

Running title: Mental Skills Training in Surgery

Application of Mental Skills Training in Surgery: A Review of its Effectiveness and Proposed Next Steps

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Abstract

INTRODUCTION: Mental skills training, which refers to the teaching of performance enhancement and stress management psychological strategies, may benefit surgeons. Our objective was to review the application of mental skills training in surgery and contrast it to other domains, examine the effectiveness of this approach in enhancing surgical performance and reducing stress, and provide future directions for mental skills training in surgery.

MATERIALS AND METHODS: A systematic literature search of Medline, PubMed, PsycINFO, and ClinicalKey was performed between 1996 and 2016. Keywords included were mental readiness, mental competency, mental skill, mental practice, imagery, mental imagery, mental rehearsal, stress management training, stress coping, mental training, performance enhancement, and surgery. Reviews of mental skills interventions in sport and well-regarded sport psychology textbooks were also reviewed. Primary outcome of interest was the effect of mental skills on surgical performance in the simulated or clinical environment.

RESULTS: Of 490 identified abstracts 28 papers met inclusion criteria and were reviewed. The majority of the literature provides evidence that mental imagery and stress management training programs are effective at enhancing surgical performance and reducing stress. Studies from other disciplines suggest that comprehensive mental skills programs may be more effective than imagery and stress management techniques alone.

CONCLUSIONS: Given the demonstrated efficacy of mental imagery and stress management training in surgery and the incremental value of comprehensive mental skills curricula used in other domains, a concerted effort should be made to apply comprehensive mental skills curricula during surgical training.

Introduction

A career in surgery is among the most psychologically demanding professions one can enter. Surgeons are required to execute complex, fine-motor skills under stressful conditions, maintain focus on intricate technical details over the duration of a surgical procedure, adapt to changing situational demands, maintain sound clinical judgment, and effectively communicate with their surgical team to produce favorable and safe outcomes for their patients.¹⁻² The cognitive demands on surgeons increase further as surgical techniques evolve and need to be adopted into practice while maintaining a busy clinical schedule.

The literature suggests that when cognitive demands exceed one's ability to manage them, the resulting response is stress.¹ Excessive intraoperative stress can negatively influence surgeons' fine motor coordination, emotional state, concentration, communication with the surgical team, and decision making ability which may lead to poor patient outcomes.³ We recently surveyed surgeons' perceptions of intraoperative stressors and coping strategies, and found that 40% of respondents had witnessed an intraoperative complication that was directly related to the surgeon's stress-level.⁴ We also found that 82% of surveyed surgeons felt that formal stress management training would be beneficial. Despite surgeons' desire for stress management training, little is being done to develop psychological competencies to manage intraoperative demands.

While the Accreditation Council of Graduate Medical Education (ACGME) has appropriately implemented a competency-based approach that focuses on milestone achievement during resident training in an effort to improve the performance of graduating residents, this approach that focuses on six domains (i.e., patient care, medical knowledge, practice-based learning and improvement, interpersonal and communication skills, professionalism, and systems-based practice⁵) does not appear to adequately address⁵ the aforementioned psychological factors

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that could negatively impact surgical performance. The inherent psychological demands of surgery, the evolution of surgical techniques, and an increased emphasis on patient safety highlight the need for the development of additional methods to enhance the performance of surgeons. In a study of psychological factors that contribute to performance excellence in surgery, McDonald et al. (1995) interviewed 33 highly proficient surgeons.⁶ Participants reported that mental readiness was a greater determinant of surgical success than technical or physical readiness, and the most important mental factors for successful surgery were: mental readiness, self-belief, positive mental imagery, full focus, distraction control, commitment, and constructive evaluation. The authors contend that surgical residents may benefit from structured mental skills training.

Mental skills are comprised of psychological competencies and tools that have been shown to improve performance in several disciplines^{2,4,6-33}. Mental skills training programs have been successfully implemented with athletes,³⁴⁻³⁷ performing artists,³⁸⁻³⁹ military personnel,⁴⁰ business professionals,⁴¹ and police special forces.⁴² Moreover, some studies have indicated that comprehensive mental skills training curricula can offer even greater benefits to performance than single-skill interventions, as they aid performers' flexibility to manage a variety of situations.³⁶⁻⁴⁰ In spite of a dearth of evidence demonstrating the effectiveness of mental skills training in high-stress occupations, there is limited research on how these skills can influence surgical performance.

The purpose of this review was to identify how mental skills training has been applied to surgery and examine its effectiveness in enhancing surgical performance, identify additional mental strategies that have been applied successfully in other disciplines, consider the potential benefits of applying these skills with surgeons, and provide future directions for the incorporation of mental skills training into surgical residencies.

