience.[80] However, recognition-primed strategies are vulnerable to fixation errors where the decision-maker may continue down a path based on prior experience without stopping to recognize a diagnostic error.[81] As non-experts, surgical trainees retain less cognitive capacity to maintain situational awareness and thus are even more vulnerable to fixation errors. Therefore, the stress of time pressure may catalyze perseveration towards

an inappropriate focus in a crisis,[82] which can lead to worsening of the crisis, increased stress and a continued cycle of iatrogenic error. Teaching residents non-technical skills including mindfulness and decision making training may help them cope with the stress of time pressure in the operating room.[83,84] This includes the teaching the importance of "slowing down when you should" to place increased effortful attention at critical moments during a surgery or when the situation changes abnormally.[85] The stress of time pressure thus significantly impacts technical and non-technical surgical performance, but its effects may be mitigated by training.

3.4.2.4 Fatigue

There has been extensive research on the effects of sleep deprivation during surgical residency, but there have been no studies on the effects of fatigue on intraoperative stress specifically. Nevertheless, insufficient sleep is one of the greatest causes of stress during residency training,[35] and sleep deprivation is a major factor in resident burnout and negatively affects mood.[15,36] Moreover, tests of sleep-deprived residents and surgeons have shown marked impairment in cognition, memory, and simulated surgical performance.[13–16] The implementation of the ACGME 80-hour work week limitation in 2003 has led to increased resident quality of life and reduced fatigue.[37–41] While there have been mixed results on the effects of work hour restrictions on patient outcomes,[38,41–47] surgical faculty and residency program directors have reported negative effects on surgical training.[40,41] Some studies have shown a reduction in the number of cases performed by residents, but other training programs have accommodated the 80 hour work week restrictions without adverse effects.[38,40,43,48–50] Clearly, sleep and fatigue are a source of stress for surgical residents, and attempts to reduce work hours may decrease the surgical exposure of residents. How this impacts the education of surgical residents and their intraoperative experiences remains unclear.

3.4.2.5 Complications, Adverse Events, and Making an Error

Surgical complications are a source of high stress for surgeons and trainees. Moulton et al.[89] highlighted the emotional roller coaster that surgeons experience after an adverse

event. Other studies have examined the effect of surgical complications and have noted extensive emotional and behavioural impacts on surgeons' well-being including shame, guilt, self-doubt, and anxiety.[90–92] Surgeons are at high risk of developing acute traumatic stress after adverse events,[93] with long-effects including unhealthy coping mechanisms such as alcohol, damage to family relationships, burnout, post-traumatic stress symptoms, and depression.[90–92,94–96] Interviews of residents suggest that they also face intense emotional distress after adverse events or medical error, including self-doubt, self-blame, shame, and fear of negative repercussions.[97,98] However, many residents feel that their residency training program does not provide a supportive environment for the discussion of medical mistakes.[99] A recent study in Canada reported that surgical residents struggle with finding professional avenues to discuss their emotional distress after a complication or adverse event.[100] The culture of surgery may also be seen as a barrier to trainees in distress, as the act of seeking help was equated with personal weakness.[100] This emphasizes the importance of promoting an atmosphere free of intimidation with a culture of continuous improvement instead of blame in surgical training. This would support the emotional needs of trainees and potentially reduce rates of burnout and depression while improving patient safety.[101]

3.4.2.6 Teamwork Issues

Conflicts between medical professionals during the course of patient care are common,[68] with one study observing daily disruptive behaviour by the surgeons 15 percent of the time.[21] The causes of conflict in the operating room include time, resources, roles, safety and sterility, and situation control,[69] with the added complexity of team members from different professions and perspectives.[70] Disruptive behaviour such as harsh language corrosively erodes teamwork[71] and increases stress and frustration in the operating room team.[21] Teamwork problems have been identified as one of the greatest sources of stress in surgeons.[72] In the dynamic and high-risk environment of the operating room, teamwork issues are linked to higher rates of surgical error,[22] complication, and mortality,[20,21,73,74] while a positive emotional climate is linked with improved

performance and patient outcomes.[75]. This demonstrates the importance of interpersonal conflict as a source of stress in the operating room and a threat to patient safety.

3.4.2.7 Trainee-Attending Interaction and the Learning Environment

The relationship with between a trainee and the attending surgeon can be one of the greatest sources of stress for surgical residents and fellows. Intimidation and harassment remain common in medical training, particularly in surgical residency, with attending physicians as the most common source of mistreatment.[102–104] Research on adult education has shown that fear, frustration, and conflict are not conducive to learning.[105] Medical students who are criticized during a surgical task have been shown to have greater stress and worse performance than students who are encouraged.[23] Particularly concerning is that mistreatment of trainees has been linked with poor mental health including depression and burnout.[106] Intimidation and disruptive behaviour also undermines patient safety.[107] The unequal power relationship between the surgeon and the trainee can reduce a learner's willingness to speak up about patient safety concerns,[108] but this can be mitigated by a supportive culture and an approachable attending.[109] Intimidation and harassment from attending physicians can cause severe stress in learners, with negative impacts on trainee mental health and patient safety.

Some of the stress from the learning environment also derives from the pervasive culture of trying to meet expectations in surgical training. Since trainees are criticized for displaying uncertainty and praised for decisiveness and confidence, they assume a "cloak of competence"[110] in an attempt to adapt to the culture around them. Therefore the pressure of trying to meet expectations in the midst of uncertainty is a common stress for surgical trainees.[111,112] The creation of a healthy learning environment for trainees is facilitated by attending physicians who set a friendly tone and are a positive role model.[113] Resident evaluations of surgical teaching consistently emphasize the importance of remaining calm and courteous and providing feedback without

belittling.[114] A respectful and encouraging learning environment is a critical component of effectively teaching the next generation of surgeons.

3.4.3 To what extent can a survey capture experiences of stress in the operating room in surgical trainees?

Based on the eight domains of stress identified from our qualitative research, we developed an instrument to assess trainee stress in the operating room. Over four months, individual question items were developed through an iterative process by the authors. The items consist of statements such as "I worried about making errors when pressured to be faster while operating." Subjects were asked to rate on a five point Likert scaled how frequently they experienced the statement during the past six months. Some items were positively worded to ask about successful coping with common stressors and to reduce acquiescence bias. Items were initially developed by the first author (RN), and were subsequently reviewed by SC and the research team. They were also reviewed by the independent interviewer (JB) from the focus groups to ensure face validity with the themes developed from the focus groups. Over 13 iterations were used to remove unnecessary items and refine the wording of statements. A consensus was reached with 31 question items. These statements were then pilot tested with four surgical residents in different specialties and training program locations across Canada, and final edits were made to ensure clarity and brevity.

The Surgical Trainee Experiences of StresS in the Operating Room (STRESSOR) instrument is found in **Appendix A.** The domains of high risk patient/complex surgery and surgical complications were mapped to three items each. The other domains were mapped to four items each, with the exception of attending temperament/learning environment which was mapped to five items by the research team to cover the breadth of experiences that fall into that domain. Subscores were calculated for each of the eight domains of stress as a mean of the items mapped to each domain. The total STRESSOR score was calculated as a sum of the eight subscores.

3.4.4 Do the results show evidence of reliability and construct validity?

All residents in English-speaking orthopaedic training programs in Canada and all surgical residents at Western University were invited to participate, with permission of their program director. A total of 452 subjects were invited to participate. To optimize our response rate, respondents were invited to enter a draw for a gift card and several email reminders were sent. The survey was available for two months and a total of 171 responses were obtained, for a response rate of 38 percent. Of these responses, 138 subjects had complete responses to the STRESSOR items, but 3 responses were eliminated because the subjects had not worked in the operating room within the past six months. A breakdown of the demographics of the final 135 analyzed complete responses is seen in **Table 3-2.**

Table 3-2: Demographics of subjects who completed the STRESSOR instrument.

	Number	Percentage
Gender		
Male	93	68.9
Female	42	31.1
Age		
25-29	59	43.7
30-34	59	43.7
35-39	16	11.9
40+	1	0.7
Level of Training		
PGY-1	21	15.6
PGY-2	28	20.7
PGY-3	28	20.7
PGY-4	22	16.3
PGY-5	22	16.3
PGY-6+	3	2.2
Clinical Fellow	11	8.1
Surgical Specialty		
Orthopaedic Surgery	101	74.8
General Surgery	8	5.9
Plastic Surgery	5	3.7
Urology	5	3.7
Neurosurgery	4	3.0
Otolaryngology	4	3.0
Obstetrics and Gynecology	4	3.0
Cardiac Surgery	2	1.5
Thoracic Surgery	1	0.7
Vascular Surgery	1	0.7

We began our analysis with a reliability assessment by using IBM SPSS Statistics 24 (IBM Corp., 2016) to calculate Cronbach's alpha. Items were appropriately reverse coded to ensure all items had the same dimensionality (higher score matches less stress and better coping). The overall reliability of the whole STRESSOR instrument was high, with a Cronbach's alpha of 0.91. Cronbach's alpha was calculated for the STRESSOR items as mapped to each of the eight domains of intraoperative stress. Corrected item-total correlations were less than 0.2 for two question items - Item 14 ("I was able to recognize when to slow down while operating.") and Item 31 ("I felt comfortable admitting when I didn't know what to do while operating."). These items were removed from further analysis, with the overall reliability of the STRESSOR scale rising to α=0.92. The Cronbach's alpha for the question items as mapped to each of the eight domains of stress, both before and after removal of low reliability items, is seen in **Table 3-3**.

Table 3-3: Reliability analysis of items as mapped to eight domains of stress.

Domain of Stress	Cronbach's Alpha with Original Items	Number of Items	Cronbach's Alpha After Items Removed	Number of Items
High Risk Patient or Surgery	0.70	3	-	-
Surgical Complications	0.59	3	-	-
Intraoperative Disruptions	0.79	4	-	-
Time Pressure	0.74	4	0.85	3
Fatigue	0.67	4	-	-
Making an Error	0.80	4	-	-
Interpersonal Conflict	0.79	4	-	-
Attending Temperament	0.70	5	0.81	4

Second order confirmatory factor analysis was performed to examine the survey's construct validity. The standardized loadings for each item are seen in **Table 3-4**. The STRESSOR items as mapped to each of their eight respective domains of intraoperative stress demonstrated adequate to good fit with an eight factor solution using Maximum Likelihood estimation, with goodness of fit indices of CFI=0.89, RMSEA=0.06 (0.05,0.07), and χ^2=554.96 (df=367), p<0.001.[115,116]

Table 3-4: Standardized loadings for each STRESSOR item as mapped to their domains of stress in an eight factor solution for confirmatory factor analysis. All loadings were significant at $p < .05$. [a] indicates items that were reverse coded for analysis.

Factor	STRESSOR Item	Loading
High Risk Patient or Surgery		**0.601**
	Item 1	0.496
	Item 2	0.675
	Item 3	0.295
Surgical Complications		**0.908**
	Item 4	0.517
	Item 5	0.472
	Item 6[a]	0.043
Intraoperative Disruptions		**0.304**
	Item 7	0.482
	Item 8	0.895
	Item 9	0.687
	Item 10[a]	0.091
Time Pressure		**0.606**
	Item 11	0.616
	Item 12	0.768
	Item 13	0.612
Fatigue		**0.371**
	Item 15	0.599
	Item 16	0.827
	Item 17[a]	0.131
	Item 18[a]	0.078
Making an Error		**0.600**
	Item 19	0.259
	Item 20	0.566
	Item 21	0.669
	Item 22	0.619
Interpersonal Conflict		**0.459**
	Item 23	0.516
	Item 24	0.653
	Item 25	0.572
	Item 26	0.270
Attending Temperament		**0.849**
	Item 27	0.377
	Item 28	0.600
	Item 29	0.607
	Item 30	0.526

This demonstrates that our instrument items addressed eight separate domains of intraoperative stress. Although factor analysis demonstrated the validity of our model of eight distinct domains of intraoperative stress, there was significant correlation between the different domains. **Table 3-5** shows the correlations between the response scores for the eight domains of intraoperative stress.

Table 3-5: Correlations (Spearman's Coefficient) between scores for each of the eight domains of intraoperative stress. * indicates statistically significant correlations ($p<0.0018$, two-tailed, after application of a Bonferonni correction).

	High Risk Patient or Surgery	Surgical Complications	Disruptions	Time Pressure	Fatigue	Making an Error	Teamwork Issues
High Risk Patient or Surgery	-						
Surgical Complications	0.50*	-					
Disruptions	0.28*	0.44*	-				
Time Pressure	0.39*	0.43*	0.39*	-			
Fatigue	0.21	0.41*	0.42*	0.35*	-		
Making an Error	0.53*	0.50*	0.31*	0.52*	0.23	-	
Teamwork Issues	0.49*	0.44*	0.33*	0.37*	0.32*	0.44*	-
Attending Temperament	0.49*	0.57*	0.36*	0.60*	0.45*	0.58*	0.49*

3.5 Discussion

We have identified eight distinct domains of stress that residents experience in the operating room. The focus groups and literature review carried out for this study demonstrate that surgical trainees experience stress from a number of sources while in the operating room. There was good agreement between the themes identified in the focus groups and in the literature review, particularly with previous studies on surgical trainee intraoperative stress by Wetzel et al.[9] and Anton et al.[10]. An exploration of the impacts of these stressors will provide a greater understanding of the resident educational experience. Most previous studies of stress in the operating room have focused on surgeons rather than surgical trainees. The relationship between the learner and the attending surgeon has been minimally explored as a source of intraoperative stress, despite extensive literature highlighting the potential for conflict in this relationship.

We have therefore developed a novel instrument (STRESSOR) to explore the stresses that learners face in the operating room. The use of a mixed methods design including qualitative research to develop this instrument introduces the risk of bias from but also allows for a more complete exploration of resident experiences. The initial results demonstrate strong reliability for both the overall STRESSOR score and for each of the individual eight domains of stress. The removal of two items that were not discriminatory based on corrected item-total correlation further increased the overall reliability for the STRESSOR score and the individual domain subscores. There was significant correlation between the eight domains of stress within STRESSOR. This is not surprising, since a resident who is excellent at managing stress in one domain, such as time pressure, is more likely to experience less stress in other domains. The instrument validity was studied using confirmatory factor analysis, with adequate to strong goodness-of-fit indices for an eight factor solution. We would expect better fit statistics with a larger sample size. This suggests that, despite our modest sample size, the STRESSOR instrument has strong reliability and moderate to good construct validity.

3.6 Conclusion

This study describes the development of a novel instrument (STRESSOR) for assessing trainee stress in the operating room. The instrument was systematically developed by beginning with exploratory focus groups to identify common themes for trainee stress in the operating room. However, since the focus groups were only held with orthopaedic residents from a single training centre, the results of the focus groups may be biased towards experiences that are not generalizable to all surgical trainees. We have mitigated this by reviewing the literature on intraoperative stress in surgical trainees, and good agreement was found between the themes identified from the focus groups and from the literature review. As well, the instrument was pilot tested with residents in different centres and surgical specialties prior to use.

One of the strengths of this study is that it captures responses from a national survey. The results should be applicable to training programs across Canada. Nevertheless, orthopaedic surgery trainees are the majority of responses in this initial validation of the STRESSOR instrument, and further study in other surgical specialties is required. The overall response rate was low at 38 percent. This resulted in smaller than expected sample size. Despite this small sample size, we were able to obtain moderate to good fit indices in our confirmatory factor analysis and strong reliability indices. We suspect that our fit indices will improve in future research utilizing the STRESSOR instrument with a larger sample size.

Because this study assessed trainee stress through a survey, subjects were asked to respond based on their past six months of experience in the operating room. However, subject responses are likely to be biased towards memories that are more recent (recency effect)[117] or memories of more traumatic events. The STRESSOR instrument may be used to assess a trainee's subjective experience of stress in the operating room over the past six months, but it does not measure that individual's present stress or their stress from other sources. Future studies studying how STRESSOR correlates with other commonly used measures of stress or anxiety such as the Perceived Stress Scale,[118] the

State Trait Anxiety Index (STAI),[119] or heart rate variability[120,121] would be valuable for comparison.

In conclusion, we have developed a novel instrument for assessing Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR). This study is novel for the use of sequential mixed methods design with both qualitative and quantitative components. We have identified eight distinct domains of intraoperative stress as experienced by learners. The instrument has been used in a national survey and shown to have high reliability and moderate to good construct validity. This study will allow the comparison of intraoperative stress to other variables including resident resiliency. A greater understanding of intraoperative stress has the potential to lead to improvements in performance and learning in surgical trainees.

3.7 References

1. Arora S, Sevdalis N. Surgical Performance Under Stress: Conceptual and Methodological Issues. In: Athanasiou T, Debas H, Darzi A, eds. *Key Topics in Surgical Research and Methodology*. Berlin, Heidelberg: Springer Berlin Heidelberg; 2010:141-150. http://link.springer.com/10.1007/978-3-540-71915-1_12. Accessed October 19, 2016.

2. Selye H. The Evolution of the Stress Concept: The originator of the concept traces its development from the discovery in 1936 of the alarm reaction to modern therapeutic applications of syntoxic and catatoxic hormones. *Am Sci*. 1973;61(6):692-699.

3. Selye H. Stress and the general adaptation syndrome. *Br Med J*. 1950;1(4667):1383.

4. Lazarus RS, Folkman S. *Stress, Appraisal, and Coping*. Springer Publishing Company; 1984. https://books.google.ca/books?hl=en&lr=&id=i-ySQQuUpr8C&oi=fnd&pg=PR5&ots=DeLMosliUh&sig=Rw7kImtjfQoy8-qussIGBqJ7RkI. Accessed March 28, 2017.

5. Lazarus RS. Coping theory and research: past, present, and future. *Psychosom Med*. 1993;55(3):234–247.

6. Fletcher D, Sarkar M. Psychological resilience. *Eur Psychol*. 2013. http://econtent.hogrefe.com/doi/full/10.1027/1016-9040/a000124. Accessed January 24, 2017.

7. Lazarus RS. From psychological stress to the emotions: A history of changing outlooks. *Annu Rev Psychol*. 1993;44(1):1–22.

8. 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(4):537–543.

9. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. *Am J Surg*. 2006;191(1):5-10.

10. 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(5):846–851.

11. 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(3):318-330.e6. doi:10.1016/j.surg.2009.10.007.

12. Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. *J Comp Neurol Psychol*. 1908;18(5):459–482.

13. 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(21). doi:10.2106/JBJS.K.00958.

14. Olasky J, Chellali A, Sankaranarayanan G, et al. Effects of sleep hours and fatigue on performance in laparoscopic surgery simulators. *Surg Endosc*. 2014;28(9):2564-2568. doi:10.1007/s00464-014-3503-0.

15. 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.

16. Weinger M, Ancoli-Israel S. Sleep Deprivation and Clinical Performance. *J Am Med Assoc*. 2002;287(8):955-957.

17. 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(5):658-665. doi:10.1016/j.surg.2007.07.034.

18. 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(9):1961-1969. doi:10.1007/s00268-011-1141-4.

19. 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(6):776-782. doi:10.1016/j.surg.2010.12.005.

20. Mazzocco K, Petitti DB, Fong KT, et al. Surgical team behaviors and patient outcomes. *Am J Surg*. 2009;197(5):678-685. doi:10.1016/j.amjsurg.2008.03.002.

21. Rosenstein AH, O'Daniel M. Impact and implications of disruptive behavior in the perioperative arena. *J Am Coll Surg*. 2006;203(1):96–105.

22. Catchpole K, Mishra A, Handa A, McCulloch P. Teamwork and Error in the Operating Room: Analysis of Skills and Roles. *Ann Surg*. 2008;247(4):699-706. doi:10.1097/SLA.0b013e3181642ec8.

23. 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(9):897-903. doi:10.3109/0142159X.2015.1114597.

24. Arora S, Sevdalis N, Aggarwal R, Sirimanna P, Darzi A, Kneebone R. Stress impairs psychomotor performance in novice laparoscopic surgeons. *Surg Endosc*. 2010;24(10):2588-2593. doi:10.1007/s00464-010-1013-2.

25. LeBlanc VR. The Effects of Acute Stress on Performance: Implications for Health Professions Education: *Acad Med*. 2009;84(Supplement):S25-S33. doi:10.1097/ACM.0b013e3181b37b8f.

26. Salehi B, Cordero MI, Sandi C. Learning under stress: the inverted-U-shape function revisited. *Learn Mem*. 2010;17(10):522–530.

27. Joëls M, Pu Z, Wiegert O, Oitzl MS, Krugers HJ. Learning under stress: how does it work? *Trends Cogn Sci*. 2006;10(4):152–158.

28. Buchanan TW, Lovallo WR. Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology*. 2001;26(3):307–317.

29. Wolf OT. The influence of stress hormones on emotional memory: relevance for psychopathology. *Acta Psychol (Amst)*. 2008;127(3):513–531.