Materials and Methods

A systematic literature search was performed from 1996 through 2016 for relevant articles on Medline, PubMed, PsycINFO, and ClinicalKey databases published since 1996. Keywords used were *mental readiness, mental competency, mental skill, cognition, mental practice, imagery, mental imagery, mental rehearsal, sport or performance psychology, stress management training, stress coping, mental training, performance enhancement, surgery, surgical performance, medicine, and medical competency*. The search produced 490 abstracts that were reviewed by two of the authors (NA and SH), who identified 161 relevant studies and pulled the full articles for further detailed review. To be included in this paper, the primary outcomes of mental skill interventions had to be surgical performance in a simulated environment or in the OR independent of involved subjects (i.e., experienced surgeons, surgical trainees, or novices).

Also, correlational studies were included if the researchers investigated the association between mental skills and surgical performance. Reviews and position papers on the effects of mental skills on surgical performance were also included, as they provide contextual discussion on the potential usefulness of mental skills training in this domain. Articles were excluded if the primary outcome was not surgical performance, or if the intervention was related to the impact of a non-mental skill on surgical performance or stress (i.e., music in the OR). Following these criteria, 28 sources were selected for inclusion in this review. Given the extensive amount of research that has been done on mental skills training in sports, published reviews of mental skills interventions and well-regarded sport psychology textbooks were also reviewed to investigate if any differences in the application of mental skills exist between surgery and sports and to assess whether other strategies exist that surgery could benefit from.

Results

Definition of Mental Skills

The term 'mental skills' is defined as a set of trainable mental abilities that underpin successful learning and performance.⁴³ In sport psychology, where mental skills have been applied widely, the primary goal of these psychological interventions is to consistently facilitate the ideal mental conditions that enable athletes to perform at their best.⁴⁴ Mental skills interventions aim to help performers consistently perform in the upper range of their abilities. Specific mental skills applied for performance enhancement have included mental imagery,⁴⁵⁻⁴⁶ energy management,^{44,47-48} attention and thought management,⁴⁸⁻⁴⁹ goal-setting,⁵⁰ and performance routines.⁵¹ In the following paragraphs we will review which of these mental skills have been used in surgery, to what extent, and what evidence of efficacy exists.

Mental Imagery

Mental imagery (synonymous with mental rehearsal and mental practice) is perhaps the most widely researched mental skill in performance psychology literature, and has been shown to be an effective method of enhancing performance. Imagery refers to the quasi-sensory experiences, which exist in the mind in the absence of those stimulus conditions, and can produce genuine sensory and perceptual experiences.⁴⁵⁻⁴⁶

Comprehensive reviews on the efficacy of imagery to enhance sport performance have shown significant benefits compared to controls.⁴⁸ Similar to athletic performance, imagery may have a number of performance enhancement benefits to surgical performance and preparation; it could help surgeons mentally prepare for a procedure ahead of time,⁴⁶ build their confidence and direct their attention on what is required to perform the procedure,^{46,52} identify potential

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complications and solutions,⁵² and help prime their muscles to physically perform as the same neural pathways are excited through imagery.⁵³

Indeed, a review that explored the potential role of imagery practice during the acquisition of surgical skills suggested that it could help surgical trainees better understand the steps of a procedure and think about how to actually perform the procedure themselves. Stated advantages included reducing the learning curve of a new procedure, transfer skills from an established technique to a novel, but related technique, limit the decay of skills, and optimize preparation for a complex procedure.⁷ Another review by Cocks et al. (2014) explored how imagery has been applied with athletes and surgeons of different experience levels and found that imagery is most useful when it is applied to expert performers as a supplemental training tool to refine and improve skills.⁸ The authors argued that many surgeons could benefit by adopting imagery as part of their surgical preparation. A recent meta-analysis studied the effects of randomized controlled trials (RCTs) that applied imagery in the acquisition of surgical skills.⁹ The majority of examined studies (i.e., five of nine) found that imagery had a positive impact on the acquisition of surgical skills. The authors contend that imagery is an effective adjunct training tool to physical practice that can aid in surgical skill acquisition.

Another paper that examined the application of imagery with surgeons, suggests that imagery has been unofficially implemented in surgical education for years.¹⁰ According to the author, surgeons use imagery to review cases before surgery, but this practice is relatively unstructured. The regular application of imagery with 30 surgical trainees in urogynecology by the author led to high satisfaction among trainees who indicated that imagery sessions were among the most valuable training elements of their rotation. Imagery has also been proposed for the practice of uncommon neurosurgical procedures before performing them on patients,¹¹ as a low-

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cost educational supplement for surgical simulation training in neurosurgery,¹² and as a method of facilitating deliberate practice by rehearsing specific tasks to overcome weaknesses in performance.¹³

Importantly, besides expert opinion, several RCTs have investigated the effects of imagery on the performance of surgeons of various experience levels. For surgical novices, Arora et al. (2011a) demonstrated that a group that received imagery training in addition to physical practice during simulated laparoscopic cholecystectomy (LC) training significantly outperformed controls that received physical practice alone based on Objective Structured Assessment of Technical Skills (OSATS) scores and had a shorter learning curve of the procedure.¹⁴ Sanders et al. (2004) also implemented an imagery intervention with novices, and found that participants who received physical suturing practice followed by guided imagery training performed statistically equal to controls who received additional physical practice when suturing a live rabbit model.¹⁵ Sanders et al. (2008) found that physical practice followed by guided imagery was as effective as physical practice on participants' suturing performance on a live animal model and imagery was more effective at aiding the transfer of surgical skills acquired in practice to a live animal model when compared to controls.¹⁶ These findings indicate that imagery may lower the cost and resource consumption of surgical training, as imagery, which costs relatively little to implement compared to physical training, is just as effective and actually enhances the transfer of surgical skills to the clinical environment.

For first year medical students learning to perform a cricothyrotomy, imagery has also been shown to be effective at enhancing skill acquisition and performance when compared to controls.¹⁷ Further, Eldred-Evans et al. (2013) assigned medical students to training groups that included fundamentals of laparoscopic surgery simulation (FLS) training only, laparoscopic virtual reality

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(VR) and FLS training, or FLS and imagery practice.¹⁸ The group that received the combined FLS and imagery training significantly outperformed the other groups in several measures of laparoscopic skills (i.e., time to complete procedure, accuracy, precision, and overall performance on FLS box and VR simulator tasks). Donnon et al. (2005) found that medical students that practiced imagery in addition to physical training in the early stages of laparoscopic suturing training slightly outperformed controls who only received physical training.¹⁹

On the other hand, imagery alone cannot replace physical practice.²⁰ Mulla et al. (2012) compared the performance of randomly assigned medical students to training either on the FLS simulator, a VR laparoscopic simulator, imagery practice only, or a control group and found that the imagery group had poorer performance compared with the FLS and VR groups. This study demonstrated the importance of implementing imagery as an adjunct to physical practice, rather than as the sole method of training. In another study, researchers found no significant differences in task time and instrument tip trajectory during laparoscopic suturing on a live Nissen fundoplication model between a group that received imagery and physical practice and a group that received only physical practice.²¹ However, 61% of participants in the imagery group rated the imagery practice as highly effective and indicated their intention to continue using it after study completion. It is unclear why imagery did not work in this study unlike the majority of available literature that supports its effectiveness. The authors postulated that it might have been more effective if implemented with more experienced surgical trainees (i.e., surgical residents).

Of studies that examined the effectiveness of imagery for surgical trainees, Komesu et al. (2009) found that obstetrics and gynecology residents that received imagery training in cystoscopy significantly outperformed controls based on objective measures of surgical performance and considered imagery to be a more useful pre-performance preparation strategy than reading a

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standard textbook.²² Further, Arora et al. (2010b) performed a study with 10 experienced surgeons (>100 LCs) and 10 novice surgeons (< 10 LCs) to develop and validate imagery as a training technique for laparoscopic surgery.²³ They found that after undergoing imagery training for the LC procedure, novice surgeons significantly improved their knowledge and confidence to perform a LC, and their ability to imagine the LC procedure. While experienced surgeons were more adept than novices at imagining the LC prior to training, they still improved their confidence and kinesthetic sensory experiences (i.e., measured with the Mental Imagery Questionnaire) for performing a LC. The authors proposed that imagery may be a time- and cost-effective technique to improve surgeons' confidence and knowledge to perform a LC. Additionally, in a recent RCT of the effects of imagery on the laparoscopic jejunojejunostomy performance of senior surgical residents during a simulated crisis scenario, Louridas et al. (2015) found that imagery trained participants demonstrated significantly greater advanced laparoscopic performance and technical skill improvements (measured by OSATS and bariatric OSATS) than controls.²⁴ Another recent RCT studied the effects of imagery on emergency, anesthesia, and surgery residents' teamwork (i.e., assessed by expert raters using the Mayo High Performance Teamwork Scale: MHPTS) during a simulated trauma resuscitation scenario.²⁵ The authors found that the imagery group significantly outperformed controls in teamwork, and concluded that imagery is an effective tool to increase team-based skills. In another recent study of the effects of guided mental imagery on residents' performance on two methods of simulated LCs (i.e., physical task on a torso trainer and VR simulator), Paige et al. (2015) found that imagery was related to improved performance of a VR two-hand clip-and-cut task.²⁶ Additionally, imagery was associated with significantly improved confidence, knowledge, and visual imagery (i.e., being able to see the image in one's mind).