30. Schwabe L, Wolf OT. Learning under stress impairs memory formation. *Neurobiol Learn Mem*. 2010;93(2):183–188.

31. Schwabe L, Wolf OT, Oitzl MS. Memory formation under stress: quantity and quality. *Neurosci Biobehav Rev*. 2010;34(4):584–591.

32. Saunders T, Driskell JE, Johnston JH, Salas E. *The Effect of Stress Inoculation Training on Anxiety and Performance.* Educational Publishing Foundation; 1996. http://psycnet.apa.org/journals/ocp/1/2/170/. Accessed March 30, 2017.

33. Creswell JW. *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*. 2nd ed. Thousand Oaks, Calif: Sage Publications; 2003.

34. Watling CJ, Lingard L. Grounded theory in medical education research: AMEE Guide No. 70. *Med Teach*. 2012;34(10):850-861. doi:10.3109/0142159X.2012.704439.

35. Aminazadeh N, Farrokhyar F, Naeeni A, et al. Is Canadian surgical residency training stressful? *Can J Surg Ott*. 2012;55(4 Suppl. 2):S145-S151.

36. Papp KK, Stoller EP, Sage P, et al. The effects of sleep loss and fatigue on resident–physicians: a multi-institutional, mixed-method study. *Acad Med*. 2004;79(5):394–406.

37. Kiernan M, Civetta J, Bartus C, Walsh S. 24 Hours On-Call and Acute Fatigue No Longer Worsen Resident Mood Under the 80-Hour Work Week Regulations. *Curr Surg*. 2006;63(3):237-241. doi:10.1016/j.cursur.2006.03.002.

38. Pape H-C, Pfeifer R. Restricted duty hours for surgeons and impact on residents quality of life, education, and patient care: a literature review. *Patient Saf Surg*. 2009;3(1):3. doi:10.1186/1754-9493-3-3.

39. Irani JL, Mello MM, Ashley SW, Whang EE, Zinner MJ, Breen E. Surgical residents' perceptions of the effects of the ACGME duty hour requirements 1 year after implementation. *Surgery*. 2005;138(2):246-253. doi:10.1016/j.surg.2005.06.010.

40. Hutter MM, Kellogg KC, Ferguson CM, Abbott WM, Warshaw AL. The Impact of the 80-Hour Resident Workweek on Surgical Residents and Attending Surgeons: *Ann Surg*. 2006;243(6):864-875. doi:10.1097/01.sla.0000220042.48310.66.

41. Harris JD, Staheli G, LeClere L, Andersone D, McCormick F. What Effects Have Resident Work-hour Changes Had on Education, Quality of Life, and Safety? A Systematic Review. *Clin Orthop Relat Res*. 2015;473(5):1600-1608. doi:10.1007/s11999-014-3968-0.

42. Kaafarani HMA, Itani KMF, Petersen LA, Thornby J, Berger DH. Does Resident Hours Reduction Have an Impact on Surgical Outcomes?1. *J Surg Res*. 2005;126(2):167-171. doi:10.1016/j.jss.2004.12.024.

43. Jamal MH, Wong S, Whalen TV. Effects of the reduction of surgical residents' work hours and implications for surgical residency programs: a narrative review. *BMC Med Educ*. 2014;14(Suppl 1):S14.

44. Businger AP, Laffer U, Kaderli R. Resident work hour restrictions do not improve patient safety in surgery: a critical appraisal based on 7 years of experience in Switzerland. *Patient Saf Surg*. 2012;6(1):1.

45. Jamal MH, Doi S a. R, Rousseau M, et al. Systematic review and meta-analysis of the effect of North American working hours restrictions on mortality and morbidity in surgical patients. *Br J Surg*. 2012;99(3):336-344. doi:10.1002/bjs.8657.

46. Baldwin K. <article-title aid="1508615">Early Effects of Resident Work-Hour Restrictions on Patient Safety: A Systematic Review and Plea for Improved

Studies</article-title> *J Bone Jt Surg Am*. 2011;93(2):e5 1. doi:10.2106/JBJS.J.00367.

47. Ellman PI, Kron IL, Alvis JS, et al. Acute Sleep Deprivation in the Thoracic Surgical Resident Does Not Affect Operative Outcomes. *Ann Thorac Surg*. 2005;80(1):60-65. doi:10.1016/j.athoracsur.2005.01.034.

48. Bruce PJ, Helmer SD, Osland JS, Ammar AD. Operative Volume in the New Era: A Comparison of Resident Operative Volume Before and After Implementation of 80-Hour Work Week Restrictions. *J Surg Educ*. 2010;67(6):412-416. doi:10.1016/j.jsurg.2010.05.007.

49. Durkin ET, McDonald R, Munoz A, Mahvi D. The Impact of Work Hour Restrictions on Surgical Resident Education. *J Surg Educ*. 2008;65(1):54-60. doi:10.1016/j.jsurg.2007.08.008.

50. Damadi A, Davis AT, Saxe A, Apelgren K. ACGME Duty-Hour Restrictions Decrease Resident Operative Volume: A 5-Year Comparison at an ACGME-Accredited University General Surgery Residency. *J Surg Educ*. 2007;64(5):256-259. doi:10.1016/j.jsurg.2007.07.008.

51. Mentis HM, Chellali A, Manser K, Cao CGL, Schwaitzberg SD. A systematic review of the effect of distraction on surgeon performance: directions for operating room policy and surgical training. *Surg Endosc*. 2016;30(5):1713-1724. doi:10.1007/s00464-015-4443-z.

52. Sevdalis N, Undre S, McDermott J, Giddie J, Diner L, Smith G. Impact of Intraoperative Distractions on Patient Safety: A Prospective Descriptive Study Using Validated Instruments. *World J Surg*. 2014;38(4):751-758. doi:10.1007/s00268-013-2315-z.

53. Parker SEH, Laviana AA, Wadhera RK, Wiegmann DA, Sundt TM. Development and Evaluation of an Observational Tool for Assessing Surgical Flow Disruptions and Their Impact on Surgical Performance. *World J Surg*. 2010;34(2):353-361. doi:10.1007/s00268-009-0312-z.

54. Healey AN, Sevdalis N, Vincent CA. Measuring intra-operative interference from distraction and interruption observedin the operating theatre. *Ergonomics*. 2006;49(5-6):589-604. doi:10.1080/00140130600568899.

55. 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(1):107-113. doi:10.1016/j.surg.2009.08.010.

56. 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(4):377-381. doi:10.1002/rcs.338.

57. Pluyter JR, Buzink SN, Rutkowski A-F, Jakimowicz JJ. Do absorption and realistic distraction influence performance of component task surgical procedure? *Surg Endosc*. 2009;24(4):902-907. doi:10.1007/s00464-009-0689-7.

58. Goodell KH, Cao CGL, Schwaitzberg SD. Effects of Cognitive Distraction on Performance of Laparoscopic Surgical Tasks. *J Laparoendosc Adv Surg Tech*. 2006;16(2):94-98. doi:10.1089/lap.2006.16.94.

59. 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(3):614-619. doi:10.1007/s00464-014-3708-2.

60. 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(11):1026–1030.

61. Weigl M, Stefan P, Abhari K, et al. Intra-operative disruptions, surgeon's mental workload, and technical performance in a full-scale simulated procedure. *Surg Endosc*. 2016;30(2):559-566. doi:10.1007/s00464-015-4239-1.

62. Wheelock A, Suliman A, Wharton R, et al. The Impact of Operating Room Distractions on Stress, Workload, and Teamwork: *Ann Surg*. 2015;261(6):1079-1084. doi:10.1097/SLA.0000000000001051.

63. Blum NJ, Lieu TA. Interrupted Care: The Effects of Paging on Pediatric Resident Activities. *Am J Dis Child*. 1992;146(7):806–808.

64. Patel SP, Lee JS, Ranney DN, et al. Resident Workload, Pager Communications, and Quality of Care. *World J Surg*. 2010;34(11):2524-2529. doi:10.1007/s00268-010-0740-9.

65. Fargen KM, O'Connor T, Raymond S, Sporrer JM, Friedman WA. An Observational Study of Hospital Paging Practices and Workflow Interruption Among On-Call Junior Neurological Surgery Residents. *J Grad Med Educ*. 2012;4(4):467-471. doi:10.4300/JGME-D-11-00306.1.

66. Hsu KE, Man F-Y, Gizicki RA, Feldman LS, Fried GM. Experienced surgeons can do more than one thing at a time: effect of distraction on performance of a simple laparoscopic and cognitive task by experienced and novice surgeons. *Surg Endosc*. 2007;22(1):196-201. doi:10.1007/s00464-007-9452-0.

67. Szafranski C, Kahol K, Ghaemmaghami V, Smith M, Ferrara JJ. Distractions and surgical proficiency: an educational perspective. *Am J Surg*. 2009;198(6):804-810. doi:10.1016/j.amjsurg.2009.04.027.

68. Katz JD. Conflict and its resolution in the operating room. *J Clin Anesth*. 2007;19(2):152-158. doi:10.1016/j.jclinane.2006.07.007.

69. Rogers DA, Lingard L. Surgeons Managing Conflict: A Framework for Understanding the Challenge. *J Am Coll Surg*. 2006;203(4):568-574. doi:10.1016/j.jamcollsurg.2006.06.012.

70. Collin K, Paloniemi S, Mecklin J-P. Promoting inter-professional teamwork and learning–the case of a surgical operating theatre. *J Educ Work*. 2010;23(1):43–63.

71. Rogers D, Lingard L, Boehler ML, et al. Teaching operating room conflict management to surgeons: clarifying the optimal approach: Teaching operating room conflict management. *Med Educ*. 2011;45(9):939-945. doi:10.1111/j.1365-2923.2011.04040.x.

72. Arora S, Hull L, Sevdalis N, et al. Factors compromising safety in surgery: stressful events in the operating room. *Am J Surg*. 2010;199(1):60-65. doi:10.1016/j.amjsurg.2009.07.036.

73. 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(21). doi:10.2106/JBJS.J.01933.

74. Cochran A, Elder WB. Effects of disruptive surgeon behavior in the operating room. *Am J Surg*. 2015;209(1):65-70. doi:10.1016/j.amjsurg.2014.09.017.

75. Nurok M, Lipsitz S, Satwicz P, Kelly A, Frankel A. A novel method for reproducibly measuring the effects of interventions to improve emotional climate, indices of team skills and communication, and threat to patient outcome in a high-volume thoracic surgery center. *Arch Surg*. 2010;145(5):489–495.

76. Shippert RD. A Study of Time-Dependent Operating Room Fees and How to save $100 000 by Using Time-Saving Products. *Am J Cosmet Surg*. 2005;22(1):25-34. doi:10.1177/074880680502200104.

77. 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(9):1481-1484. doi:10.1007/s00464-002-9224-9.

78. Espin SL, Lingard LA. Time as a Catalyst for Tension in Nurse-Surgeon Communication. *AORN J*. 2001;74(5):672-682. doi:10.1016/S0001-2092(06)61766-3.

79. Svenson O, Maule AJ. *Time Pressure and Stress in Human Judgment and Decision Making*. Springer Science & Business Media; 1993.

80. Flin R, Youngson G, Yule S. How do surgeons make intraoperative decisions? *Qual Saf Health Care*. 2007;16(3):235-239. doi:10.1136/qshc.2006.020743.

81. Xiao Y, Mackenzie CF, others. Decision making in dynamic environments: Fixation errors and their causes. In: *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol 39. SAGE Publications; 1995:469–473. http://pro.sagepub.com/content/39/9/469.short. Accessed November 1, 2016.

82. Moulton CE, Regehr G, Mylopoulos M, MacRae HM. Slowing Down When You Should: A New Model of Expert Judgment: *Acad Med*. 2007;82(Suppl):S109-S116. doi:10.1097/ACM.0b013e3181405a76.

83. Dedy NJ. Nontechnical Skills in Postgraduate Surgical Education. 2015. https://tspace.library.utoronto.ca/handle/1807/70813. Accessed October 19, 2016.

84. Fry H, Kneebone R, eds. *Surgical Education*. Vol 2. Dordrecht: Springer Netherlands; 2011. http://link.springer.com/10.1007/978-94-007-1682-7. Accessed November 24, 2016.

85. Moulton C, Regehr G, Lingard L, Merritt C, MacRae H. "Slowing down when you should": initiators and influences of the transition from the routine to the effortful. *J Gastrointest Surg*. 2010;14(6):1019–1026.

86. Zheng B, Jiang X, Atkins MS. Detection of Changes in Surgical Difficulty Evidence From Pupil Responses. *Surg Innov*. 2015:1553350615573582.

87. Marrelli M, Gentile S, Palmieri F, Paduano F, Tatullo M. Correlation between Surgeon's Experience, Surgery Complexity and the Alteration of Stress Related Physiological Parameters. Bencharit S, ed. *PLoS ONE*. 2014;9(11):e112444. doi:10.1371/journal.pone.0112444.

88. Berguer R, Smith WD, Chung YH. Performing laparoscopic surgery is significantly more stressful for the surgeon than open surgery. *Surg Endosc*. 2001;15(10):1204–1207.

89. Luu S, Patel P, St-Martin L, et al. Waking up the next morning: surgeons' emotional reactions to adverse events. *Med Educ*. 2012;46(12):1179-1188. doi:10.1111/medu.12058.

90. Pinto A, Faiz O, Bicknell C, Vincent C. Surgical complications and their implications for surgeons' well-being: Surgical complications and their implications for surgeons' well-being. *Br J Surg*. 2013;100(13):1748-1755. doi:10.1002/bjs.9308.

91. Abd Elwahab S, Doherty E. What about doctors? The impact of medical errors. *The Surgeon*. 2014;12(6):297-300. doi:10.1016/j.surge.2014.06.004.

92. Sirriyeh R, Lawton R, Gardner P, Armitage G. Coping with medical error: a systematic review of papers to assess the effects of involvement in medical errors on healthcare professionals' psychological well-being. *Qual Saf Health Care*. 2010;19(6):1–8.

93. Flint L. Acute traumatic stress among surgeons after major surgical complications by A. Pinto, O. Faiz, C. Bicknell, and C. Vincent. *Am J Surg*. 2014;208(4):648-649. doi:10.1016/j.amjsurg.2014.06.019.

94. de Boer JC, Lok A, van't Verlaat E, Duivenvoorden HJ, Bakker AB, Smit BJ. Work-related critical incidents in hospital-based health care providers and the risk of post-traumatic stress symptoms, anxiety, and depression: a meta-analysis. *Soc Sci Med*. 2011;73(2):316–326.

95. Leape LL, Berwick DM. Medical error: the second victim. *BMJ*. 2000;320:785–8.

96. Shanafelt TD, Balch CM, Bechamps G, et al. Burnout and medical errors among American surgeons. *Ann Surg*. 2010;251(6):995–1000.

97. Engel KG, Rosenthal M, Sutcliffe KM. Residents' responses to medical error: coping, learning, and change. *Acad Med*. 2006;81(1):86–93.

98. Muller D, Ornstein K. Perceptions of and attitudes towards medical errors among medical trainees. *Med Educ*. 2007;41(7):645-652. doi:10.1111/j.1365-2923.2007.02784.x.

99. Kaldjian LC, Forman-Hoffman VL, Jones EW, Wu BJ, Levi BH, Rosenthal GE. Do faculty and resident physicians discuss their medical errors? *J Med Ethics*. 2008;34(10):717–722.

100. Balogun JA, Bramall AN, Bernstein M. How Surgical Trainees Handle Catastrophic Errors: A Qualitative Study. *J Surg Educ*. 2015;72(6):1179-1184. doi:10.1016/j.jsurg.2015.05.003.

101. West CP, Tan AD, Habermann TM, Sloan JA, Shanafelt TD. Association of resident fatigue and distress with perceived medical errors. *Jama*. 2009;302(12):1294–1300.

102. Fnais N, Soobiah C, Chen MH, et al. Harassment and Discrimination in Medical Training: A Systematic Review and Meta-Analysis. *Acad Med*. 2014;89(5):817-827. doi:10.1097/ACM.0000000000000200.

103. Karim S, Duchcherer M. Intimidation and harassment in residency: a review of the literature and results of the 2012 Canadian Association of Interns and Residents National Survey. *Can Med Educ J*. 2014;5(1):e50.

104. Daugherty SR, Baldwin Jr DC, Rowley BD. Learning, satisfaction, and mistreatment during medical internship: a national survey of working conditions. *JAMA*. 1998;279(15):1194–1199.

105. Knowles MS, Holton EF, Swanson RA. The Adult Learner: The Definitive Classic in Adult Education and Human Resource Development. *ResearchGate*. January 1998. https://www.researchgate.net/publication/44837893_The_Adult_Learner_The_Definitive_Classic_in_Adult_Education_and_Human_Resource_Development. Accessed January 4, 2017.

106. Cook AF, Arora VM, Rasinski KA, Curlin FA, Yoon JD. The Prevalence of Medical Student Mistreatment and Its Association With Burnout: *Acad Med*. 2014;89(5):749-754. doi:10.1097/ACM.0000000000000204.

107. Alert SE. Behaviors that undermine a culture of safety. *Sentin Event Alert*. 2008;(40). http://www.methodisthealthsystem.org/documents/Medical%20Staff/Sentinel%20Event%20Alert%20Issue%2040.pdf. Accessed January 3, 2017.

108. Walton MM. Hierarchies: the Berlin Wall of patient safety. *Qual Saf Health Care*. 2006;15(4):229-230. doi:10.1136/qshc.2006.019240.

109. Sur MD, Schindler N, Singh P, Angelos P, Langerman A. Young surgeons on speaking up: when and how surgical trainees voice concerns about supervisors' clinical decisions. *Am J Surg*. 2016;211(2):437-444. doi:10.1016/j.amjsurg.2015.10.006.

110. Haas J, Shaffir W. *Becoming Doctors: The Adoption of a Cloak of Competence*. Greenwich, Conn.: JAI Press; 1987.

111. Beagan BL. "Even if I Don't Know What I'm Doing I Can Make It Look like I Know What I'm Doing": Becoming a Doctor in the 1990s. *Can Rev Sociol Can Sociol*. 2001;38(3):275–292.

112. Jin CJ, Martimianakis MA, Kitto S, Carol-anne EM. Pressures to "measure up" in surgery: managing your image and managing your patient. *Ann Surg*. 2012;256(6):989–993.

113. Schwind CJ, Boehler ML, Rogers DA, et al. Variables influencing medical student learning in the operating room. *Am J Surg*. 2004;187(2):198-200. doi:10.1016/j.amjsurg.2003.11.024.

114. Iwaszkiewicz M, DaRosa DA, Risucci DA. Efforts to Enhance Operating Room Teaching. *J Surg Educ*. 2008;65(6):436-440. doi:10.1016/j.jsurg.2008.07.006.

115. Byrne BM. *Structural Equation Modeling with EQS: Basic Concepts, Applications, and Programming*. Lawrence Erlbaum Associates; 2006.

116. Kline RB. *Principles and Practice of Structural Equation Modeling*. Guilford Press; 2005.

117. Glenberg AM, Bradley MM, Kraus TA, Renzaglia GJ. Studies of the long-term recency effect: Support for a contextually guided retrieval hypothesis. *J Exp Psychol Learn Mem Cogn*. 1983;9(2):231.

118. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. 1983:385–396.

119. JULIAN LJ. Measures of Anxiety. *Arthritis Care Res*. 2011;63(0 11). doi:10.1002/acr.20561.

120. 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(2):165-174. doi:10.1007/s00420-013-0847-z.

121. Abatzoglou S. Physiological and psychological responses of surgeons and trainees. 2016. http://ir.lib.uwo.ca/etd/4335/. Accessed January 29, 2017.

Chapter 4

4 Exploring Intraoperative Stress and Resilience in Surgical Trainees: Do These Factors Influence Resident Attrition?

4.1 Introduction

The operating room is a stressful environment for surgical trainees as they attempt to perform technically demanding tasks while learning and refining their skills. High stress has been associated with detrimental impacts on technical and non-technical performance in surgeons and trainees, while also potentially hindering learning. However, individual responses to stress are highly variable, and psychological resilience can help explain why some individuals flourish instead of wilting under stress. Resilience allows individuals to thrive despite adversity and is a modifiable trait that has been studied in various populations including physicians. In this study, surgical trainee experiences of stress during surgery will be assessed using a new instrument. The relationships between intraoperative stress, resilience, and resident attrition will be explored. Understanding the interactions between stress and resiliency may suggest directions to improve performance, learning, and mental health in surgical trainees while reducing resident attrition.

4.2 Background

Surgeons and surgical trainees face extensive stress in the operating room as they manage the challenges of learning and performing surgery in a high pressure environment.[1] Previous studies have highlighted the sources of stress that learners experience in the operating room including fatigue, disruptions, teamwork issues, time pressure, a complex surgery, a high risk patient, surgical complications, or tension with the attending

surgeon.[2,3] Therefore stress is common during surgery, and this has impacts on technical and non-technical performance as well as learning.