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In contrast, Geoffrion et al. (2012) found that imagery prior to vaginal hysterectomy (VH) did not enhance residents' surgical performance when compared to controls.²⁷ Nonetheless, residents who practiced imagery reported that they felt that their performance was improved after imagery practice, and rated their confidence to perform a VH as higher compared to the control group. Not assessing the participants' imagery ability (i.e., one's ability to generate and control their mental images) and imagery script compliance (i.e., actual adherence to the imagery script) have been cited as important limitations of this study.²⁸

Imagery has also been found effective when applied with experienced surgeons. Immenroth et al. (2007) conducted a randomized controlled trial with 98 experienced surgeons undergoing laparoscopic training, and assigned participants to a mental training group, an additional technical training group, and a control group.²⁹ The mental training group worked with a performance psychologist to develop a preoperative mental skills routine, which included self-talk of the steps to perform a LC, a brief relaxation exercise, and imagery related to the procedure. The authors found that LC performance (assessed with OSATS) on a physical simulator was significantly higher at post-test for the mental training group that also regarded mental skills as a valuable tool in their education. The authors concluded that in addition to physical training, mental training is a cost-effective method of optimizing surgical outcomes for LCs. In their study of the influence of an imagery intervention on open and endovascular arterial procedure outcomes, Patel et al. (2012) found that vascular surgeons who received imagery training had significantly less intraoperative errors during critical stages of arterial procedures.³⁰ The authors concluded that surgeons who engage in structured imagery prior to critical stages of procedures may experience a reduction in the severity and occurrence of intraoperative errors.

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In a comprehensive review of the application of imagery in surgery, Sevdalis et al. (2013) identified a number of deficits in the literature that warrant consideration.³¹ The authors justifiably argue that some studies in this area are limited by methodological weaknesses surrounding their lack of adequate mental imagery assessments, use of poorly validated mental imagery interventions, and unsatisfactory experimental designs. While we agree that there are shortcomings in some studies on imagery and surgical performance, there is appreciable evidence to support further investigation of the impact of imagery to enhance surgeons' performance. Sevdalis et al. (2013) offer a similar conclusion, and explain that imagery is a cost-effective training tool that can be used easily without the need for dedicated resources, and is effective at helping surgeons prepare for surgical performance.

In summary, the majority of the available literature supports the effectiveness of imagery in enhancing surgical performance for all levels of experience and suggests that imagery should be an integral part of surgical training. Imagery has been shown to be a cost-effective training supplement to physical practice that cuts down on resource consumption,^{12-13,17,23,29,31} and enhances surgeons' performance through improved acquisition and performance of surgical skills,^{13-16,18-19,22,24,29-30} knowledge,^{11,23,26} confidence,^{23,26-27} and team-based skills.²⁵

Stress Management Techniques

Stress can be a significant barrier to successful surgical performance. For surgeons, there are a number of potential factors that can lead to stress.³² Surgical novices are the most susceptible to be negatively affected by intraoperative stress, as they have far less experience and coping resources to manage the cognitive demands of surgery.¹ In a RCT to determine if imagery could be implemented with novice surgeons to reduce their perceived stress while performing VR LCs, participants experienced significantly lower stress compared to a control group (measured

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subjectively with the State-Trait Anxiety Inventory (STAI), and objectively with heart rate and cortisol levels).³² Besides imagery, stress management interventions have also incorporated energy and attention management skills to reduce the negative impact of stress on surgical performance.

Energy Management

Energy management skills are often incorporated in stress management programs due to their ability to help performers regulate physiological arousal, which has been identified as one of the most impactful factors to physical performance.⁵⁴ The catastrophe model, which attempts to explain the arousal-performance relationship, asserts that performance is determined by the dynamic interaction of physiological arousal and cognitive anxiety.⁵⁵ If cognitive anxiety is low, performance will follow an inverted-U shape as arousal increases from low to high. However, if cognitive anxiety is elevated, performance will increase with arousal to a certain point after which there will be a dramatic drop in performance. This performance degradation is drastic and very difficult to recover from, which illustrates the need for performers to regulate their arousal. One of the most impactful methods to reduce the effects of stress is to use breathing-based relaxation strategies that focus on deep, rhythmic, diaphragmatic breathing to counter the shallow breathing response to stress.⁴⁷⁻⁴⁸ Shallow breathing is the autonomic response to prepare the body to fight or flee against a perceived threat, to ensure oxygen is entering the blood stream. Deep breathing counters this response, and leads to a calming effect.

Attention/Thought Management

For high performers in any domain, optimal concentration is one of the most essential cognitive factors for performing one's best.⁵⁶ The most significant element of concentration is selective attention on task-relevant cues and the ability to screen out distracting and irrelevant stimuli. A potential barrier to concentration is when attention is directed to stress, anxiety, and negative

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thoughts. Attention and thought management skills like cognitive restructuring (i.e., acknowledging a negative thought and reframing it from a positive perspective), positive thought control (i.e., replacing negative thoughts with positive self-instruction), and attentional refocusing (i.e., switching focus from stressful to innocuous stimuli) are effective at directing one's attention to relevant, constructive thoughts.⁴⁸⁻⁴⁹

Maher et al. (2013) implemented a stress management program with first- and third-year surgical residents who were asked to perform a high-stress patient care module.² The stress management group received training in energy and attention management techniques and imagery. While not statistically significant, there was a trend toward enhanced technical performance (i.e., measured with OSATS) for the experimental group, yet there were no differences in anxiety levels (i.e., subjectively measured with the STAI, and objectively measured with heart rate variability). The limitations of this study, mainly lack of randomization and the overwhelming amount of stress from the simulation, may have impacted the researchers' ability to detect notable differences in stress. However, the stress management training was rated as valuable by 91% of participants. In a RCT that implemented a stress management intervention with experienced surgeons, the experimental group displayed significantly increased observed teamwork (i.e., measured with the Observational Teamwork Assessment for Surgery), increased coping skills (i.e., measured with the Surgical Coping Questionnaire), and reduced stress (i.e., measured with heart rate variability) compared to controls.³³ The authors assessed performance during a simulated carotid endarterectomy and implemented imagery to help participants rehearse the endarterectomy procedural steps, enhance their awareness of potential stressors, and identify the need for positive coping responses. The intervention also consisted of general relaxation training, which the authors

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did not elaborate on. Experimental group participants experienced improved technical skills, confidence, and decision-making after this training.

While few studies exist, the results from stress management interventions with surgeons are encouraging. Mental skills like imagery^{32,33} and relaxation training³³ have been shown to be effective at reducing surgeons' stress. It is clear from the aforementioned studies that the combination of mental skills may offer increased benefits to surgeons. Nevertheless, comprehensive mental skills training curricula are rarely used in surgery but have proven effective in other high-stress domains as demonstrated in the next paragraphs.

Comprehensive Mental Skills Training Programs

The benefit of comprehensive mental skills training programs is that rather than implementing a single mental skill, which may be effective at improving one aspect of performance, they offer much broader benefits to performance by implementing several mental skills. The mental skills can then be used to help the performer adapt to changing situational demands and overcome most performance barriers. Noteworthy mental skills that have been prominently included in comprehensive programs outside of surgery include goal setting and pre-performance routines.

Goal Setting

Goal setting is a motivation theory of human behavior that attempts to explain the relationship between goals and task performance.⁵⁰ Locke and Latham (1990) proposed that goals represent the object or aim of an action, and can consist of completion of a task or attaining a specific standard of proficiency. There are several moderator variables that can influence the effectiveness of goals, including: difficulty (i.e., linear relationship between difficulty and performance), specificity (i.e., specific goals are more effective than vague goals), and time orientation (i.e., short vs. long-term).

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Performance routines

Besides goal setting, surgeon's preparation for surgery may benefit from the implementation of performance routines that consist of a combination of the aforementioned mental skills, to develop consistent habits for performance. In athletics, performance routines are considered to be a combination of pre-planned sequences of task-relevant thoughts, arousal-related cues and ritualized patterns of behaviors that athletes engage in prior to the start of their performance.⁵¹ It is generally believed that routines help performers focus their attention on task-relevant cues, achieve their optimal level of arousal, and trigger well-learned movement patterns. In a review of performance routines in sport, Cotterill (2010) found that elite athletes have consistent routines in duration and behavioral composition for every performance.

Several studies have demonstrated the effectiveness of comprehensive mental skills curricula. Von Guenther et al. (2010) implemented weekly mental skills training sessions with six elite cross-country skiers that included skills such as: goal setting, imagery, energy management, attention management, confidence, motivation, and performance routines.³⁶ The program's effectiveness was assessed by comparing scores on psychological skill assessments at baseline and three follow-up periods. At the conclusion of the competitive season, all participants improved in goal setting, 83% improved in self-talk, relaxation, and imagery scores while reducing their anxiety, 67% improved in emotional control and self-confidence, and 50% improved their attentional control. Lastly, all skiers rated the effectiveness of the program as high. While the sample size for this study was small, the results indicate a high-level of efficacy for comprehensive mental skills training. Mamassis and Doganis (2004) introduced a comprehensive mental skills program with elite junior tennis players.³⁷ This program included goal setting, attention and energy management strategies, and imagery. The researchers found that when compared to controls, the

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mental training group demonstrated higher self-confidence, and shifted their perception of how anxiety impacted performance indicative that cognitive restructuring led to a positive change in their perceptions of anxiety.