There has been extensive research on how stress affects performance in the workplace and in the operating room. Moderate stress can encourage optimal performance but high levels of stress impair performance as demands outweigh the available resources. This inverted-U-shape relationship between stress and performance is known as the Yerkes-Dodson Law.[4,5] Surgeons have reported that mild stress increases concentration and focus, but high stress impairs dexterity, judgment, and communication while increasing intraoperative mistakes.[2,3,6] Elevated stress and poor stress coping strategies have been linked with technical errors in laparoscopic surgery.[7,8] Stress also hinders non-technical performance including attention, decision making, communication, and team performance.[2,6,9,10] These negative effects can combine in the high risk environment of the operating room and lead to errors, with 40 percent of surgeons having witnessed an intraoperative complication directly related to surgeon stress.[3]

Stress also has significant effects on learning, as high levels of stress impair working memory and memory retrieval including the recall of information or skills.[11,12] While moderate stress increases memory formation and consolidation, excessively high stress is detrimental to learning.[13,14] This is particularly true of *distracting* stress, as memories formed are more likely to center around the distraction rather than the material to be learned. A resident who is being berated for making a surgical error is more likely to remember the distracting stressor (being berated) than to learn from the error. Therefore moderate and appropriate stress can be beneficial while training in the operating room, but stress which is distracting or excessively high impairs learning.[14–16]

While stress is ubiquitous in the operating room, its effects vary between individuals. Why do some individuals thrive under stress while others struggle? The variation between individual responses to stress may be explained by studying psychological resilience. Resilience is defined as the "dynamic capability which can allow people to thrive on challenges given appropriate social and personal contexts"[17]. Whether

conceptualized as a trait[18], a process[19], or an outcome,[20] resilience explains why some individuals "bounce back, cope successfully, and function above the norm in spite of significant stress or adversity."[21] Resiliency is a multi-dimensional construct that is modulated by personal and environmental factors.[22–24] Resilience has been studied across a variety of populations[25] and has been shown to be modifiable and to vary over time.[18,22,26] Interventions to increase resiliency have been shown to be effective in physicians, with benefits including decreased stress and anxiety and improved quality of life.[27,28] The importance of resilience in physicians is increasingly recognized, and the CANMEDS 2015 framework includes an emphasis on "Resilience for sustainable practice" as a component of physician competency[29].

The extensive stresses that trainees face during surgery may contribute to resident burnout and attrition. Chronic job stress has detrimental psychological and physical effects including burnout.[30,31] Burnout is highly prevalent in surgical residency, and is associated with worse mental health and greater depressive symptoms.[32,33] Burnout has also been linked to worse job satisfaction and greater job withdrawal and attrition.[34] Trainee attrition is common in surgical training, with reported voluntary attrition rates as high as 18-26 percent during the course of surgical residency.[35–37] Factors which have been linked to attrition include female gender[37], work-life balance, and employment prospects.[36] However, the relationships between intraoperative stress, resiliency, and resident attrition have not been previously studied.

4.2.1 Research Questions

Given that surgical trainees face high stress in the operating room with potentially detrimental impacts on performance, learning, and trainee attrition, further research is required on trainee resilience and experiences of stress in the operating room. Our primary hypothesis is that increased trainee resilience is correlated with decreased intraoperative stress. However, in order to test this hypothesis, a greater exploration regarding intraoperative stress and resilience in trainees is required. Our research in this area focuses on answering the following questions:

1. What is the variation in experiences of intraoperative stress and stress coping mechanisms in surgical trainees?
2. What is the variation in resilience in surgical trainees?
3. What is the relationship between stress and resilience in this population?
4. How does this relationship vary by gender, age, and year of training?
5. What is the relationship between resiliency, stress, and trainee attrition?

4.3 Methods

In order to assess stress and resiliency in surgical trainees, we chose to use an electronically distributed survey to allow for anonymous responses and distribution to a large number of subjects. The survey consisted of demographic information, questions about stressors and stress coping mechanisms, an instrument assessing psychological resiliency, and an instrument assessing intraoperative stress.

Over 19 measures of resilience exist for a variety of populations with different levels of evidence supporting their reliability and validity. A methodological review of resilience measurement scales in 2011 highlighted the challenges of selecting a measure of resilience, with the Connor-Davidson Resilience Scale (CD-RISC)[18] among the highest scoring scales by psychometric properties.[38] The CD-RISC was the only scale whose responsiveness was studied, and abbreviated (10-item and 2-item) forms of the CD-RISC are also available and have been validated.[39,40] The 10 item CD-RISC instrument was chosen for this study for its shorter length and the previous literature demonstrating its responsiveness to a single-factor solution.[41–43] Permission was obtained from the authors of the CD-RISC-10 for its use in this study.

In order to assess surgical stress in trainees, we developed a novel instrument (Surgical TRainee Experiences of Stress in the Operating Room – STRESSOR). This instrument was developed using a sequential mixed methods design. We began with a qualitative exploration of the causes of stress in the operating room. Focus groups with 23 orthopaedic surgery residents at Western University were held with an independent

interviewer. We then used thematic analysis[44] to analyze the transcripts of these focus groups. The transcripts were systematically reviewed with line-by-line coding and iterative review until we reached saturation for causes of stress in the operating room. These sources of stress were categorized into eight common domains of stress, and these were reinforced with a review of the literature on sources of stress in trainees and surgeons. The 8 domains of intraoperative stress we identified are shown in **Table 4-1**.

Table 4-1: Domains of Intraoperative Stress

High Risk Patient or Surgery
Surgical Complications
Disruptions
Time Pressure
Fatigue
Making an Error
Teamwork Issues
Attending Temperament

From these 8 domains, we developed a new instrument for measuring intraoperative stress. This took over four months in consultation with three surgeons, an expert in survey development and medical education, and the independent interviewer from the focus groups. The final instrument has 31 items structured as statements. Subjects are asked to rate how *frequently* they experience stress corresponding to statements such as "I felt anxious when my pager went off while I was operating" or "I felt able to judge whether I was too tired to safely operate". Responses are selected on a 5-point Likert scale from "almost never" to "almost always". These items correspond with the eight domains of intraoperative stress and include both negatively worded statements (greater stress) and positively worded statements (better stress coping) to reduce acquiescence bias.

The final survey is seen in **Appendix B**. It includes demographic information, the CD-RISC-10 resiliency instrument, questions regarding the most severe sources of stress and the most helpful stress coping mechanisms, and the STRESSOR instrument. Subject attitudes towards trainee attrition were also surveyed by asking subjects to score whether

they had seriously considered switching residency programs or medicine because of stress they had experienced in the operating room on a 5-point Likert scale from "Strongly Agree" to "Strongly Disagree". A similar scale has been used in prior studies on trainee attrition and has been shown to correlate with actual trainee attrition.[35,45] The survey was pilot tested with four residents in different programs across Canada. After institutional research ethics board approval, the survey was distributed to two cohorts; all orthopaedic residents in English language training programs in Canada and all surgical residents and clinical fellows at Western University. Trainees were invited to participate with the permission of their program director. The survey was distributed electronically using Qualtrics and responses were collected anonymously. After survey closure, the results were analysed using IBM SPSS Statistics 24 (IBM Corp., 2016). Items that showed poor corrected item-total correlation were eliminated. The STRESSOR instrument was validated in this population, as demonstrated in **Chapter 3**.

The distribution of STRESSOR scores, STRESSOR subscores for each of the eight domains of stress, and CD-RISC-10 scores was examined and normality of these measures was assessed using Q-Q plots and the Shapiro-Wilks test. Reliability testing for the CD-RISC-10 in this population was performed using Cohen's alpha. The construct validity of the CD-RISC-10 was assessed using exploratory factor analysis. Univariate analysis using Pearson's correlation was used to study relationships between CD-RISC-10 and age and year of training. Univariate comparison of CD-RISC-10 scores by gender and surgical specialty (orthopaedic vs. non-orthopaedic) was performed using independent samples student's t-test. Similarly, univariate analysis using Pearson's correlation was used to study relationships between STRESSOR and age and year of training. Univariate comparison of STRESSOR scores by gender and surgical specialty (orthopaedic vs. non-orthopaedic) was performed using independent samples student's t-test.

The relationship between STRESSOR and CD-RISC-10 scores was examined using linear regression. Correlation was performed to compare individual STRESSOR

subscores with CD-RISC-10. Multiple linear regression was used to study the relationship of STRESSOR against variables which were statistically significant during univariate analysis. For linear regressions, the normal distribution of residuals was verified with a p-p plot, and homoscedasticity was verified with a scatterplot of Standardized Predicted Values versus Standardized Residuals. STRESSOR and CD-RISC-10 scores were compared against resident attitudes towards attrition using one-way Welch's ANOVA and Spearman's correlation. All correlations and t-tests were performed with two-tailed tests and a Bonferroni correction was applied where appropriate for multiple correlations.

4.4 Results

The survey was made available for two months and 171 responses were collected for a 36 percent response rate. Of these, three subjects declined to participate, and a further three subjects were excluded for not having worked in the operating room environment in the six months prior to taking the survey. Thirty subjects only partially completed the survey, and 134 complete responses were obtained. **Figure 4-1** shows the distribution of complete and incomplete responses obtained. Available responses were analyzed for descriptive statistics. Incomplete responses were excluded pairwise for correlation and regression analyses. The demographics of the subjects are shown in **Table 4-2**.

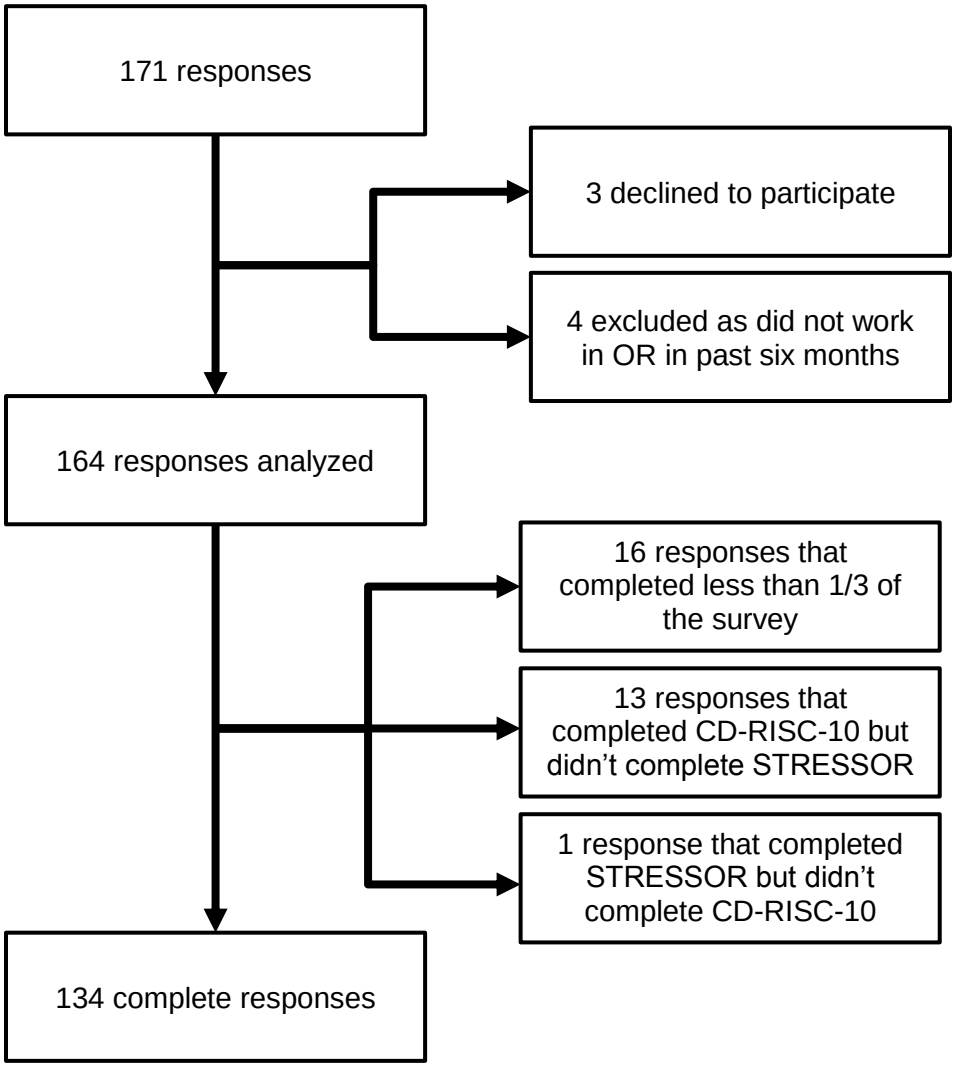

Figure 4-1: Distribution of excluded, incomplete, and complete survey responses.

Table 4-2: Demographics of subjects who responded to the survey.

Age	Number	Percentage
18-24	2	1.22
25-29	74	45.12
30-34	69	42.07
35-39	17	10.37
40+	2	1.22
Gender		
Male	109	66.46
Female	55	33.54
Level of Training		
PGY-1	28	17.18
PGY-2	34	20.86
PGY-3	33	20.25
PGY-4	26	15.95
PGY-5	26	15.95
PGY-6+	3	1.84
Clinical Fellow	13	7.98
Surgical Specialty		
Orthopaedic Surgery	117	71.78
General Surgery	14	8.59
Plastic Surgery	6	3.68
Urology	6	3.68
Otolaryngology	5	3.07
Obstetrics and Gynecology	5	3.07
Neurosurgery	4	2.45
Cardiac Surgery	3	1.84
Vascular Surgery	2	1.23
Thoracic Surgery	1	0.61

4.4.1 What is the variation in experiences of intraoperative stress and stress coping mechanisms in surgical trainees?

Subjects were asked to rate the three *greatest* sources of stress they experienced in the operating room. As shown in **Figure 4-2**, time pressure, attending temperament, and being paged were rated as the three highest intraoperative stressors. Making an error,

fatigue, surgical complications, high risk patient, teamwork issues all scored as lesser stressors, respectively. Other responses collected include feeling unprepared or a lack of personal time.

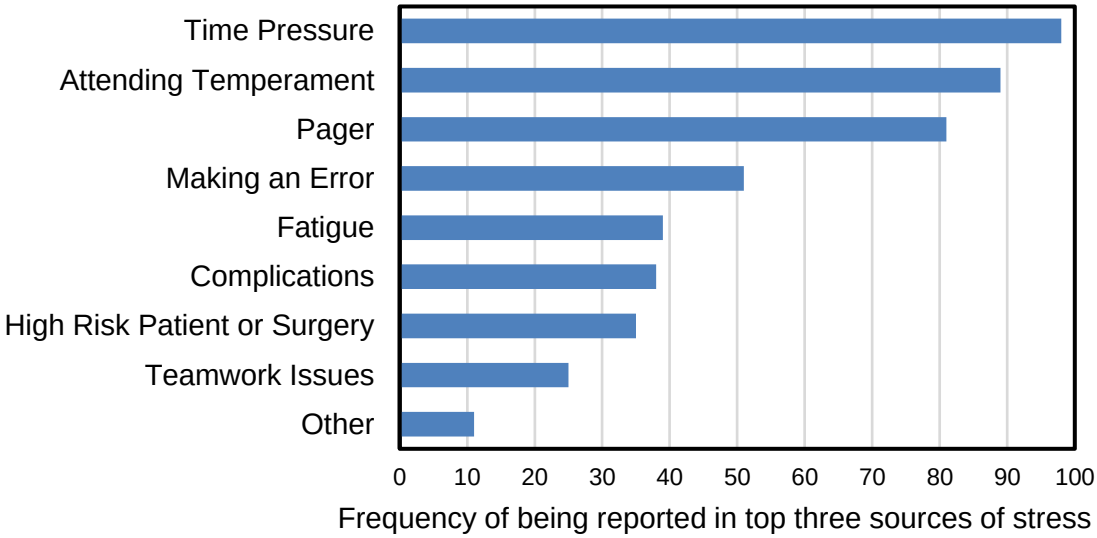

Figure 4-2: The sources of intraoperative stress.

Subjects were also asked to report the stress coping strategies that they found the most helpful. As shown in **Figure 4-3**, the three strategies reported as most useful are team communication (talking through a problem out loud), having a colleague or fellow available to answer questions, or mental rehearsal.

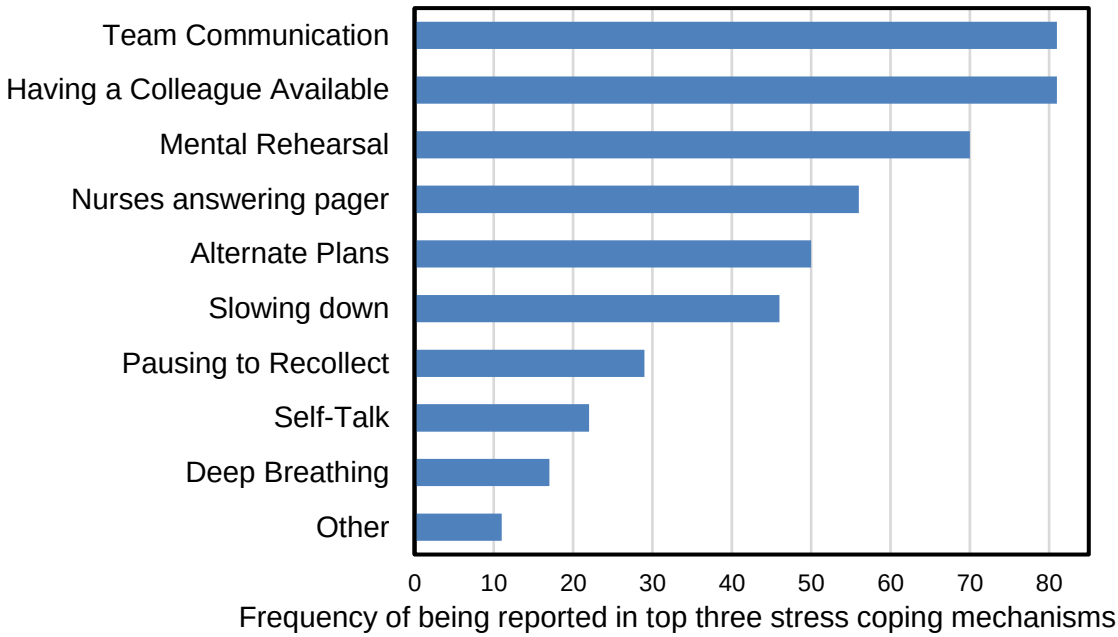

Figure 4-3: The most useful stress coping strategies.

The STRESSOR instrument was completed by 135 respondents. The mean STRESSOR score was 22.5 (SD = 4.4), with higher scores indicating greater intraoperative stress and a theoretical maximum score of 40. The distribution of STRESSOR scores is shown in **Figure 4-4**. Normality testing using a Q-Q plot (**Appendix C, Figure C-1**) and a Shapiro-Wilk test (p=0.935) show excellent fit with a normal distribution, suggesting that STRESSOR may be treated as a parametric variable for this study.

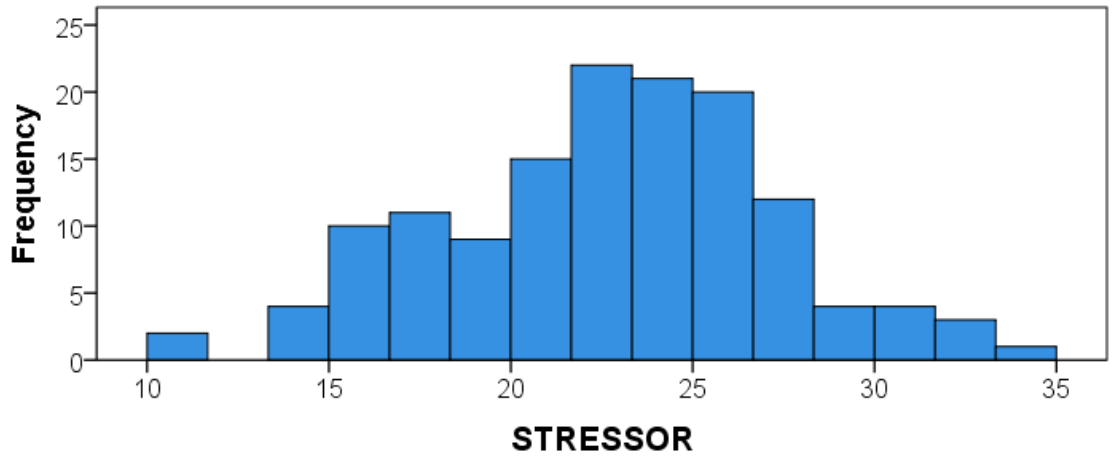

Figure 4-4: Histogram of STRESSOR scores.