Comprehensive mental skills programs have also been used with musicians. Clark and Williamon (2011) developed a music-specific mental skills program and delivered it to a group of advanced music students, who integrated the skills in their musical training over a period of nine weeks.³⁸ The authors found that the experimental group enjoyed practice activities more, experienced a significant increase in self-confidence, and had more vivid imagery compared to controls. This group also perceived greater control over anxiety than the control group. In another study with musicians, researchers implemented a short-term cognitive restructuring intervention with thirty-three students, novices, and professionals.³⁹ The intervention consisted of three group workshops that taught participants how to increase self-awareness, attention and energy management strategies, and imagery to improve confidence and concentration. The researchers found that the experimental group experienced significantly decreased self-reported anxiety and increased musical performance quality (i.e., while the control group's performance decreased).

Another prominent area where mental skills training has been applied is the armed forces. McCrory et al. (2013) introduced a mental skills training program consisting of goal setting, imagery, and attention management during individual mental skills coaching with military pilot trainees to enhance their confidence to operate the aviation equipment and manage stress. At the conclusion of the study, participants displayed significantly increased confidence, reduced anxiety, and increased self-regulatory behavior (e.g. flight planning, remembering flight brief information, contingency planning, etc.). The authors argued that mental skills training programs are a cost-

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effective method of enhancing learning strategies, reducing training-program attrition, and reducing training and retraining costs.

Comprehensive mental skills training programs have clearly been shown to be effective at enhancing performance in a variety of domains. These programs are versatile and help performers adapt to dynamic and cognitively demanding performance situations. While such curricula have rarely been used in surgery, their effectiveness and preliminary results of studies applying them to surgery^{32,33} suggest that they should be considered for implementation in surgical training.

Discussion

A career in surgery is an incredibly psychologically demanding profession, as surgeons are required to maintain attention on critical details for extensive periods of time during procedures, complete extremely complex fine-motor skills under duress, maintain decision making ability in high-stress clinical situations, and be cognitive flexible to adjust to ever-changing situational demands.¹ These cognitive demands, among others, can create stress and ultimately lead to poor patient outcomes. Surgical trainees, who have limited first-hand experience performing surgical procedures, may be particularly susceptible to experience deleterious effects to surgical performance due to stress.

Mental skills, or trainable psychological techniques, have been shown to enhance performance in other domains and attenuate performance declines in response to stress.³⁴⁻⁴² Skills like mental imagery,⁴⁵⁻⁴⁶ energy management,^{44,47-48} attention management,⁴⁸⁻⁴⁹ goal setting,⁵⁰ and pre-performance routines⁵¹ are particularly effective mental skills for performance enhancement. There have been increasing attempts to implement mental imagery^{10,14-27,29-30} and stress management programs^{2,32-33} with surgeons. The research on mental skills in surgery has largely demonstrated that these skills are highly effective at enhancing surgical performance and skill

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acquisition,^{13-16,18,22,24,29-30} increasing knowledge,^{11,23} confidence,^{23,26-27,} team-based skills,²⁵ and reducing stress³²⁻³³ in surgeons of all experience levels. However, in addition to mental imagery, which has received the bulk of attention in surgical literature, the other skills we have identified may be beneficial to surgeons.

For surgeons, energy management techniques, which include relaxation strategies like centered breathing that aim to counter the autonomic response to increased adrenaline,⁴⁷⁻⁴⁸ may be effective to ensure that arousal is maintained at an optimal level for performance in situations during surgery that cause stress levels to increase. Surgeons may also be able to derive performance benefits from attention and thought management skills, as these techniques may be able to prevent their thoughts from shifting off-target or quickly bring them back on-target, which can help maintain their full concentration to the procedure. Goal setting, the process of setting a series of specific, stepwise goals at the intraoperative level may help orient surgeons to what is required to prepare for the next step in a procedure and work towards completion of the procedure sequentially. While most surgeons are likely setting goals for procedures informally, they would likely benefit greatly from regular, formalized goal-setting in their surgical preparation. Performance routines are also pertinent to surgical performance, as cognitive mediation prior to performance could help surgeons attend to task-relevant thoughts and eliminate external distractions prior to performance. Furthermore, routines may help surgeons achieve their Individual Zone of Optimal Functioning, which is a personalized combination of thoughts, emotions, and level of cognitive and physiological arousal that enable performers to optimize their performance.⁵⁶ While these techniques have been highly effective in other disciplines, they have rarely, if ever, been applied to surgical training (see Figure 1).

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Comprehensive mental skills curricula offer even greater performance enhancement benefits, as they offer training on multiple mental skills that help performers better adapt to changing situational demands during performance. Evidence on the high efficacy of comprehensive mental skills curricula has been displayed in athletics,³⁶⁻³⁷ the performing arts,³⁸⁻³⁹ and the military.⁴⁰ Our review suggests that comprehensive curricula, that include the aforementioned mental skills, should be implemented in surgery and be adopted widely as surgeons can clearly benefit from them. The authors of this review are currently developing such a comprehensive mental skills curriculum for surgeons and examining its effectiveness during surgical training.

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Table 1. Mental Skills Research in Surgery

<i>Authors</i>	<i>MS Intervention</i>	<i>Subjects</i>	<i>Aim of Study</i>	<i>Performance Measure</i>	<i>Outcomes</i>
Aoun et al 2011	Imagery	Surgeons	Position paper on whether imagery can enhance neurosurgical skills	N/A	Imagery proposed as a method to practice uncommon neurosurgical procedures before performing them
Arora, Aggarwal, Sevdalis et al 2010	Imagery	Experienced surgeons and surgical novices	RCT to develop and validate imagery as a training technique for laparoscopic surgery	Knowledge, confidence, ability to imagine a laparoscopic cholecystectomy	Novice surgeons significantly improved their knowledge, confidence, and ability to imagine the LC procedure; experienced surgeons improved their confidence and kinesthetic sensory experiences to perform LC
Arora, Aggarwal, Sirimanna et al 2010	Imagery	Surgical novices	RCT to study the effects of imagery on surgical performance	Simulated Laparoscopic Cholecystectomy, measured with OSATS	Imagery training in addition to physical practice significantly improved performance and shortened learning curve compared to controls
Arora, Aggarwal, Moran et al 2011	Imagery	Surgical novices	RCT to assess if imagery can reduce stress while performing VR Laparoscopic Cholecystectomy	Stress measured with STAI, heart rate, and cortisol.	Imagery group experienced significantly lower stress compared to a control group
Bathalon et al 2005	Imagery	Surgical novices	RCT to determine effects of imagery on surgical acquisition and performance	Simulated cricothyrotomy, assessed with OSCE testing the performance of the different steps of the technique, the time required and its fluidity	Imagery was shown to be effective at enhancing skill acquisition and performance compared to a control group
Cocks et al 2014	Imagery	Surgeons of all experience levels	Review of how imagery has been applied with athletes and surgeons	N/A	Imagery is most useful to expert performers as a supplemental training tool

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Donnon et al 2005	Imagery	Surgical novices	RCT to assess the effects of imagery on laparoscopic suturing performance	Performance on a laparoscopic training apparatus	Imagery in addition to physical was more effective than physical training alone in the early stages of skill acquisition
Eldred-Evans et al 2013	Imagery	Surgical novices	RCT to assess the effects of imagery on laparoscopic surgery performance	Performance on FLS box and VR simulator tasks	Group that received the combined FLS and imagery training significantly outperformed the other groups in several measures of laparoscopic skills
Geoffrion et al 2012	Imagery	Surgical residents	RCT to assess the effects of imagery on vaginal hysterectomy performance compared to controls	Surgeon-rated, procedure-specific global rating scale	Imagery did not enhance residents' surgical performance compared to controls; Imagery group reported that their performance was improved after imagery practice, and rated their confidence to perform a VH as higher compared to controls
Hall 2002	Imagery	Surgeons of all experience levels	Review of impact of imagery on surgical skill acquisition	N/A	Imagery practice aids the explicit learning of surgical skills
Immenroth et al 2007	Routines, self-talk, relaxation, imagery	Experienced surgeons	RCT to assess impact of mental training, additional technical training, or no additional training on surgical simulator performance	Laparoscopic cholecystectomy performance on a physical simulator, measured with OSATS	LC performance was significantly higher at post-test for the mental training group
Jungmann et al 2011	Imagery	Surgical novices	RCT to test of effects of imagery and physical practice vs. physical practice only	Task time and instrument tip trajectory during laparoscopic suturing on a live Nissen fundoplication model	No significant differences in task time and instrument tip trajectory, 61% of participants in the imagery group rated the imagery practice as highly effective
Komesu et al 2009	Imagery	Surgical residents	RCT of effectiveness of imagery compared to controls who read a textbook	Objective measures of cystoscopy performance	Imagery group significantly outperformed controls