Subscores were calculated for each of the eight domains of stress in the STRESSOR instrument. The median scores and interquartile range are shown in **Figure 4-5**. However, normality testing on the individual subscores for the eight domains of stress show that most of these subscores do not fit a normal distribution, as seen in **Table 4-3**. The domains which are the most *frequent* sources of stress are time pressure, intraoperative disruptions, and attending temperament.

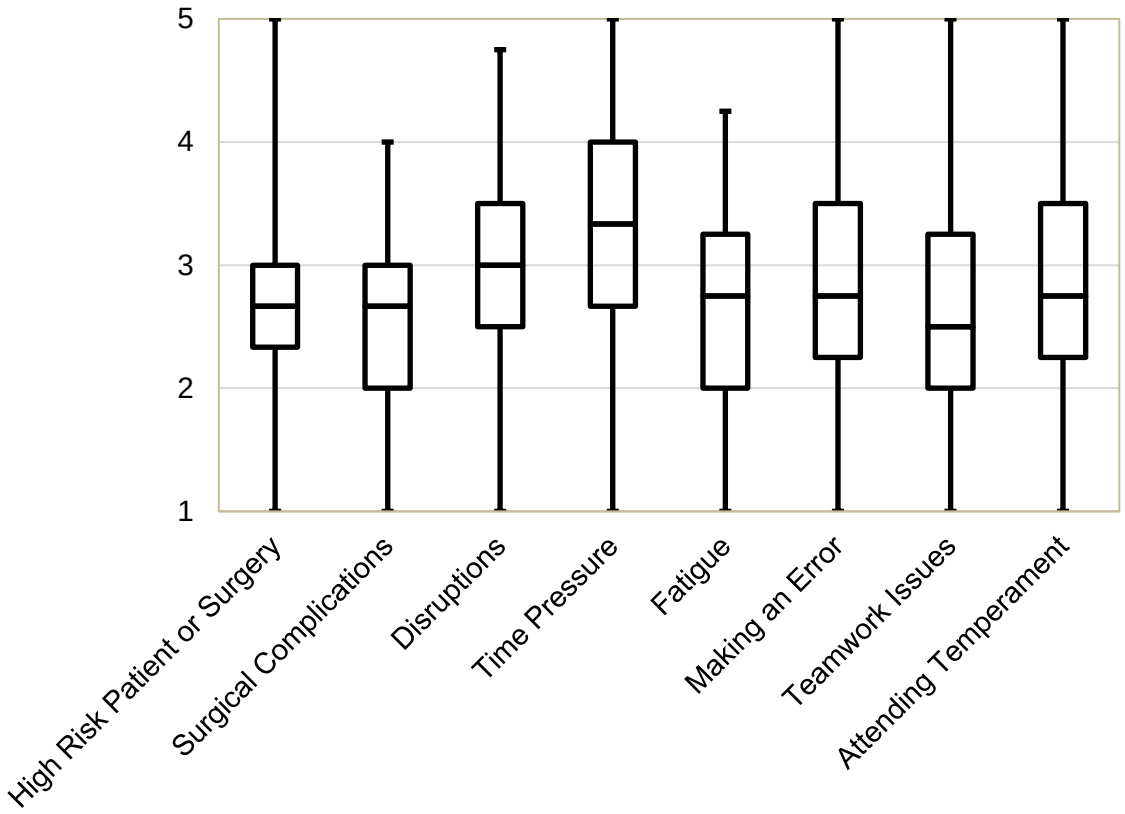

Figure 4-5: STRESSOR subscores by domain of intraoperative stress.

Table 4-3: Normality testing of STRESSOR subscores for the eight domains of stress. Note that a significance <0.05 suggests a non-normal distribution.

Domain of Stress	Shapiro-Wilk Test	
	Statistic	*p*-value
High Risk Patient or Surgery	0.961	0.001
Surgical Complications	0.969	0.004
Disruptions	0.981	0.057
Time Pressure	0.971	0.005
Fatigue	0.974	0.010
Making an Error	0.987	0.221
Teamwork Issues	0.972	0.006
Attending Temperament	0.987	0.214

4.4.2 What is the variation in resilience in surgical trainees?

The CD-RISC-10 instrument was completed by 147 subjects, and the mean resilience score was 28.8 (SD=4.4). Three subjects scored the maximum score of 50. The distribution of CD-RISC-10 scores is shown in **Figure 4-6**. Normality testing using a Q-Q plot (**Appendix C, Figure C-2**) and a Shapiro-Wilk test (p=0.331) show an excellent fit with a normal distribution, suggesting that CD-RISC-10 may be treated as a parametric variable for this study.

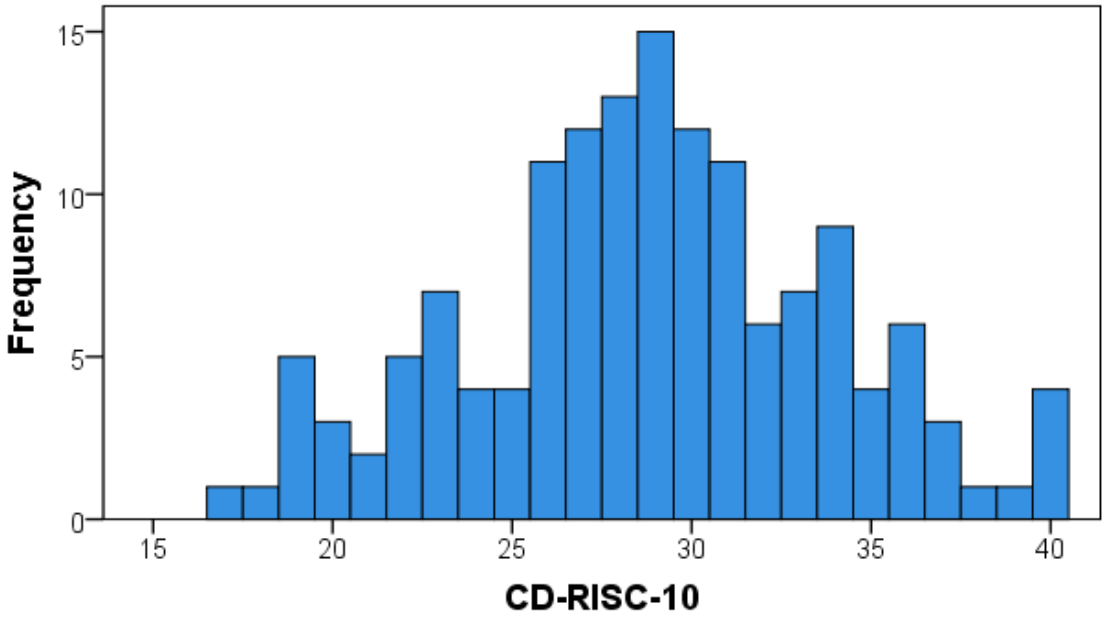

Figure 4-6: Histogram of CD-RISC-10 scores.

The reliability of the CD-RISC-10 was high in this population of surgical trainees, with a Cohen's alpha of 0.85. Exploratory factor analysis for the CD-RISC-10 items was performed using maximum likelihood and orthogonal rotation and a single factor solution was the preferred solution. The initial Eigen values showed that the first factor explained 43.9 percent of the variance, the second factor 11.4 percent of the variance, and the third

factor 9.8 percent of the variance. The scree plot (**Appendix C, Figure C-3**) showed a "levelling off" of the Eigen values after the first factor, and a two-factor solution demonstrated significant cross-loading above 0.3 on three items. A single factor solution had good fit and the table of loading factors is seen in **Appendix C, Table C-1**.

Correlation testing using Pearson's correlation demonstrates that resilience is independent of age (r=0.09, p=0.285). Increasing year of training is weakly correlated with higher resilience (r=0.188, p=0.023). Males have higher CD-RISC-10 scores (mean=29.6, SD=4.9) than females (mean=27.3, SD=5.0); t(145)=2.72, p=0.007). Orthopaedic trainees have higher CD-RISC-10 scores (mean=29.5, SD=5.0) than trainees in non-orthopaedic surgical specialties (mean=27.2, SD=4.7); t(145)=2.52, p=0.013. These results show that males have slightly higher resilience than females, and orthopaedic trainees have slightly higher resilience than trainees in other surgical specialties.

4.4.3 What is the relationship between stress and resilience in this population?

Linear regression was used to study the relationship between intraoperative stress (STRESSOR score) and resilience (CD-RISC-10 score). Increased resilience is associated with lower intraoperative stress and this relationship is moderate in strength but highly statistically significant (F(1,132)=24.17, p<0.001, R^2=0.155), as seen in **Figure 4-7**. The p-p plot (**Appendix C, Figure C-4**) shows an appropriate distribution of the residuals.

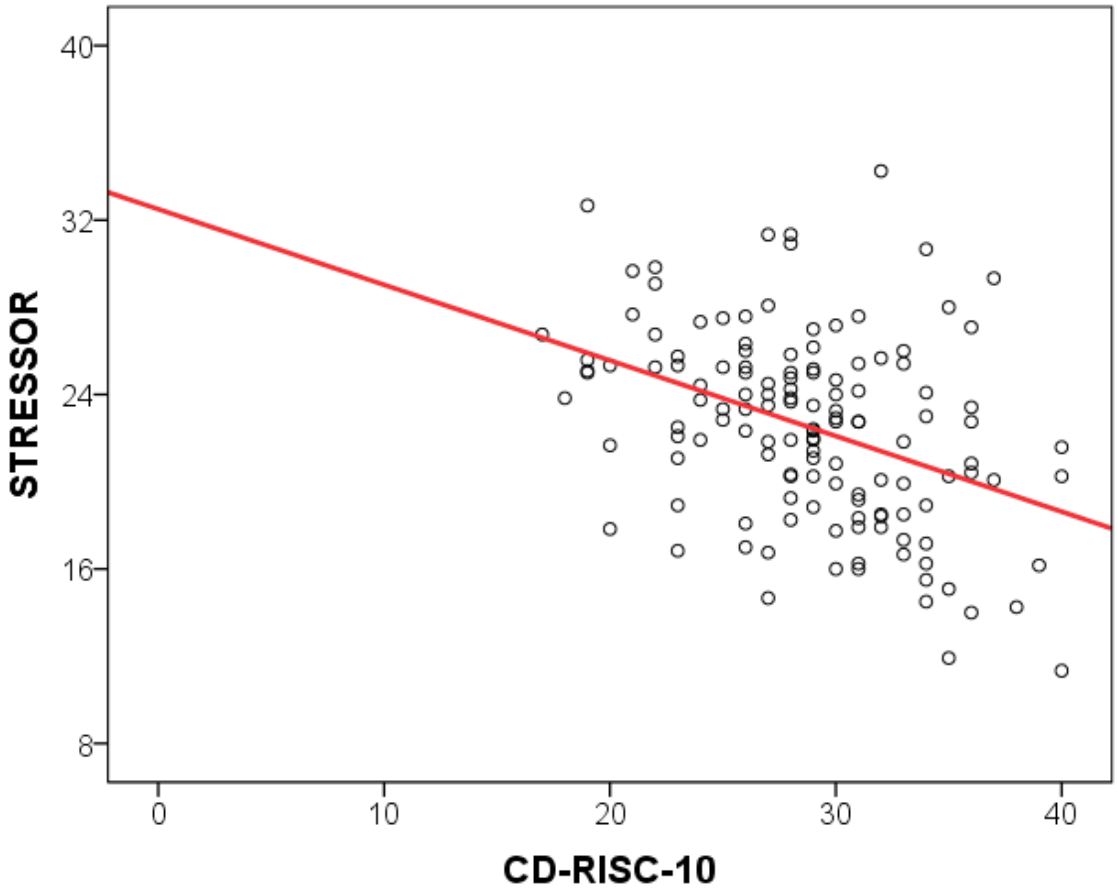

Figure 4-7: Scatterplot showing the relationship between intraoperative stress (STRESSOR score) and resilience (CD-RISC-10 score). This relationship is statistically significant (p<0.001, R^2=0.155). Note that the vertical and horizontal scores are based on the absolute value of the STRESSOR and CD-RISC-10.

To further understand the nuances of the relationship between intraoperative stress and resilience, we examined each of the STRESSOR subscores through Spearman's correlation as the residuals are not normally distributed. Spearman's coefficients are presented in **Table 4-4**. Increasing resilience is associated with lower stress in each of the domains of stress except Teamwork Issues and Disruptions.

Table 4-4: Correlations (Spearman's rho) between resilience (CD-RISC-10) and STRESSOR subscores for each of the eight domains of stress. With a Bonferroni correction, the relationships marked with an asterisk (*) are statistically significant (p<0.0063).

	Spearman's Coefficient	p-value
High Risk Patient or Surgery	-0.315	<0.001*
Surgical Complications	-0.373	<0.001*
Disruptions	-0.195	0.024
Time Pressure	-0.257	0.003*
Fatigue	-0.355	<0.001*
Making an Error	-0.297	<0.001*
Teamwork Issues	-0.153	0.078
Attending Temperament	-0.428	<0.001*

4.4.4 How does this relationship vary by gender, age, and year of training?

Univariate analysis using Pearson's correlation showed that lower STRESSOR scores are statistically correlated to increasing level of training (r=-0.24, p=0.005). There is a trend between increasing age and lower STRESSOR scores, but this does not reach statistical significance (r=-0.16, p=0.061). There is no significant difference in the STRESSOR scores for males (mean=22.1, SD=4.7) versus females (mean=23.3, SD=3.4); t(133)=1.38, p=0.17. As well, there is no significant difference in the STRESSOR scores for orthopaedic trainees (mean=22.3, SD=4.2) compared to trainees in non-orthopaedic specialties (mean=23.1, SD=4.8); t(133)=1.00, p=0.32. This demonstrates that intraoperative stress is independent of gender or surgical specialty.

Multivariate analysis with multiple linear regression identifies a significant regression equation (F(2,131)=15.35, p<0.001) with an R^2 of 0.19. Both CD-RISC-10 (β=-0.32,

p<0.001) and level of training (β=-0.48, p=0.019) remain a statistically significant predictors of STRESSOR scores. Collinearity diagnostics show no collinearity between CD-RISC-10 and level of training, with a tolerance of 0.98. The p-p plot (**Appendix C, Figure C-6**) shows a normal distribution of the residuals.

4.4.5 What is the relationship between resiliency, stress, and trainee attrition?

In response to the statement "Because of the stress I have experienced while in the operating room, I have seriously considered switching residency programs or leaving medicine", 16 percent of subjects responded with "strongly agree" or "somewhat agree". The distribution of responses is seen in **Table 4-5**.

Table 4-5: Distribution of responses to Likert-scale question item about the statement "Because of the stress I have experienced while in the operating room, I have seriously considered switching residency programs or leaving medicine."

Response	Number	Percent
Strongly disagree (1)	74	55.2
Somewhat disagree (2)	26	19.4
Neutral (3)	12	9.0
Somewhat agree (4)	15	11.2
Strongly agree (5)	7	5.2

STRESSOR and CD-RISC-10 scores were compared against resident attitudes towards attrition using one-way ANOVA analysis with a Welch correction because variances were not homogenous. Statistically significant differences were found between the different responses to trainee attrition compared to STRESSOR scores (F=6.95, p<0.001). As well, statistically significant differences were found between the different responses to trainee attrition compared to CD-RISC-10 scores (F=8.53, p<0.001). Plots of how the STRESSOR and CD-RISC-10 scores vary with different responses to the resident attrition question are seen in **Figure 4-8**, **Figure 4-9,** and **Figure 4-10**. Resident attrition is positively correlated to STRESSOR and negative correlated to CD-RISC-10

scores using Spearman's rho, as seen in **Table 4-6.** This demonstrates that trainees with greater intraoperative stress or lower resilience are more likely to report wanting to leave their residency training program.

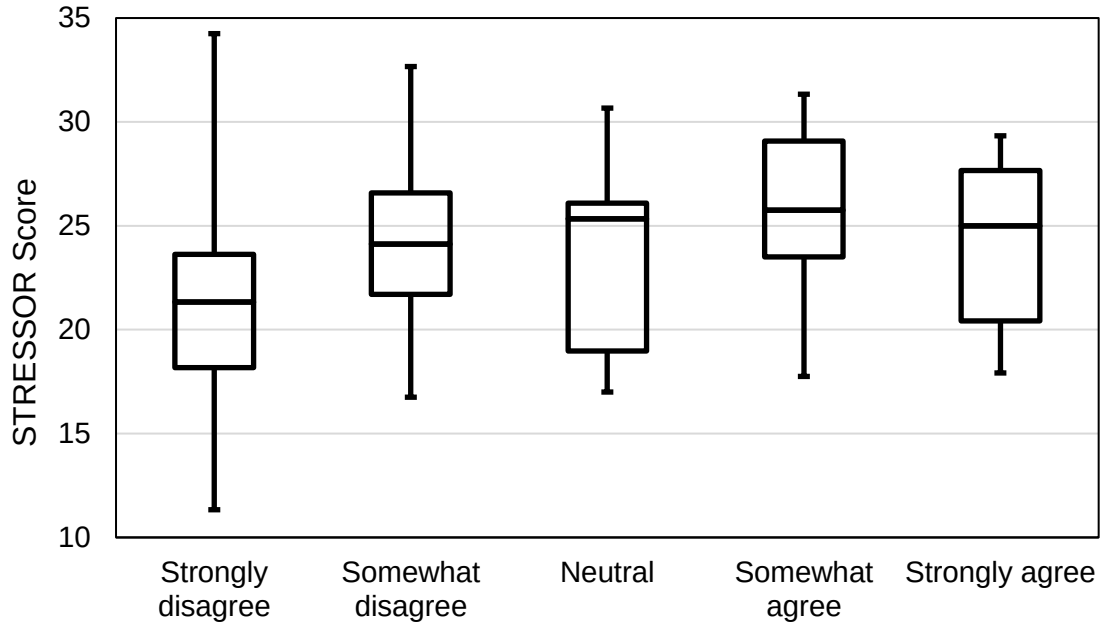

Figure 4-8: A plot of STRESSOR scores versus responses to "Because of the stress I have experienced while in the operating room, I have seriously considered switching residency programs or leaving medicine."

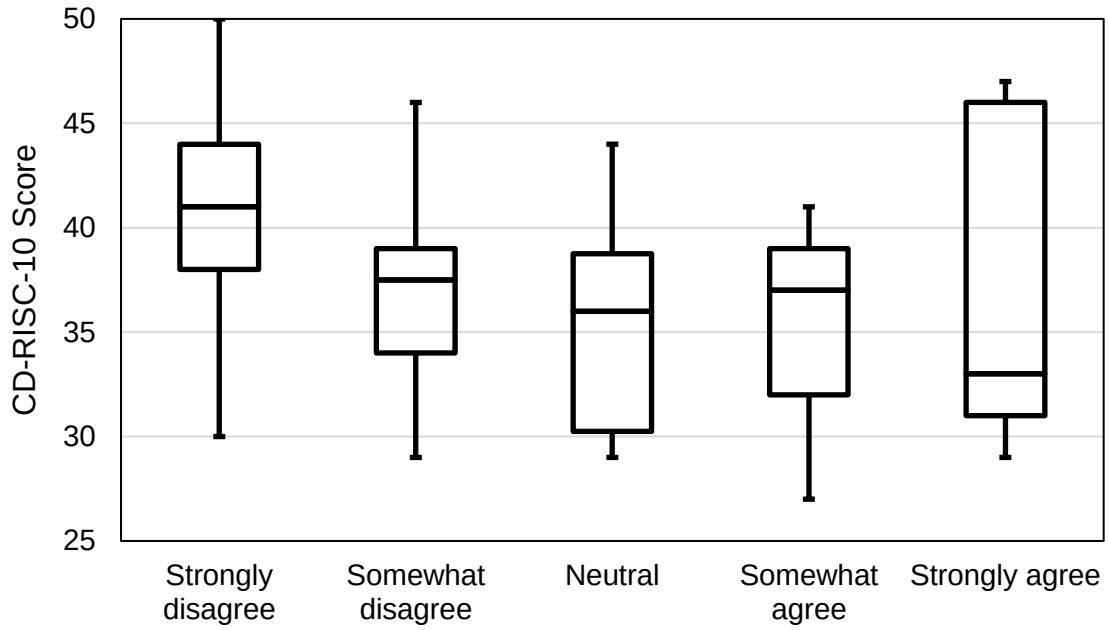

Figure 4-9: A plot of CD-RISC-10 scores versus responses to "Because of the stress I have experienced while in the operating room, I have seriously considered switching residency programs or leaving medicine."