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<p> Lorello et al 2015 </p>	<p> Imagery </p>	<p> Emergency medicine, anesthesia, and surgical residents </p>	<p> RCT of the effects of imagery on team-based skills </p>	<p> Teamwork measured with MHPTS </p>	<p> Imagery group significantly outperformed controls in teamwork </p>
<p> Louridas et al 2015 </p>	<p> Imagery </p>	<p> Surgical residents </p>	<p> RCT of the effects of imagery on surgical performance in a simulated crisis scenario </p>	<p> Laparoscopic jejunojunostomy performance, measured with OSATS and bariatric OSATS </p>	<p> Imagery trained participants demonstrated significantly greater advanced laparoscopic performance and technical skill improvements </p>
<p> Maher et al 2013 </p>	<p> Relaxation, attention management, imagery, positive self-talk </p>	<p> Surgical residents </p>	<p> RCT to determine the effects of a stress management program during the performance of a high-stress patient care module </p>	<p> Technical performance (OSATS), stress (STAI, HRV) </p>	<p> Not statistically significant, trend toward enhanced technical performance for the experimental group, no differences in anxiety levels </p>
<p> Marcus et al 2013 </p>	<p> Imagery </p>	<p> Surgeons </p>	<p> Review of theory of how imagery could enhance neurosurgery performance </p>	<p> N/A </p>	<p> Imagery proposed as a low-cost educational supplement for surgical simulation training in neurosurgery </p>
<p> Mulla et al 2012 </p>	<p> Imagery </p>	<p> Surgical novices </p>	<p> RCT to test effects of imagery compared to physical practice only and control groups </p>	<p> Time, precision, accuracy, and performance of laparoscopic tasks on VR and BT simulators </p>	<p> The imagery group had poorer performance compared with the FLS and VR groups </p>
<p> Paige et al. 2015 </p>	<p> Imagery </p>	<p> Surgical Residents </p>	<p> Study of the effects of guided mental imagery on performance on two methods of simulated LCs </p>	<p> One and two-handed clip and cut, dissection of triangle of Calot, dissection critical view, removal of gall bladder </p>	<p> Imagery was related to improved performance of a VR two-hand clip- and significantly improved confidence, knowledge of the procedure, and visual imagery </p>
<p> Patel et al 2012 </p>	<p> Imagery </p>	<p> Experienced surgeons </p>	<p> RCT to assess the incidence of errors before and </p>	<p> Procedures evaluated by a trained observer, </p>	<p> Imagery group had significantly less intraoperative errors </p>

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			after implementation of structured imagery	categorized by type, danger, and delay	during critical stages of arterial procedures
Pugh 2012	Imagery	N/A	Commentary on benefits of warm-ups and imagery to surgical practice	N/A	Imagery may facilitate deliberate practice to overcome weaknesses
Rao et al 2015	Imagery	Surgeons of all experience levels	Meta-analysis of the effectiveness of imagery in the acquisition of surgical skills	N/A	Imagery can be an effective supplemental tool to technical training in the acquisition of surgical skills
Rogers 2006	Imagery	Surgical residents and fellows	Position paper to examine the application of imagery in surgery	N/A	Surgeons use imagery routinely to review cases before surgery
Sanders, Sadoski, Bramson et al 2004	Imagery	Surgical novices	RCT to test the effects of physical practice and mental imagery rehearsal on learning basic surgical procedures	Suturing an incision on a live rabbit, rated by a physician	Physical practice followed by guided imagery training performed statistically equal to controls who received additional physical practice
Sanders, Sadoski, Van Walsum et al 2008	Imagery	Surgical novices	RCT of effectiveness of imagery to learn of basic surgical skills compared with textbook study	Suturing an incision on a live rabbit, rated by a physician	Physical practice followed by guided imagery was as effective as physical practice on suturing performance on a live animal model and more effective at aiding the transfer of surgical skills
Sevdalis et al 2013	N/A	N/A	Response paper to methodological issues with Geoffrion et al.'s (2012) study	N/A	Not assessing the participants' imagery ability and imagery script compliance are important limitations of the study

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Sevdalis et al 2013	N/A	N/A	Review of imagery in surgical literature	N/A	Imagery is a cost-effective training tool that can be used anywhere, at any time, without the need for dedicated resources, and is an effective tool to prepare for surgical performance
Wetzel et al 2011	Imagery, relaxation	Experienced surgeons	RCT to determine if imagery training could help participants cognitively walk through procedural steps and enhance their awareness of potential surgical stressors	Teamwork (OTAS), stress coping skills (SCQ), stress (HRV), Qualitative analysis of confidence, decision-making, technical skills	Experimental groups had higher teamwork, increased coping skills, reduced stress, enhanced confidence, decision-making, and technical skills

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