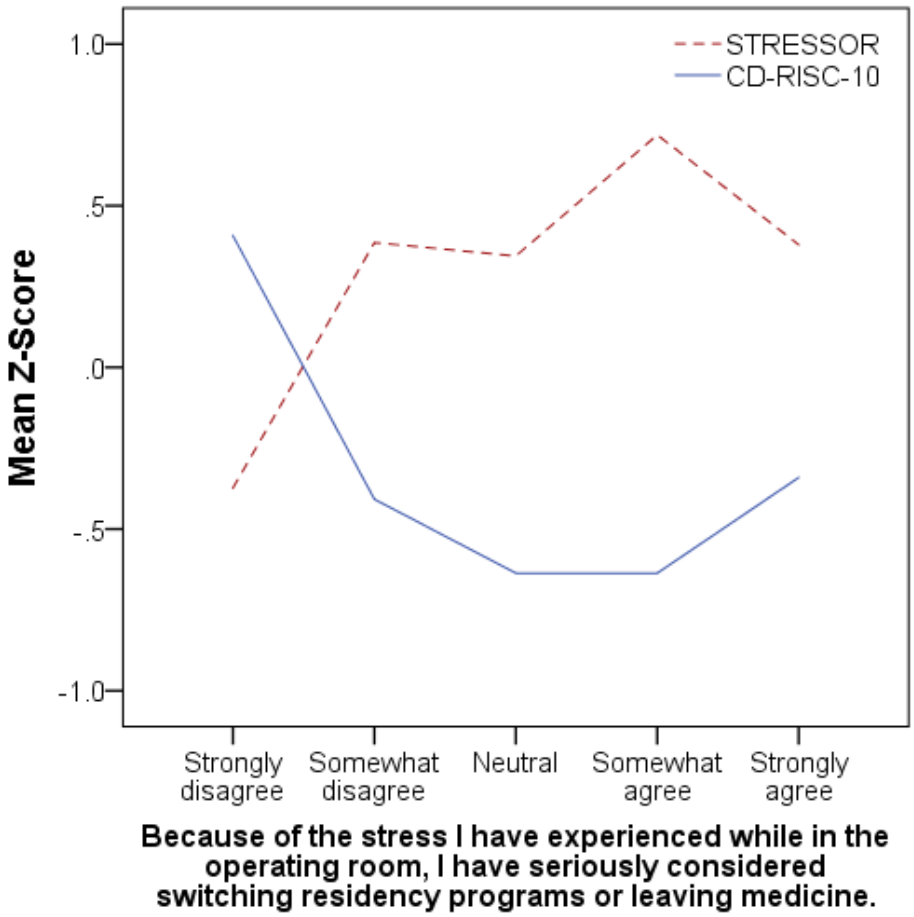

Figure 4-10: Plot of standardized STRESSOR and CD-RISC-10 scores against responses to item about trainee attrition.

Table 4-6: Correlation (Spearman's rho) of trainee desire to leave their residency program against intraoperative stress (STRESSOR) and resilience (CD-RISC-10) scores

	Spearman's correlation coefficient	***p*-value**
STRESSOR	0.42	<0.001
CD-RISC-10	-0.43	<0.001

The STRESSOR and CD-RISC scores for subjects who responded “strongly disagree” to the statement about resident attrition were compared against those who responded “somewhat disagree”. Using a post-hoc Dunnett’s C test with one-way ANOVA, statistically significant differences exist between the “strongly disagree” and “somewhat disagree” groups for both STRESSOR and CD-RISC scores ($p<0.05$). Interestingly, subjects who report that they “strongly disagree” with the statement about leaving residency have less stress and more resilience than subjects who responded “somewhat disagree”.

4.5 Discussion

Despite attempts to increase the response rate including emailed reminders, having the survey available for two months, and offering subjects an opportunity to enter a draw for a gift card, the response rate was limited in this study. A total of 171 responses to the survey were collected and 164 responses met inclusion criteria, with an overall response rate of 38 percent. The response rate among orthopaedic residents across Canada was 39 percent, compared to 36 percent among surgical residents and fellows at Western University. There were a significant number of incomplete responses (30/164). There was no significant differences between the STRESSOR and CD-RISC-10 scores for incomplete responses compared to complete responses. We have reported the demographic information with as many subjects as possible, while only reporting comparisons between measures (such as the correlation between STRESSOR and CD-RISC-10) when the data required is complete (pairwise deletion). This serves to maximize the use of available data while trying to maintain as representative a sample as possible.

Although the overall response rate was low, we were still able to collect sufficient responses to allow for statistical analyses to answer the research questions. However the results may be influenced by non-response bias, as individuals who did not complete the survey may have different resilience and intraoperative stress than those who participated

in the study. It is difficult to theorise whether stress and resilience in non-responders is higher or lower, or if individuals that chose not to participate were simply less interested in this research topic.

4.5.1 Intraoperative Stress and Sources of Stress

In this research we have surveyed surgical trainees to assess their experiences of intraoperative stress and their psychological resilience. We have developed and deployed a novel instrument (STRESSOR) for the assessment of intraoperative stress in surgical trainees which has previously shown strong reliability and good validity. The range of STRESSOR scores in this study ranges from 11.3 to 34.3, with a mean score of 22.5. Normality testing shows excellent fit with a normal distribution, suggesting that STRESSOR may be treated as a parametric variable for this study and any future applications. However, most of individual subscores for the eight domains of stress do not fit a normal distribution and therefore caution should be used in analyzing these subscores independently of the total STRESSOR Score. The median STRESSOR subscores all fall between 2.50 and 3.33, suggesting a strong central clustering tendency which is a known effect with Likert scales.[46] Nevertheless the STRESSOR instrument has good performance with a useful range of responses for each of the subscores.

The three highest average STRESSOR subscores are time pressure, intraoperative disruptions, and attending temperament, suggesting that these are the three *most frequent* sources of stress experienced by subjects. This matches the three *greatest* sources of stress as ranked by subjects of time pressure, attending temperament, and being paged. While it is quite likely that the most frequent stressors are also the greatest sources of stress, this may also be influenced by recall bias. Subjects are more likely to remember and report based on more recent experiences or experiences associated with a strong emotional response.[9,47]

The greatest sources of stress for surgical trainees found in this study are among the stressors reported in previous studies. Wetzel et al.[2] included “time pressure” and

"distractions" as sources of stress in surgeons and trainees, but did not assess the severity of different stressors. Anton et al.[3] asked trainees to rate the severity of stress associated with different sources of stress. "Time pressure", "Rarely performed procedure", and "Technical challenge" were the stressors most frequently reported as "extremely stressful", while "Multitasking" was the stressor *least* reported as "extremely stressful". Trainees specifically identified "issues with attending surgeon" as a significant source of stress but did not assess the severity of this stressor. Therefore the severity of stressors identified in this study are different than those previously studied, but this may be explained by the differences in methodology.

This study and the STRESSOR instrument focuses on acute stress in the operating room specifically. Generalized chronic stress and the consequences of chronic stress, such as depression and burnout, have not been assessed. Moreover, while the STRESSOR instrument asks trainees about their experiences of stress over the past six months, it has not been compared or correlated with other measures of stress. Further research should compare STRESSOR against other measures of stress such as Perceived Stress Scale[48] or the Job Stress Scale[49]. It would also be interesting to see how the STRESSOR compares to objective measures of stress such as heart rate variability[50,51] or salivary cortisol levels[52].

4.5.2 Stress Coping Mechanisms

The three stress coping mechanisms that have been reported as the most useful are team communication (talking through a problem out loud), having a colleague or fellow available to answer questions, or mental rehearsal / pre-visualizing steps. These coping mechanisms have previously been reported in the literature as useful to surgeons and trainees. Wetzel et al.[2] emphasized the importance of team communication and leadership in dealing with high-stress intraoperative situations. Team communication and mental rehearsal were also reported as useful stress coping strategies by surgical trainees in the study by Anton et al.[3]

Although other studies of surgical trainees have not reported on the role of discussing the case with a colleague or surgical fellow, this coping strategy was strongly identified in the initial focus groups and therefore included in the answer choices for this study. Help-seeking behaviour by attending surgeons has previously been studied by Novick et al.[53] Attending surgeons reported the importance of asking colleagues for help for technical assistance as well reassurance regarding decision making. In this study, trainees felt reassured by having someone other than their attending available to answer questions. This highlights the hierarchical nature of medical training and the apprehension that learners can have about being judged for asking questions.[54] It remains critical for attendings to create a safe learning environment where trainees feel comfortable asking for help when required.

There is strong evidence for the effectiveness of mental rehearsal for improving operative performance and decreasing intraoperative stress. Mental rehearsal is the systematic and detailed mental rehearsal of surgical steps without actually performing them. Wetzel's study in 2011 found that surgeons who received education on stress management techniques and mental rehearsal training had significantly lower stress and better teamwork than the control group.[55] Arora's 2011 randomized control study on novice surgeons found that mental rehearsal improved technical performance and decreased subjective stress, heart rate, and salivary cortisol.[56,57]

4.5.3 Psychological Resilience

In this study, the mean CD-RISC-10 score in surgical trainees is 28.8 (SD=4.4). In comparison, the mean CD-RISC-10 in the general US adult population is 31.8 (SD=5.4).[58] Similarly, Rahimi et al.[59] found that the mean CD-RISC-10 in Canadian medical students was 29.7. Therefore surgical trainees in this study were *not* more resilient than the general population or Canadian medical students. The finding that males have slightly higher resilience than females in this study reflects the results of a previous study of medical students.[59]

While surgical trainees experience significant stress, their psychological resilience is not particularly high. This finding is interesting and somewhat surprising because there is pre-existing literature demonstrating that a surgical personality may exist. Surgeons have been found to have greater Tough-Mindedness than general practitioners and anesthesiologists, suggesting that surgeons are less likely to be swayed by emotions.[60] Compared to other physicians, surgeons and surgical residents have higher levels of extraversion and conscientiousness, and lower levels of neuroticism.[61–64] Surgeons have also been shown to have higher levels of aggression than internists.[65,66] In two studies comparing specialties using the Psychopathic Personality Inventory, surgery ranked among top two highest scoring specialties.[67,68] These personality differences are even seen before surgical residency, as medical students who choose a surgical residency have higher self-esteem, a greater internal locus of control, and lower experienced stress than their non-surgically interested colleagues.[69] However, while surgery as a profession may encourage the self-selection of psychologically distinct individuals, surgical trainees are actually *less resilient* than the general population and Canadian medical students. The myth of the superhuman surgeon may not extend to psychological resilience, and surgical trainees are not more resilient than other medical trainees.

4.5.4 Stress and Resiliency

We began this study by hypothesizing that increased trainee resilience is correlated with decreased intraoperative stress. Our hypothesis was upheld, with increasing resilience as measured by CD-RISC-10 correlating with decreased STRESSOR scores. This relationship was highly statistically significant ($p<0.001$), but moderate in strength ($r=-0.39$). Therefore resilience is moderately protective against intraoperative stress. This matches the findings of other studies in the literature, with resilience protective against perceived stress in medical students[59] and against post-traumatic stress symptoms in surgeons[70]. As well, increasing year of training was shown to be protective against intraoperative stress, independent of resilience. This suggests that more experienced surgical trainees find the operating room to be less stressful, perhaps through the development of improved stress coping mechanisms.

Resilience is negatively correlated with STRESSOR subscores in each of the domains of stress. Therefore greater resilience is associated with less stress in each of the domains of intraoperative stress, but the magnitude of the relationship varies. The weakest correlation is between resilience and teamwork issues. This may be because it is difficult for a surgical trainee to moderate conflict between other members of the surgical team, such as between the attending physician and the anesthesiologist. In contrast, higher resilience is most strongly correlated with less stress from attending temperament. This may be because more resilient individuals feel more confident in their self-worth independent of their relationship with their attending and are less affected by criticism from their attending. Resilience has been shown to be associated with internal attributes including self-efficacy, an internal locus of control, and emotional stability, as well as external attributes including supportive relationships and family cohesion.[71,72] These factors help explain why more resilient individuals are distinctly less stressed by their attending's mood or reactions.

If resilience is modifiable and increased resilience is protective against stress, then resilience training interventions may be valuable for decreasing stress and the effects of stress. Multiple studies have examined resilience training interventions such as cognitive behavioral therapy or mindfulness training. Although there is substantial variation in the content, delivery, and duration of studied interventions, a recent meta-analysis showed that resilience training is beneficial for increasing resilience, decreasing stress, and reducing depression.[73] Similarly, a systematic review of resilience training in the workplace showed that resilience training can improve resilience, self-efficacy, and reduce stress, depression, and anxiety.[74] Resilience training for physicians, including facilitated discussion groups and cognitive behavioural training, has been shown to be effective.[75] A study of medical residents showed a trend towards decreased depression and anxiety in female and junior residents after mindfulness-based resiliency training.[76] Therefore physicians and medical trainees also benefit from increased resilience, and it has been suggested that resilience should be selected for and specifically taught to medical students[77].

4.5.5 Trainee Attrition

Voluntary resident attrition is common, with rates of 17 to 26 percent found in the literature over a 5 to 7-year residency.[36,37,78] A study of general surgery residents found that 58 percent of subjects had seriously considered quitting residency at some point.[35] In this study, 16 percent of subjects responded that they had seriously considered leaving their residency program because of intraoperative stress specifically. Although the two samples may be dissimilar, the difference in these two rates of seriously considering quitting residency may be because residents often leave for reasons other than intraoperative stress. Work-life balance and career prospects have been identified the primary reasons for resident attrition in Canadian surgical residents.[36] However, this study is the first comparing intraoperative stress and trainee attrition.

In this study, increased intraoperative stress and wanting to leave residency are moderately correlated, and decreased resilience is also moderately correlated with trainee attrition. However, our instrument for assessing trainee attrition is blunt, with only a single 5-point scale item. This markedly limits the degree to which this study explores resident attrition. The large variation in responses suggests that subjects may interpret the same question in different ways. As well, subjects who report that they "strongly disagree" with the statement about leaving residency have less stress and more resilience than subjects who responded differently (**Figure 4-10**). Thus respondents who select "strongly disagree" may be distinct from other subjects in this study, and further study is needed to explore attitudes towards trainee attrition. Therefore, future work exploring intraoperative stress, resilience, and attrition should utilize a more robust instrument for resident attrition. Moreover, by surveying residents who have *not* left their training program, this study is attempting to draw conclusions only from the surviving residents. In order to truly understand trainee attrition, the subjects of future research should be residents who have left a surgical training program. Studying the resilience of individuals who have actually left their residency program and comparing those results to this study would allow a better exploration of the relationship between resilience and trainee attrition.

4.6 Conclusion

Stress remains a constant and important factor in the daily lives of surgical trainees, particularly in the operating room. In this study, a novel instrument to assess intraoperative stress has been distributed as part of a national survey on stress and resilience in surgical trainees. Time pressure, intraoperative disruptions, and attending temperament were rated as the greatest and most common stressors. Surgical trainees are not more resilient than other medical trainees or the general population. In keeping with the original hypothesis of this study, trainee resilience is moderately protective against intraoperative stress and against residents wanting to leave their surgical residency. Therefore interventions to increase resilience may be useful for reducing intraoperative stress and resident attrition.

4.7 References

1. Arora S, Sevdalis N. Surgical Performance Under Stress: Conceptual and Methodological Issues. In: Athanasiou T, Debas H, Darzi A, eds. *Key Topics in Surgical Research and Methodology*. Berlin, Heidelberg: Springer Berlin Heidelberg; 2010:141-150. http://link.springer.com/10.1007/978-3-540-71915-1_12. Accessed October 19, 2016.

2. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. *Am J Surg*. 2006;191(1):5-10.

3. 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(5):846–851.

4. 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(3):318-330.e6. doi:10.1016/j.surg.2009.10.007.

5. Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. *J Comp Neurol Psychol*. 1908;18(5):459–482.

6. 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(4):537–543.

7. Arora S, Sevdalis N, Aggarwal R, Sirimanna P, Darzi A, Kneebone R. Stress impairs psychomotor performance in novice laparoscopic surgeons. *Surg Endosc*. 2010;24(10):2588-2593. doi:10.1007/s00464-010-1013-2.

8. 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(12):1554–1559.

9. LeBlanc VR. The Effects of Acute Stress on Performance: Implications for Health Professions Education: *Acad Med*. 2009;84(Supplement):S25-S33. doi:10.1097/ACM.0b013e3181b37b8f.

10. Starcke K, Brand M. Decision making under stress: a selective review. *Neurosci Biobehav Rev*. 2012;36(4):1228–1248.

11. 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. doi:10.1016/j.nlm.2014.01.015.

12. Kuhlmann S. Impaired Memory Retrieval after Psychosocial Stress in Healthy Young Men. *J Neurosci*. 2005;25(11):2977-2982. doi:10.1523/JNEUROSCI.5139-04.2005.

13. Salehi B, Cordero MI, Sandi C. Learning under stress: the inverted-U-shape function revisited. *Learn Mem*. 2010;17(10):522–530.

14. Joëls M, Pu Z, Wiegert O, Oitzl MS, Krugers HJ. Learning under stress: how does it work? *Trends Cogn Sci*. 2006;10(4):152–158.

15. Schwabe L, Wolf OT. Learning under stress impairs memory formation. *Neurobiol Learn Mem*. 2010;93(2):183–188.

16. Schwabe L, Wolf OT, Oitzl MS. Memory formation under stress: quantity and quality. *Neurosci Biobehav Rev*. 2010;34(4):584–591.

17. Wagnild GM, Collins JA. Assessing resilience. *J Psychosoc Nurs Ment Health Serv*. 2009;47(12):28–33.

18. Connor KM, Davidson JRT. Development of a new resilience scale: The Connor-Davidson Resilience Scale (CD-RISC). *Depress Anxiety*. 2003;18(2):76-82. doi:10.1002/da.10113.

19. Luthar SS, Cicchetti D, Becker B. The Construct of Resilience: A Critical Evaluation and Guidelines for Future Work. *Child Dev*. 2000;71(3):543-562. doi:10.1111/1467-8624.00164.

20. Leipold B, Greve W. Resilience: A conceptual bridge between coping and development. *Eur Psychol*. 2009;14(1):40–50.

21. Tusaie K, Dyer J. Resilience: A historical review of the construct. *Holist Nurs Pract*. 2004;18(1):3–10.

22. Windle G. What is resilience? A review and concept analysis. *Rev Clin Gerontol*. 2011;21(2):152–169.

23. Fletcher D, Sarkar M. Psychological resilience. *Eur Psychol*. 2013. http://econtent.hogrefe.com/doi/full/10.1027/1016-9040/a000124. Accessed January 24, 2017.

24. Pooley JA, Cohen L. Resilience: A definition in context. *Aust Community Psychol*. 2010;22(1):30–37.

25. Shastri PC. Resilience: Building immunity in psychiatry. *Indian J Psychiatry*. 2013;55(3):224-234. doi:10.4103/0019-5545.117134.

26. Ong AD, Bergeman CS, Boker SM. Resilience comes of age: Defining features in later adulthood. *J Pers*. 2009;77(6):1777–1804.

27. 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(8):858–861.

28. 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(6):358–363.

29. Frank JR, Snell L, Sherbino J. CanMEDS 2015 physician competency framework. *R Coll Physicians Surg Can*. 2015.

30. Cordes CL, Dougherty TW. A review and an integration of research on job burnout. *Acad Manage Rev*. 1993;18(4):621–656.

31. McManus IC, Winder BC, Gordon D. The causal links between stress and burnout in a longitudinal study of UK doctors. *The Lancet*. 2002;359(9323):2089–2090.

32. Martini S, Arfken CL, Churchill MA, Balon R. Burnout comparison among residents in different medical specialties. *Acad Psychiatry*. 2004;28(3):240–242.

33. Prins JT, Gazendam-Donofrio SM, Tubben BJ, Van Der Heijden FM, Van De Wiel H, Hoekstra-Weebers JE. Burnout in medical residents: a review. *Med Educ*. 2007;41(8):788–800.

34. Maslach C, Schaufeli WB, Leiter MP. Job burnout. *Annu Rev Psychol*. 2001;52(1):397–422.

35. Gifford E, Galante J, Kaji AH, et al. Factors Associated With General Surgery Residents' Desire to Leave Residency Programs: A Multi-institutional Study. *JAMA Surg*. 2014;149(9):948. doi:10.1001/jamasurg.2014.935.

36. Adams S, Ginther DN, Neuls E, Hayes P. Attitudes and factors contributing to attrition in Canadian surgical specialty residency programs. *Can J Surg J Can Chir*. 2017;60(4):4616.

37. 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(3):265–272.

38. Windle G, Bennett KM, Noyes J. A methodological review of resilience measurement scales. *Health Qual Life Outcomes*. 2011;9(1):1.

39. Campbell-Sills L, Stein MB. Psychometric analysis and refinement of the connor–davidson resilience scale (CD-RISC): Validation of a 10-item measure of resilience. *J Trauma Stress*. 2007;20(6):1019–1028.

40. Jeong HS, Kang I, Namgung E, et al. Validation of the Korean version of the Connor–Davidson Resilience Scale-2 in firefighters and rescue workers. *Compr Psychiatry*. 2015;59:123-128. doi:10.1016/j.comppsych.2015.01.006.

41. Wang L, Shi Z, Zhang Y, Zhang Z. Psychometric properties of the 10-item Connor–Davidson Resilience Scale in Chinese earthquake victims. *Psychiatry Clin Neurosci*. 2010;64(5):499–504.

42. 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.

43. Madewell AN, Ponce-Garcia E. Assessing resilience in emerging adulthood: The Resilience Scale (RS), Connor–Davidson Resilience Scale (CD-RISC), and Scale of Protective Factors (SPF). *Personal Individ Differ*. 2016;97:249–255.

44. Watling CJ, Lingard L. Grounded theory in medical education research: AMEE Guide No. 70. *Med Teach*. 2012;34(10):850-861. doi:10.3109/0142159X.2012.704439.

45. Sullivan MC, Yeo H, Roman SA, et al. Surgical Residency and Attrition: Defining the Individual and Programmatic Factors Predictive of Trainee Losses. *J Am Coll Surg*. 2013;216(3):461-471. doi:10.1016/j.jamcollsurg.2012.11.005.

46. Laerhoven H van, Zaag-Loonen H van der, Bhf D. A comparison of Likert scale and visual analogue scales as response options in children's questionnaires. *Acta Paediatr*. 2004;93(6):830-835. doi:10.1080/08035250410026572.

47. Cushing BE, Ahlawat SS. Mitigation of recency bias in audit judgment: The effect of documentation. *Auditing*. 1996 Oct 1;15(2):110.

48. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. 1983:385–396.

49. Parker DF, DeCotiis TA. Organizational determinants of job stress. *Organ Behav Hum Perform*. 1983;32(2):160–177.

50. Abatzoglou S. Physiological and psychological responses of surgeons and trainees. 2016. http://ir.lib.uwo.ca/etd/4335/. Accessed January 29, 2017.

51. Vrijkotte TG, van Doornen LJ, de Geus EJ. Effects of Work Stress on Ambulatory Blood Pressure, Heart Rate, and Heart Rate Variability. 2000. http://www.vu-

ams.nl/fileadmin/user_upload/publications/Vrijkotte_2000.pdf. Accessed January 26, 2017.

52. Marrelli M, Gentile S, Palmieri F, Paduano F, Tatullo M. Correlation between Surgeon's Experience, Surgery Complexity and the Alteration of Stress Related Physiological Parameters. Bencharit S, ed. *PLoS ONE*. 2014;9(11):e112444. doi:10.1371/journal.pone.0112444.

53. Novick RJ, Lingard L, Cristancho SM. The Call, the Save, and the Threat: Understanding Expert Help-Seeking Behavior During Nonroutine Operative Scenarios. *J Surg Educ*. 2015;72(2):302-309. doi:10.1016/j.jsurg.2014.09.009.

54. Haas J, Shaffir W. *Becoming Doctors: The Adoption of a Cloak of Competence*. Greenwich, Conn.: JAI Press; 1987.

55. Wetzel CM, George A, Hanna GB, et al. Stress Management Training for Surgeons—A Randomized, Controlled, Intervention Study: *Ann Surg*. 2011;253(3):488-494. doi:10.1097/SLA.0b013e318209a594.

56. Arora S, Aggarwal R, Moran A, et al. Mental Practice: Effective Stress Management Training for Novice Surgeons. *J Am Coll Surg*. 2011;212(2):225-233. doi:10.1016/j.jamcollsurg.2010.09.025.

57. Arora S, Aggarwal R, Sirimanna P, et al. Mental practice enhances surgical technical skills: a randomized controlled study. *Ann Surg*. 2011;253(2):265–270.

58. Campbell-Sills L, Forde DR, Stein MB. Demographic and childhood environmental predictors of resilience in a community sample. *J Psychiatr Res*. 2009;43(12):1007-1012. doi:10.1016/j.jpsychires.2009.01.013.

59. Rahimi B, Baetz M, Bowen R, Balbuena L. Resilience, stress, and coping among Canadian medical students. *Can Med Educ J*. 2014;5(1). http://www.academia.edu/download/46626734/Resilience_stress_and_coping_among_Canad20160619-1713-yg9lab.pdf. Accessed June 26, 2017.

60. Borges NJ, Osmon WR. Personality and Medical Specialty Choice: Technique Orientation versus People Orientation. *J Vocat Behav*. 2001;58(1):22-35. doi:10.1006/jvbe.2000.1761.

61. McGreevy J, Wiebe D. A preliminary measurement of the surgical personality. *Am J Surg*. 2002;184(2):121–125.

62. 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(3):182–186.

63. 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(10):1293–1297.

64. Hoffman BM, Coons MJ, Kuo PC. Personality differences between surgery residents, nonsurgery residents, and medical students. *Surgery*. 2010;148(2):187–193.

65. 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(5):901–907.

66. 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(12):83.

67. Pegrum J, Pearce O. A stressful job: are surgeons psychopaths? *Bull R Coll Surg Engl*. 2015;97(8):331-334. doi:10.1308/rcsbull.2015.331.

68. Ahmed F, Khan T, Rashid W, Akhtar S, Khan ZR, Ahmed B. A descriptive analysis of psychological traits among the health-care providers. *CHRISMED J Health Res*. 2017;4(2):76. doi:10.4103/cjhr.cjhr_85_16.

69. Linn BS, Zeppa R. Does surgery attract students who are more resistant to stress? *Ann Surg*. 1984;200(5):638.

70. 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(1):179-184. doi:10.1097/TA.0b013e3182984a7d.

71. Friborg O. *Validation of [a] Scale to Measure Resilience in Adults*. Department of Psychology, Faculty og social Sciences, University of Tromsø; 2005. https://www.researchgate.net/profile/Oddgeir_Friborg/publication/261096803_Validation_of_a_scale_to_measure_resilience_in_adults/links/0a85e5332d4a29af62000000.pdf. Accessed October 19, 2016.

72. Kilic SA, Dorstyn DS, Guiver NG. Examining factors that contribute to the process of resilience following spinal cord injury. *Spinal Cord*. 2013;51(7):553–557.

73. 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(10):e111420.

74. 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(3):533–562.

75. 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(1):9-12. doi:10.1007/s40596-015-0475-x.

76. 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. doi:10.2147/AMEP.S88580.

77. 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(4):349-356. doi:10.1111/j.1365-2923.2011.04188.x.

78. Wasserman MA. A strategy to reduce general surgery resident attrition: a resident's perspective. *JAMA Surg*. 2016;151(3):215–216.

Chapter 5

5 Discussion and Conclusions

5.1 Introduction

Intraoperative stress is a ubiquitous and important part of the learning environment for surgical trainees. Residents and fellows in surgery face stress from a variety of sources as they attempt to learn and perform technically demanding tasks. Excessively high stress is linked with impaired technical and non-technical performance in surgeons and trainees and also has adverse effects on learning. However, psychological resilience allows some individuals to thrive in spite of stress and adversity. Resilience in physicians is modifiable and resilience training is beneficial for decreasing stress and improving quality of life. This study has examined the stress that surgical trainees experience in the operating room through the development of a new instrument. The relationships between intraoperative stress and resilience were explored. Furthermore, trainee attitudes towards leaving their training program were explored and compared to stress and resilience. This research provides a deeper understanding of intraoperative stress and resilience, which allows for recommendations to reduce resident attrition while improving trainee performance and learning.

5.2 Intraoperative Stress and its Measurement

In this research project, we began by wanting to study stress and resilience but identified the need for an instrument to assess intraoperative stress in surgical trainees. We have described and quantified how learners experience intraoperative stress through the development and use of the Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR) instrument. The reliability and validity of this instrument have been demonstrated, as seen in **Chapter 3**. STRESSOR should be incorporated into future studies on intraoperative stress in surgical trainees. However, the reliability and validity

of STRESSOR should continue to be analyzed in future studies to provide the benefit of a larger sample size and to assess its psychometric properties in different populations (such as medical students in the operating room).

This research project and the STRESSOR instrument have focused on exploring acute stress in the operating room. Generalized chronic stress and its effects, including burnout, have not been addressed in this research. How intraoperative stress correlates with generalized stress and mental health in trainees is beyond the scope of this research and is a field for future study. STRESSOR should also be compared to instantaneous measures of intraoperative stress such as the State-Trait Anxiety Index (STAI)[1] or objective measures such as heart rate variability[2,3] or salivary cortisol levels.[4]

The eight domains of stress identified in this study form a useful structure for understanding intraoperative stress in surgical trainees. These eight domains are: High Risk Patient or Surgery, Surgical Complications, Disruptions, Time Pressure, Fatigue, Making an Error, Teamwork Issues, and Attending Temperament. While other studies have assessed causes of stress in trainees, none have divided the multitude of stressors into distinct domains. The three stressors identified as most severe and most frequent were time pressure, intraoperative disruptions, and attending temperament. Understanding the multi-factorial causes of why trainees experience stress and anxiety during surgery may help residency programs develop interventions to address these stressors while improving trainee coping skills.

5.3 Stress Coping Mechanisms

In this study, the three most useful stress coping mechanisms identified are team communication (talking through a problem out loud), having a colleague or fellow available to answer questions, or mental rehearsal / pre-visualizing steps. These stress coping mechanisms have also been reported in prior studies of surgeon and trainee stress.[5,6] There is strong evidence demonstrating the effectiveness of mental rehearsal for

decreasing intraoperative stress and improving performance.[7–9] However, it is interesting to note that the stress coping strategies that are most helpful don't necessarily correlate with the greatest sources of stress. For example, despite intraoperative disruption being a high source of stress, "having a nurse answer the pager" is only a moderately scored coping mechanism. Similarly, teamwork issues were a low source of stress, but team communication is rated as the most useful stress coping mechanism. This suggests that stressors for which good coping skills are already utilized are rated as less stressful, while issues that residents do not have strategies to manage are likely to be rated as more stressful.

The effectiveness of "having a colleague available to answer questions" as a stress coping mechanism is not surprising. Asking colleagues for help has been identified by attending surgeons as useful for technical assurance and reassurance regarding decision making.[10] However, in the hierarchical establishment of surgical training, learners can have high apprehension about being judged for asking questions.[11] Surgical trainees may find it useful to seek out other residents or colleagues to answer questions because it provides a neutral perspective without the fear of being judged by the attending surgeon. Therefore the attending physician retains an important role and can reduce resident stress by providing a safe learning environment where trainees feel comfortable asking for help when required.

5.4 Resilience

Resilience was assessed in this study using the ten-item Connor-Davidson Resiliency Scale (CD-RISC-10), which has been previously validated in multiple studies.[12,13] Most surgical trainees are highly resilient when compared to the general population[14] or to Canadian medical students.[15] This matches prior studies demonstrating that a "surgical personality" may exist, with surgeons demonstrating higher levels of extraversion and conscientiousness, lower levels of neuroticism, and high stress immunity.[16–20] These

differences begin even in medical school,[21] suggesting that surgery as profession seems to encourage the self-selection of psychologically distinct and perhaps more resilient individuals.

5.5 Relating Stress and Resilience

This research project began with the hypothesis that resilience is protective against intraoperative stress. The results of the survey indicate that increasing resilience moderately correlates with decreased intraoperative stress, upholding our hypothesis. Resilience has been found to be protective against stress and anxiety in other populations, including young adults,[22] athletes,[13] medical students,[15] and trauma surgeons.[23] If increased resilience is protective against stress, then resilience training interventions can decrease stress and the negative impacts of high stress. Two reviews of the extensive literature on resilience training show that it is beneficial for improving resilience, self-efficacy while decreasing stress, depression, and anxiety.[24,25] Resilience training interventions, such as facilitated discussion groups or cognitive behavioural training, have been shown to be effective in physicians and residents.[26,27]

5.6 Trainee Attrition

Rates of voluntary attrition during surgical residency training have been reported to be as high as 18 to 26 percent.[28–30] Trainees choose to leave their surgical residency program for a number of reasons, including work-life balance and career prospects.[29] Attrition is a great concern for surgical training programs and program directors, as residents who leave create a shortage of workers to cover clinical duties and impact the harmony and morale of the remaining residents.[31] The resident who leaves is also affected by the academic and financial challenges of seeking a new career path while sacrificing the time spent in the program they have left.[32]

In this study, subjects who had seriously considered leaving residency had significantly higher intraoperative stress and lower resilience. However, although the instrument used for assessing attrition in this study has been used in other studies of resident attrition, it was only a single 5-point Likert scale item. This limits the ability of this study to explore subject attitudes towards attrition. Subjects who "strongly disagree" with considering leaving their training program have less stress and higher resilience than other subjects, even compared to those who "somewhat agree" with the attrition statement. Therefore those that select "strongly disagree" may be distinct group from other subjects in this study, but the bluntness of the resident attrition instrument limits more detailed analysis.

By only surveying trainees who have *not* left their training program, this study's ability to draw conclusions about resident attrition is limited. Future work comparing resident attitudes towards attrition should utilize a more robust instrument, which could be created by adding additional question items. The design of such an instrument should include assessing individuals who have actually left a surgical training program. A deeper exploration of the relationship between resilience and trainee attrition should also compare the resilience of those who have left their residency program to trainees who have remained in their original training program.

5.7 Implications for Surgical Training

This study has significant implications in surgical training. Increased resilience correlates with lower intraoperative stress, which in turn has been linked to improved operative performance and learning. Given the benefits of increased resilience, surgical residency programs should consider resilience as an important variable during the selection of incoming residents. Changing the resident selection process to emphasize stress management skills and emotional intelligence has previously been shown to reduce surgical resident attrition.[33] In addition, a number of authors have advocated including resilience and stress management training during residency to improve trainee

performance and mental health both within and outside of the operating room.[27,34,35] Training surgical residents on stress management strategies has been shown to reduce resident stress and improve surgical performance in a simulated carotid endarterectomy.[9] A pilot study is currently underway assessing the impact of mindfulness training on resilience, general stress, and cognitive performance in surgical interns.[36]

Nevertheless, the average surgical resident remains highly resilient, and resilience training should not be used as a replacement for a supportive work environment.[37] It is important to remember that resilience is a multi-dimensional construct, with important contributions from an individual's social and work contexts.[38] Intimidation and harassment remain common in medical training[39] and are particularly prevalent in surgical specialties.[40] In addition, mistreatment of trainees is associated with poor mental health including depression and burnout.[41]

Qualitative interviews with residents who have left surgical residency have emphasized the scars left by negative interactions with authority and the lack of safe spaces to share concerns about the training process.[32] In contrast, supportive relationships with faculty including mentors has been shown to be protective against resident attrition.[42] Healthy attending behaviours including remaining calm and courteous, providing feedback without belittling, and being a positive role model have been associated with a positive learning environment.[43,44] Therefore while resilience training can play a role in reducing intraoperative stress, a supportive learning environment remains critical for effectively teaching the next generation of surgeons.

5.8 Conclusions

Surgical trainees face stress from a number of sources in the operating room, and excessively high stress can impair surgical performance and adversely affect learning. In this research we have used qualitative methods to identify eight distinct domains of intraoperative stress: High Risk Patient or Surgery, Surgical Complications, Disruptions,

Time Pressure, Fatigue, Making an Error, Teamwork Issues, and Attending Temperament. These domains have formed the basis for the design of a novel instrument for assessing trainee intraoperative stress (STRESSOR), and the reliability and validity of this instrument have been shown through this research project. The intraoperative stress and resilience of surgical residents have been assessed using a national survey and the results have been analyzed.

This project has explored the sources of stress and stress coping mechanisms that learners experience in the operating room, as well as measuring the resilience of surgical trainees. The three sources of stress which are the most frequent and the most severe are time pressure, intraoperative disruptions, and attending temperament. Stress coping strategies which are effective include team communication (talking through a problem out loud), having a colleague or fellow available to answer questions, or mental rehearsal / pre-visualizing steps. Surgical trainees typically have high psychological resilience compared to the general population or to medical students. Resilience is higher in males than females and in orthopaedic trainees compared to trainees in non-orthopaedic surgical programs.

We have upheld our primary hypothesis, which was that increasing resilience is correlated with lower intraoperative stress. Greater resilience and higher year of training are both correlated with less intraoperative stress in this study. Trainees who are less resilient or stressed in the operating room are more likely to consider leaving their surgical training program. Therefore resilience training may be useful for reducing intraoperative stress and resident attrition. However, resilience training does not replace the need for a supportive work environment.

As stated by Sheryl Sandberg, "We are not born with a fixed amount of resilience. It is a muscle that everyone can build."[45] Resilience training has been shown to be effective for improving resilience and mental health in a variety of populations including physicians, residents, and medical students. Resilience training may play an important role in

improving the performance, learning, and quality of life for surgeons in training while reducing trainee attrition.

5.9 References

1. Spielberger CD, Gorsuch RL, Lushene RE. Manual for the state-trait anxiety inventory. 1970. https://ubir.buffalo.edu/xmlui/handle/10477/2895.

2. Abatzoglou S. Physiological and psychological responses of surgeons and trainees. 2016. http://ir.lib.uwo.ca/etd/4335/. Accessed January 29, 2017.

3. Vrijkotte TG, van Doornen LJ, de Geus EJ. Effects of Work Stress on Ambulatory Blood Pressure, Heart Rate, and Heart Rate Variability. 2000. http://www.vu-ams.nl/fileadmin/user_upload/publications/Vrijkotte_2000.pdf. Accessed January 26, 2017.

4. Marrelli M, Gentile S, Palmieri F, Paduano F, Tatullo M. Correlation between Surgeon's Experience, Surgery Complexity and the Alteration of Stress Related Physiological Parameters. Bencharit S, ed. *PLoS ONE*. 2014;9(11):e112444. doi:10.1371/journal.pone.0112444.

5. Wetzel CM, Kneebone RL, Woloshynowych M, et al. The effects of stress on surgical performance. *Am J Surg*. 2006;191(1):5-10. doi:10.1016/j.amjsurg.2005.08.034.

6. 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(5):846–851.

7. Arora S, Aggarwal R, Moran A, et al. Mental Practice: Effective Stress Management Training for Novice Surgeons. *J Am Coll Surg*. 2011;212(2):225-233. doi:10.1016/j.jamcollsurg.2010.09.025.

8. Arora S, Aggarwal R, Sirimanna P, et al. Mental practice enhances surgical technical skills: a randomized controlled study. *Ann Surg*. 2011;253(2):265–270.

9. Wetzel CM, George A, Hanna GB, et al. Stress Management Training for Surgeons—A Randomized, Controlled, Intervention Study: *Ann Surg*. 2011;253(3):488-494. doi:10.1097/SLA.0b013e318209a594.

10. Novick RJ, Lingard L, Cristancho SM. The Call, the Save, and the Threat: Understanding Expert Help-Seeking Behavior During Nonroutine Operative Scenarios. *J Surg Educ*. 2015;72(2):302-309. doi:10.1016/j.jsurg.2014.09.009.

11. Haas J, Shaffir W. *Becoming Doctors: The Adoption of a Cloak of Competence*. Greenwich, Conn.: JAI Press; 1987.

12. Wang L, Shi Z, Zhang Y, Zhang Z. Psychometric properties of the 10-item Connor–Davidson Resilience Scale in Chinese earthquake victims. *Psychiatry Clin Neurosci*. 2010;64(5):499–504.

13. 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.

14. Campbell-Sills L, Forde DR, Stein MB. Demographic and childhood environmental predictors of resilience in a community sample. *J Psychiatr Res*. 2009;43(12):1007-1012. doi:10.1016/j.jpsychires.2009.01.013.

15. Rahimi B, Baetz M, Bowen R, Balbuena L. Resilience, stress, and coping among Canadian medical students. *Can Med Educ J*. 2014;5(1). http://www.academia.edu/download/46626734/Resilience_stress_and_coping_among_Canad20160619-1713-yg9lab.pdf. Accessed June 26, 2017.

16. McGreevy J, Wiebe D. A preliminary measurement of the surgical personality. *Am J Surg*. 2002;184(2):121–125.

17. 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(3):182–186.

18. 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(10):1293–1297.

19. Hoffman BM, Coons MJ, Kuo PC. Personality differences between surgery residents, nonsurgery residents, and medical students. *Surgery*. 2010;148(2):187–193.

20. Ahmed F, Khan T, Rashid W, Akhtar S, Khan ZR, Ahmed B. A descriptive analysis of psychological traits among the health-care providers. *CHRISMED J Health Res*. 2017;4(2):76. doi:10.4103/cjhr.cjhr_85_16.

21. Linn BS, Zeppa R. Does surgery attract students who are more resistant to stress? *Ann Surg*. 1984;200(5):638.

22. Limonero JT, Tomás-Sábado J, Gómez-Romero MJ, et al. Evidence for Validity of the Brief Resilient Coping Scale in a Young Spanish Sample. *Span J Psychol*. 2014;17. doi:10.1017/sjp.2014.35.

23. 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(1):179-184. doi:10.1097/TA.0b013e3182984a7d.

24. 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(10):e111420.

25. 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(3):533–562.

26. 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(1):9-12. doi:10.1007/s40596-015-0475-x.

27. 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. doi:10.2147/AMEP.S88580.

28. Gifford E, Galante J, Kaji AH, et al. Factors Associated With General Surgery Residents' Desire to Leave Residency Programs: A Multi-institutional Study. *JAMA Surg*. 2014;149(9):948. doi:10.1001/jamasurg.2014.935.

29. Adams S, Ginther DN, Neuls E, Hayes P. Attitudes and factors contributing to attrition in Canadian surgical specialty residency programs. *Can J Surg J Can Chir*. 2017;60(4):4616.

30. 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(3):265–272.

31. Longo WE. Attrition: our biggest continuing challenge. *Am J Surg*. 2007;194(5):567-575. doi:10.1016/j.amjsurg.2007.08.010.

32. Bongiovanni T, Yeo H, Sosa JA, et al. Attrition from surgical residency training: perspectives from those who left. *Am J Surg*. 2015;210(4):648-654. doi:10.1016/j.amjsurg.2015.05.014.

33. Kelz RR, Mullen JL, Kaiser LR, et al. Prevention of Surgical Resident Attrition by a Novel Selection Strategy: *Trans Meet Am Surg Assoc*. 2010;128:140-147. doi:10.1097/SLA.0b013e3181f27a50.

34. Anton NE, Stefanidis D. Should surgeons have mental skills training? *Eur J Cardiothorac Surg*. 2016;50(1):1-3. doi:10.1093/ejcts/ezw071.

35. 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(4):349-356. doi:10.1111/j.1365-2923.2011.04188.x.

36. Mindful Mental Training for Surgeons to Enhance Resilience and Performance Under Stress - Full Text View - ClinicalTrials.gov. https://clinicaltrials.gov/ct2/show/NCT03141190. Accessed June 27, 2017.

37. Balme E, Gerada C. Supporting GPs to remain mentally healthy: What works? *InnovAiT Educ Inspir Gen Pract*. 2016;9(6):342-346. doi:10.1177/1755738016638702.

38. Windle G. What is resilience? A review and concept analysis. *Rev Clin Gerontol*. 2011;21(2):152–169.

39. Karim S, Duchcherer M. Intimidation and harassment in residency: a review of the literature and results of the 2012 Canadian Association of Interns and Residents National Survey. *Can Med Educ J*. 2014;5(1):e50.

40. Daugherty SR, Baldwin Jr DC, Rowley BD. Learning, satisfaction, and mistreatment during medical internship: a national survey of working conditions. *JAMA*. 1998;279(15):1194–1199.

41. Cook AF, Arora VM, Rasinski KA, Curlin FA, Yoon JD. The Prevalence of Medical Student Mistreatment and Its Association With Burnout: *Acad Med*. 2014;89(5):749-754. doi:10.1097/ACM.0000000000000204.

42. Wasserman MA. A strategy to reduce general surgery resident attrition: a resident's perspective. *JAMA Surg*. 2016;151(3):215–216.

43. Schwind CJ, Boehler ML, Rogers DA, et al. Variables influencing medical student learning in the operating room. *Am J Surg*. 2004;187(2):198-200. doi:10.1016/j.amjsurg.2003.11.024.

44. Iwaszkiewicz M, DaRosa DA, Risucci DA. Efforts to Enhance Operating Room Teaching. *J Surg Educ*. 2008;65(6):436-440. doi:10.1016/j.jsurg.2008.07.006.

45. Sandberg S, Grant A. *Option B: Facing Adversity, Building Resilience, and Finding Joy*. Knopf Doubleday Publishing Group; 2017.

Appendix A: Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR) Instrument

31 questions assessing 8 domains of stress. Subjects are asked to respond based on frequency on 5-point Likert scale. Note: Items marked with an asterisk (*) are scored in reverse (almost never = 5, seldom = 4, sometimes = 3, often = 2, almost always = 1).

Thinking back to your time as a resident/fellow in the operating room over the past six months, how often did you experience the following <u>during surgery</u>?

1 = almost never, 2 = seldom, 3 = sometimes, 4 = often, 5 = almost always

1. I was worried about how to handle difficult steps during an operation.
2. I felt uncomfortable about the complexity of the surgical case.
3. I was anxious during surgery because the patient was at a high risk of medical or surgical complications.

4. When I wasn't making progress while operating, I froze and couldn't think of what to do next.
5. I became frustrated when the surgery wasn't going smoothly.
6. I was able to remain calm despite complications happening during a surgery.*

7. I felt frustrated about intraoperative disruptions (eg/ pager, phone call, case-irrelevant conversations).
8. I felt anxious when my pager went off while I was operating.
9. I worried about what I was being paged/called about.
10. I was able to cope well with interruptions while operating.*

11. I worried about making errors when pressured to be faster while operating.
12. I was afraid of being penalized for being too slow when operating.
13. I felt under pressure when the operating room was running behind schedule.
14. I was able to recognise when to slow down while operating.*

15. I felt unprepared to operate when I stayed in the OR post-call.
16. I worried about making errors while operating because I was tired.
17. I felt able to judge whether I was too tired to safely operate.*
18. I felt confident in my ability to operate, even though I was hazy from being tired.*

19. I felt anxious about making an error that would harm the patient while operating.
20. I obsessed for a long time over an error I made when operating.
21. I felt like a failure after making a surgical error.
22. I struggled to cope with my emotions after a patient suffered from an error I made while operating.

23. I found it stressful when my attending and the anesthesiologist weren't getting along.
24. I felt anxious when my attending spoke harshly to the nurses during surgery.
25. I felt uncomfortable because of conflict between my attending and other learners in the operating room.
26. I struggled to remain calm when nurses were unhelpful while I was operating.

27. I had difficulty operating because I felt stressed by my attending's mood.
28. I froze when my attending criticized me during an operation.
29. I worried about being shamed for making an intraoperative error.
30. I worried about how I was being judged during an operation.
31. I felt comfortable admitting when I didn't know what to do while operating.*

Appendix B: Survey

Note: this survey was distributed electronically using Qualtrics. All responses were collected anonymously.

Letter of Information and Consent

Title: Surgical Trainee Resiliency and Experiences of StresS in the Operating Room (STRESSOR)

Principal Investigator:
Dr. Brent Lanting, MD, MSc, FRCSC

Co-Investigators:
Dr. Richard Ng, MD, FRCSC
Dr. James Howard, MD, MSc, FRCSC
Dr. Saad Chahine, PhD

Invitation to Participate in Research:
You are being invited to participate in a study designed to explore the resiliency, experiences of stress, and coping mechanisms that surgical trainees face in the operating room. You were selected to participate in this study because you have been identified as surgery resident or clinical fellow in Canada. Please read this letter carefully and feel free to ask any questions if anything is unclear.

Study Information:
The purpose of this study is to assess the causes and experiences of intraoperative stress among surgical trainees and identify the coping mechanisms that trainees use. Psychological resilience will also be assessed to identify any correlation with intraoperative stress levels and coping mechanisms. This study will be useful in designing interventions to improve the performance and education of surgical trainees. There will be two arms of the study to investigate intraoperative stress in different populations of trainees. One arm will include all orthopaedic residents and clinical fellows in Canada, and the other will include all surgery residents and clinical fellows in select specialties at the University of Western Ontario. Surgical trainees will be invited to participate in this study if permission is granted from their residency program director / fellowship director.

Voluntary Participation:
Your participation in this study is voluntary. You may decide not to be in this study, or to be in the study now and then change your mind later. You may choose to not participate or to leave the study at any time without affecting your academic standing or training evaluations. You may refuse to answer any question you do not want to answer. If you wish to withdraw from the study after submitting the survey form, please contact Dr. Richard Ng within 2 weeks of survey submission with the date and time of your survey submission.

You do not waive any legal rights by starting the survey.

What are the responsibilities of the study participants?

If you agree to participate in this study, you will be asked to complete an online survey that should take 10-15 minutes. This survey will ask you questions about your experiences in the operating room, including stresses and coping mechanisms you use when you experience stress. After completing the survey you will be asked if you want to submit your email to participate in a draw for a $50 gift card.

What are the risks of participating in this study?
There are no risks to participation in this study. Your participation is voluntary and you may choose to not answer questions that you are not comfortable with. You may withdraw from the study if you contact us within 2 weeks of submitting the survey.

What are the benefits of participating in this study?
There are no direct benefits to participating in this study. The information gained from this study will be useful for designing interventions to reduce the stress of trainees to improve their surgical education and performance.

Confidentiality
The surveys are hosted by Qualtrics on Western University servers and all data collected in this study will be stored for 15 years after which it will be destroyed according to approved policies. Your demographic information including age, gender, year of training, and site of training will be collected in this survey to be used for data analysis and reporting in aggregate.

You may choose to submit your email at the end of the survey for entry into a prize draw for a $50 gift card to the retailer of your choice. These email addresses will be kept confidential and not revealed to anyone outside the study team.

Whom do participants contact for questions?
If you have questions about this study, please contact Dr. Richard Ng.
If you have any questions about your rights as a research participant or the conduct of this study, you may contact the Office of Human Research Ethics.

By starting this survey, you indicate that you have read the letter of information above and consent to participate in this study.

a. I have read the information above and consent to participating in this study.
b. No, I decline to participate

1.) What is your age?
a. 18-24
b. 25-29
c. 30-34
d. 35-39
e. 40+

2.) What is your gender?
a. Male
b. Female
c. Another
d. Prefer not to say

3.) What is your current level of training?
a. PGY-1

b. PGY-2
c. PGY-3
d. PGY-4
e. PGY-5
f. PGY 6+
g. Clinical Fellow

4.) Have you worked in the operating room in the past 6 months?

a. Yes
b. No

5.) Please identify your surgical specialty.

i. Cardiac Surgery
ii. General Surgery
iii. Neurosurgery
iv. Obstetrics and Gynecology
v. Ophthalmology
vi. Orthopaedic Surgery
vii. Otolaryngology
viii. Paediatric Surgery
ix. Plastic Surgery
x. Thoracic Surgery
xi. Urology
xii. Vascular Surgery

6.) (Only available if Orthopaedic Surgery was selected)

Please identify your site of training

i. University of British Columbia
ii. University of Alberta
iii. University of Calgary
iv. University of Saskatchewan
v. University of Manitoba
vi. University of Western Ontario
vii. McMaster University
viii. Northern Ontario School of Medicine
ix. University of Toronto
x. Queen's University
xi. University of Ottawa
xii. McGill University
xiii. Dalhousie University
xiv. Memorial University

7.) What are the three most <u>severe</u> causes of stress that you have experienced while in the operating room?

a. Please select 3 from the list below, or if not listed, include in "Other"
   i. My pager or phone going off
   ii. Fatigue
   iii. Surgical errors that I made
   iv. My attending's temperament
   v. Interpersonal conflict between surgical staff and nursing/anesthesia
   vi. Interpersonal conflict between myself and my attending
   vii. Time / Pressure to be faster
   viii. Complex Case / High Risk Patient
   ix. Complications during surgery
   x. Other _____

8.) What are the three things that you find <u>most helpful</u> for dealing with stress in the operating room?

a. Please select 3 from the list below, or if not listed, include in "Other"
   i. Mental rehearsal / pre-visualizing steps
   ii. Stopping and standing back / pausing to recollect
   iii. Deep breathing / relaxation exercises
   iv. Self-talk ("you can do this")
   v. Team communication / talk through the problem out loud
   vi. Slowing down
   vii. Having alternative plans/options for difficult steps (Plan B, Plan C, etc.)
   viii. Nurses answering my pager
   ix. Having a colleague / fellow available to answer questions during surgery
   x. Other _____

9.) Connor-Davidson Resilience Score – 10 items (CD-RISC-10)

Due to copyright restrictions this scale cannot be reproduced here.

10.) Surgical TRainee Experiences of StresS in the Operating Room (STRESSOR) Instrument

Please refer to **Appendix A.**

11.) Because of the stress I have experienced <u>while in the operating room</u>, I have seriously considered switching residency programs or leaving medicine.

1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree

Appendix C: Statistical Plots and Tables

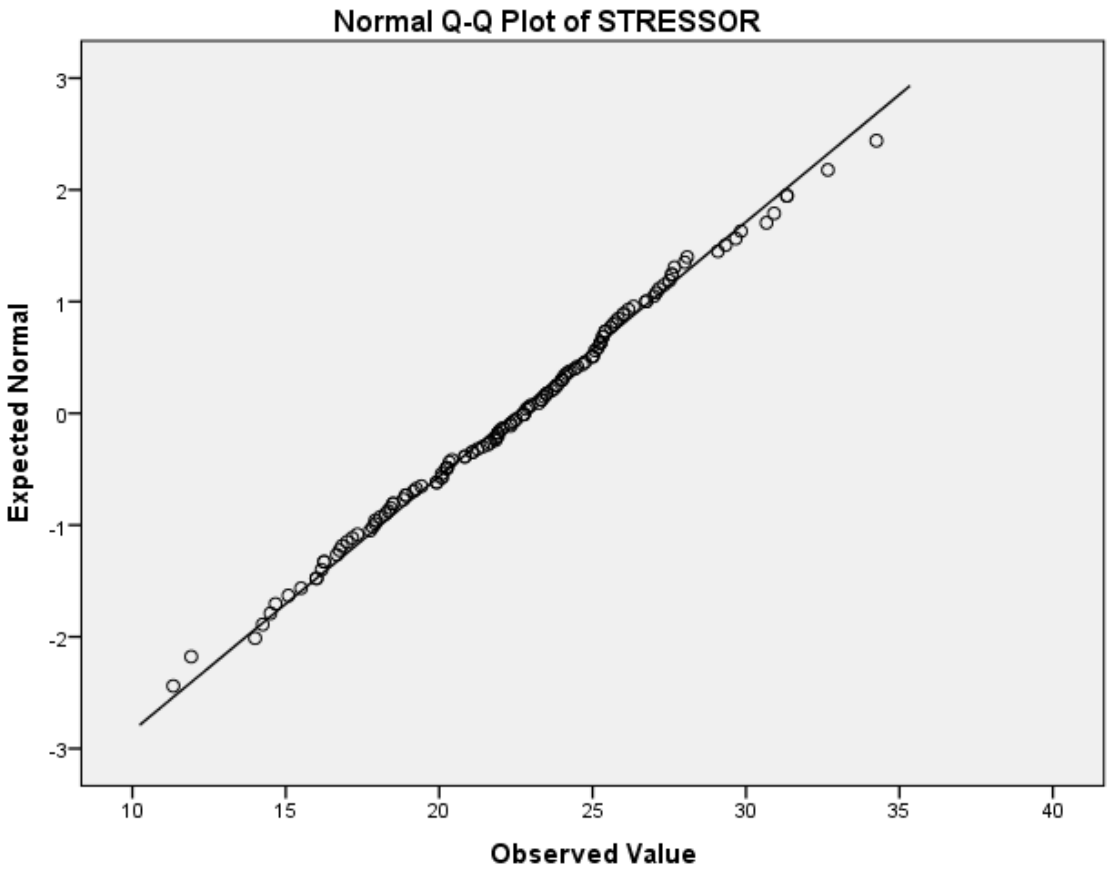

Figure C-1: Q-Q plot of STRESSOR scores showing a close fit with a normal distribution.

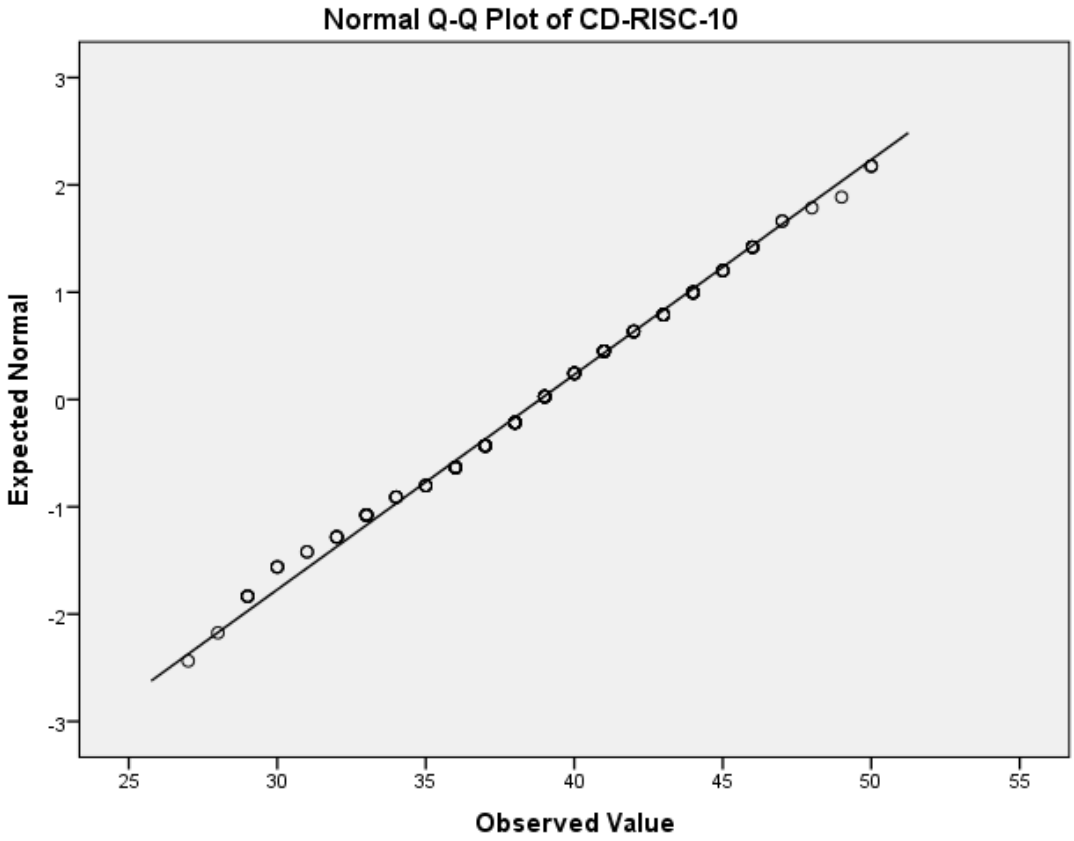

Figure C-2: Q-Q plot of CD-RISC-10 scores showing a close fit with a normal distribution.

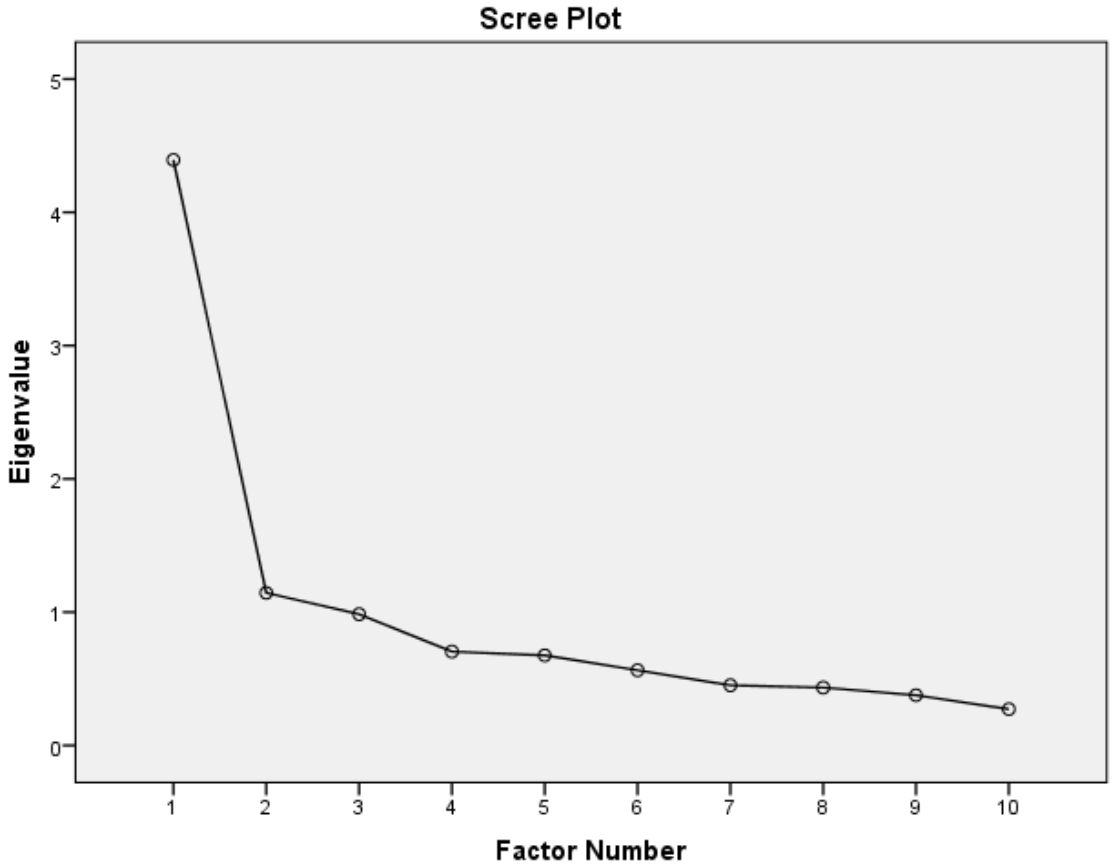

Figure C-3: Scree plot for exploratory factor analysis of CD-RISC-10 scores.

Table C-1: Factor loadings with a single-factor solution for exploratory factor analysis for the CD-RISC-10 items in this population.

CD-RISC-10 Item	Factor Loading
1	0.56
2	0.56
3	0.45
4	0.46
5	0.66
6	0.73
7	0.65
8	0.70
9	0.75
10	0.56

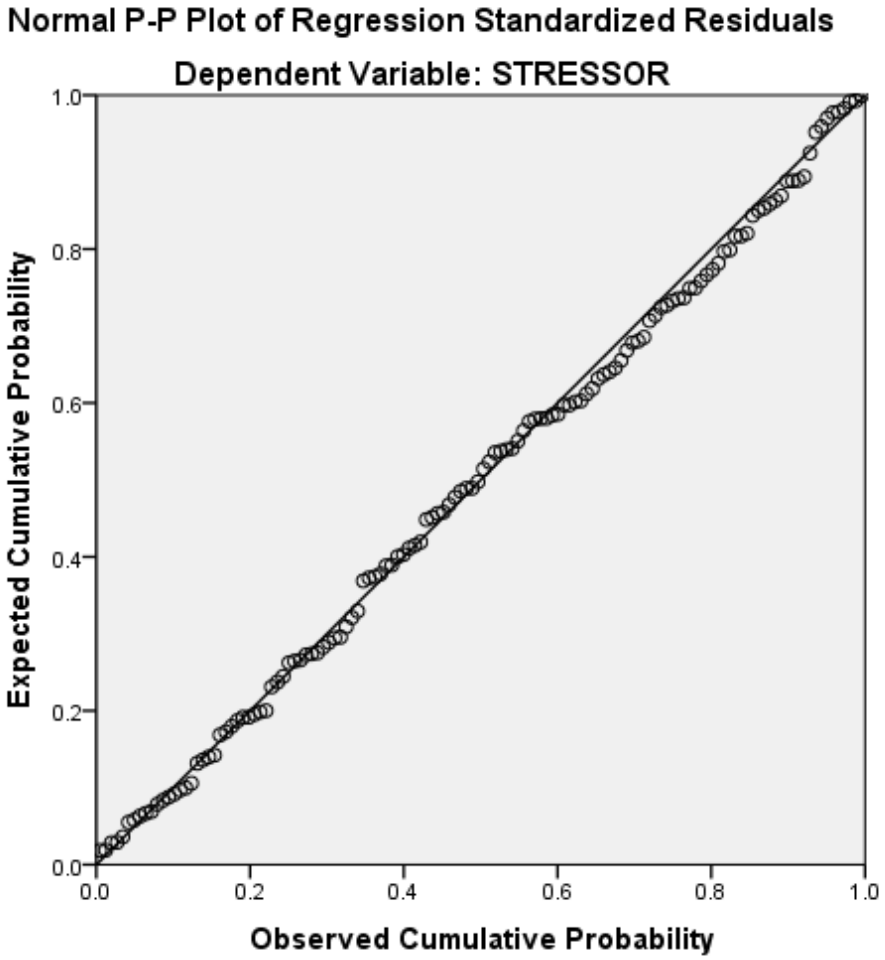

Figure C-4: p-p plot showing a normal distribution of residuals for the linear regression of STRESSOR against CD-RISC-10.

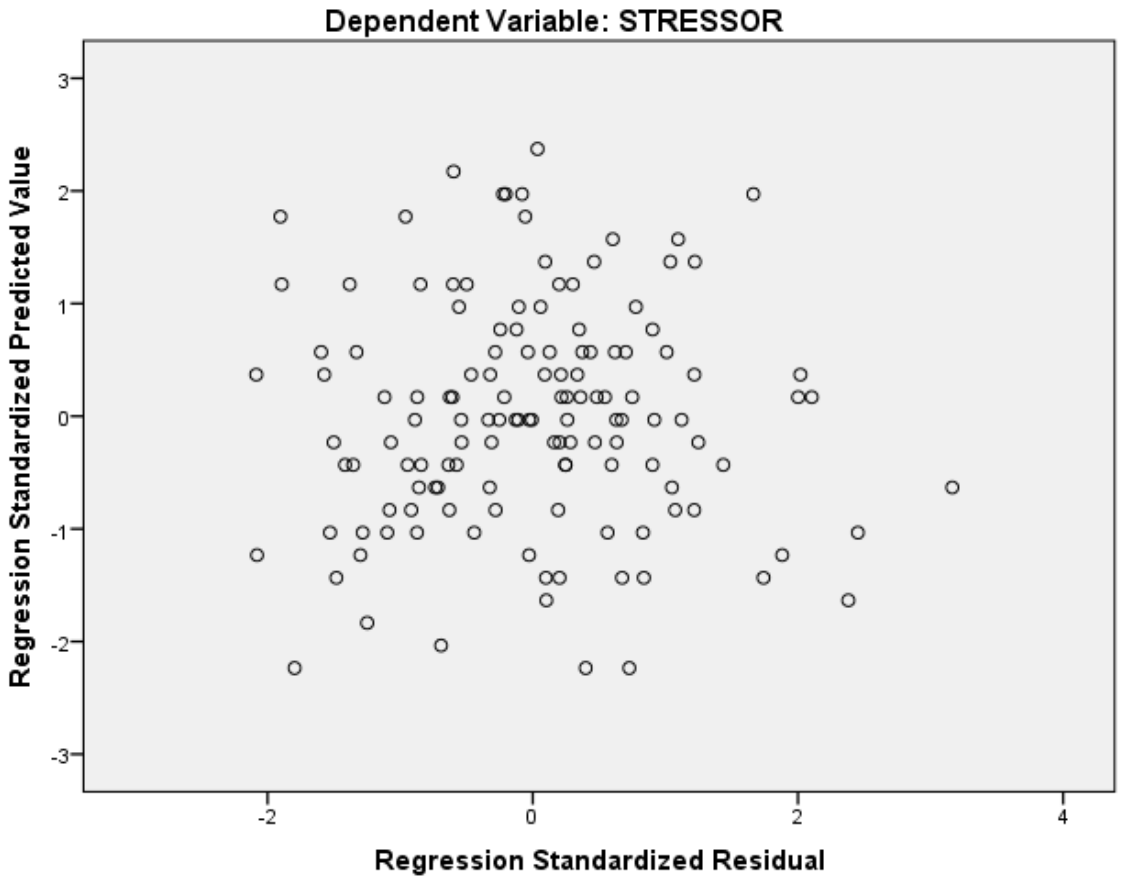

Figure C-5: A scatterplot of Standardized Predicted Values versus Standardized Residuals for the linear regression of STRESSOR versus CD-RISC-10. This plot demonstrates homogenous variance of residuals (homoscedasticity).

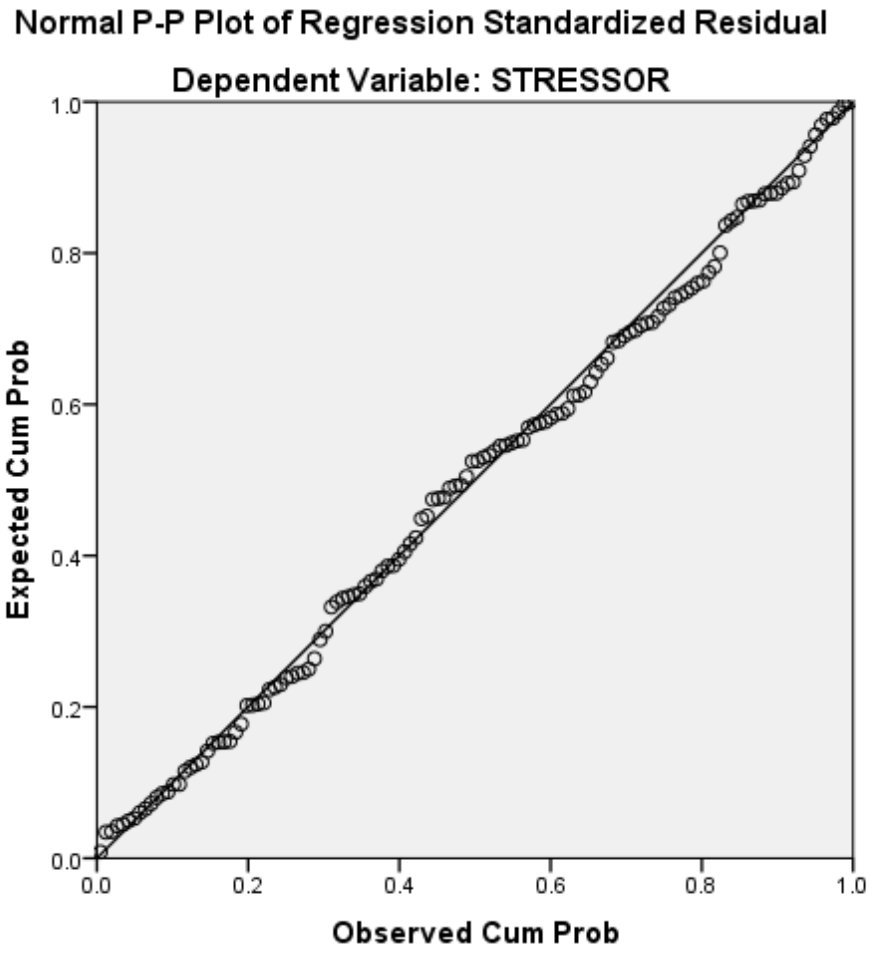

Figure C-6: p-p plot showing a normal distribution of residuals for the multiple linear regression of STRESSOR against CD-RISC-10 and year of training.

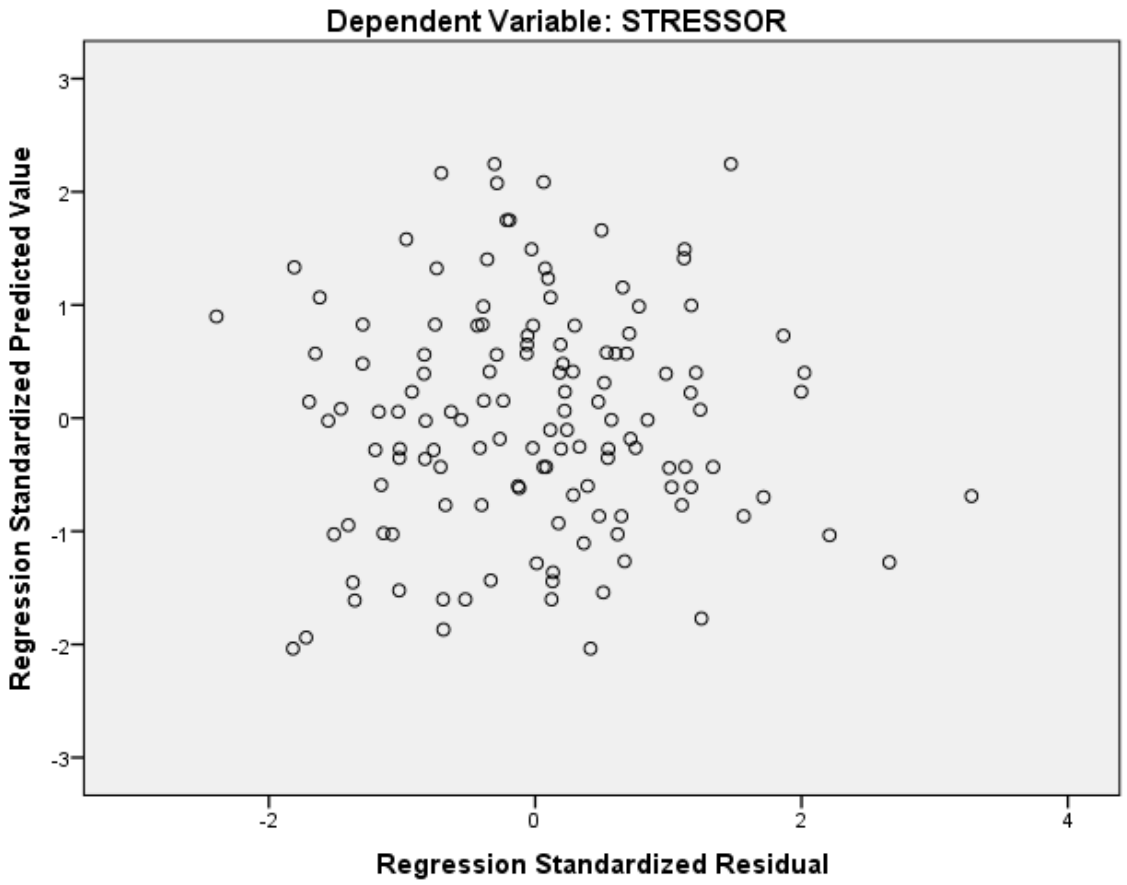

Figure C-7: A scatterplot of Standardized Predicted Values versus Standardized Residuals for the multiple linear regression of STRESSOR versus CD-RISC-10 and year of training. This plot demonstrates homogenous variance of residuals (homoscedasticity).

Appendix D: Research Ethics Approvals

Western Research

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Brent Lanting
Department & Institution: Schulich School of Medicine and Dentistry\Orthopaedic Surgery, London Health Sciences Centre

Review Type: Delegated
HSREB File Number: 108756
Study Title: Surgical Trainee Resiliency and Experiences of Stress in the Operating Room (STRESSOR)

HSREB Initial Approval Date: January 19, 2017
HSREB Expiry Date: January 19, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Revised Western University Protocol	Received January 3, 2017	
Revised Letter of Information & Consent		2016/12/21
Instruments	Survey for 2nd arm of study	
Instruments	Survey for 1st arm of study	
Data Collection Form/Case Report Form	CD-RISC assessment tool	2014/02/20
Recruitment Items	Recruitment Email 1st Arm (Ortho)	
Recruitment Items	Recruitment Email 2nd Arm (UWO)	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Western Research

Western University Health Science Research Ethics Board
HSREB Amendment Approval Notice

Principal Investigator: Dr. Brent Lanting
Department & Institution: Schulich School of Medicine and Dentistry\Orthopaedic Surgery,London Health Sciences Centre

Review Type: Delegated
HSREB File Number: 108756
Study Title: Surgical Trainee Resiliency and Experiences of Stress in the Operating Room (STRESSOR)

HSREB Amendment Approval Date: February 23, 2017
HSREB Expiry Date: January 19, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Instruments	Ortho survey - Received February 3, 2017	
Instruments	UWO survey - Received February 3, 2017	

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the amendment to the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

LAWSON
HEALTH RESEARCH INSTITUTE

LAWSON FINAL APPROVAL NOTICE

LAWSON APPROVAL NUMBER: R-17-007

PROJECT TITLE: Surgical Trainee Resiliency and Experiences of Stress in the Operating Room (STRESSOR)

PRINCIPAL INVESTIGATOR: Dr. Brent Lanting

LAWSON APPROVAL DATE: January 23, 2017

Health Sciences REB#: 108756

Please be advised that the above project was reviewed by the Clinical Research Impact Committee and Lawson Administration and the project:

Was Approved

Please provide your Lawson Approval Number (R#) to the appropriate contact(s) in supporting departments (eg. Lab Services, Diagnostic Imaging, etc.) to inform them that your study is starting. The Lawson Approval Number must be provided each time services are requested.

Dr. David Hill
V.P. Research
Lawson Health Research Institute

CURRICULUM VITAE

RICHARD NG, BSc, MD, MSc, FRCSC

Education

- Fellowship in Orthopaedic Trauma, Royal Infirmary of Edinburgh, 2017-2018
- Fellowship in Adult Hip and Knee Reconstruction, London Health Sciences Centre, 2016 – 2017
- MSc. in Surgery, University of Western Ontario, 2016 – 2017
- Orthopaedic Surgery Residency. University of Calgary, 2010 – 2016
- Medical Doctor (M.D.), University of British Columbia, 2006 – 2010
- B.Sc. in Mechanical Engineering, University of Alberta, 2002 – 2006

Certifications

- Fellow of Royal College of Surgeons of Canada (FRCSC) in Orthopaedic Surgery, 2016
- Medical Council of Canada Qualifying Examination (MCCQE) Part 1 and 2

Honors and Awards

- Award winning 2017 MSc in Surgery Colloquium Presentation.
- 2015 Spencer McLean Memorial Award, Division of Orthopaedic Surgery, University of Calgary
- 2006 Gold Medal from Association of Professional Engineers, Geologists, and Geophysicists of Alberta (APEGGA) for highest graduating GPA in Mechanical Engineering

Ongoing Research

Surgical Trainee Resilience and Experiences of Stress in the Operating Room

- **Richard Ng,** Brent Lanting, James Howard, Saad Chahine

Is Octaplex safe for reversal of warfarin anticoagulation in hip fracture patients?

- **Richard Ng**, Meer-Taher Shabani-Rad, Charles MacAdams
- Data collection complete, manuscript preparation underway

The clinical load and shift test: Is it better than the radiographic stress view for diagnosing instability in supination external rotation ankle fractures?

- R Buckley, L Harmer, **R Ng**, S Puloski, P Duffy, R Korley, K Carcary, D Brister
- Project funded and approved by ethics

Research and Publications

- Dressler, Jena L., **Richard T. Ng**, Alidad Amirfazli, and Jason P. Carey. "Development and evaluation of a multi-axis biomechanical testing apparatus for knee." International Journal of Experimental and Computational Biomechanics 1, no. 3 (2010): 271-295.
- **Ng, Richard**. “Polyhedra with Six Vertices.” Pi in the Sky Sep. 2002: 26-27.
- Barrington Leigh, Robert, and **Richard Ng**. “Minimizing Aroma Loss.” College Mathematics Journal 30 No. 5 (1999): 356-58.
- Barrington-Leigh, Robert and **Richard Travis Ng**. "Zigzag.” Abacus 8 No. 5 (1998): 318-320.

Presentations

- Western University Department of Surgery Research Day — Jun. 23, 2017
  Award Winning MSc Student Colloquium Presentation:
  Resiliency in the Operating Room: Exploring Trainee Stress During Surgery and the Role of Individual Resilience
- Canadian Orthopaedic Association Annual Meeting — Jun. 19, 2016
  Results of Octaplex for reversal of Warfarin anticoagulation in hip fracture patients
- University of Calgary Surgeons’ Day — Jun. 12, 2015
  Octaplex is effective for the reversal of warfarin anticoagulation in hip fracture patients
- Upper Extremity Rounds: Chronic Distal Biceps Ruptures — Oct. 1, 2014
- Arthroplasty Rounds: Bearing Choices in Young Adults — Sep. 4, 2012
- Plastic Surgery Rounds: Perilunate Dislocation — Sep. 14, 2010
- Trauma Rounds: Management of Pelvic and Acetabular Fractures — Jul. 30, 2010

Academic Half Day:

- Revision Knee Arthoplasty: Complications — Oct. 1, 2015
- Talar Osteochondral Lesions — Jun. 4, 2015
- Pediatric Elbow Fractures — Jan. 8, 2015
- Glenohumeral Arthritis — Oct. 29, 2014
- Tumor Case Presentations — May 15, 2014
- Knee: Rehabilitation and Orthotics — Dec. 19, 2013
- Shoulder and Humerus Anatomy and Cases — Jul. 18, 2013
- Hallux Valgus — Jun. 13, 2013
- Glenohumeral Arthritis — Nov. 1, 2012
- Total Hip Arthroplasty: Complications and Rehabilitation — Sep. 20, 2012
- Knee Osteoarthritis: Nonsurgical Treatment — Sep. 1, 2011
- Biomechanical Considerations of Fractures and Fixation — Apr. 28, 2011
- Knee: Patient Evaluation & Imaging — Mar. 17, 2011

Pediatric Orthopedics Rounds:

- Snapping Hip (Coxa Saltans) — Jan. 13, 2015
- DVT Prophylaxis in Pediatric Orthopaedic Patients — May 7, 2013
- Pediatric Radial Neck Fractures — Apr. 23, 2013
- Postoperative Blindness after Spine Surgery in the Prone Position — Jun 21, 2011