



Development of surgical skills and performance

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ABSTRACT

The main objectives of this article are to help surgeons understand some important factors that influence surgical performance, and provide them with some advice to improve their surgical skills. Progression of surgical skill through novice-expert continuum and factors that influence this progression are discussed. One of these influential factors is the surgeon's stress resilience. Scientific evidence regarding physiologic processes that underlie stress resilience and the effectiveness of psychological tools to improve this innate characteristic is reviewed. The impact of self-esteem and the importance of deliberate practice on achieving higher levels of surgical performance are also discussed.

Innate characteristics are not rigid and can be improved by a variety of psychological tools including mental practice and self-talk. Stress management training programs and courses would be beneficial for surgeons with limited stress latitude and resilience. Deliberate practice is a powerful and efficient strategy to improve surgical performance.

Key words: Deliberate practice; Dexterity; Expert; Stress; Surgical performance; Surgical skill.

Introduction

Surgeons can be classified as novice, competent, proficient and expert according to the stage of surgical skill acquisition and the level of surgical performance. The transition from one stage to the next is a gradual one, and a surgeon may be at different stages for different surgical procedures.

Novices have little or no previous experience in the intended surgical procedure. They need clear rules and instructions to complete a surgical procedure. Novice surgeons seem unsure about the next step in the course of a procedure, and the surgical procedure progresses slowly with frequent lack of forward progression.

As surgeons progress from novice to competent, they acquire some experience and adequate abilities to perform a surgical procedure safely and produce acceptable outcomes. Compared to novices, competent surgeons show significant improvements in the speed with which instru-

ments are manipulated and make significantly fewer errors during an operation. The once-rigid rules for novices become more like guidelines for competent surgeons. In this stage of surgical skill, movements of the hands and instruments are somewhat erratic and jerky.

All individuals, including surgeons, have a finite amount of attentional resources. Novice surgeons and, to a lesser degree, competent surgeons use most of their attentional resources concentrating on technical aspects of task performance rather than on higher level activities such as thinking about the next step of the procedure, attending to atypical anatomical variations, and preventing an imminent complication. They become so focused on the technical aspects of the surgical procedure that they have less attentional resources to be aware of and deal with these issues intraoperatively [1].

While competent surgeons are able to complete a procedure with acceptable results, surgeons in the proficient stage generate the same outcomes faster and more efficiently. A proficient surgeon can perform a surgical procedure smoothly and virtually automatically with a minimal amount of effort. In fact, technical automatization is the hallmark of the proficient stage. Movements of the hands and instruments are smooth and automatic. When performance has reached this level of automaticity, additional experience will not improve the quality of performance. A big challenge for proficient surgeons is to avoid arrested development associated with automaticity. At the proficient stage, some surgeons are not motivated to improve their performance beyond its current level, which results in premature arrest of surgical skill development [2]. The proficient stage is the comfort zone of a surgeon. However, great things never arise from comfort zone. Those proficient surgeons who desire to go beyond their current level of reliable performance should resist tendencies toward automaticity by actively setting higher performance standards and new goals such as increasing the speed, accuracy, and safety of the surgical procedure [3]. Deliberate practice can help surgeons to go beyond this stage.

Aspiring for excellent surgical outcomes with the least possible morbidity is critical for transforming a proficient surgeon into an expert. The hallmark of expert surgeons is that they perform surgical procedures very accurately with reproducible superior outcomes. An expert surgeon has established a sequence of highly coordinated movements, which are integrated in time and are characterized by a rhythmic structure. Fluency of motion is a characteristic feature of expert surgeons. This is something beyond technical automatization. Expert surgeons look graceful while operating [4]. Surgeons who eventually reach the expert stage have a deep commitment to surgery. They find and use the most effective way of performing a surgical task. Experts have a vision of what is possible and greatly contribute to improvements in the field.

Factors Influencing Surgical Performance

In the field of surgery, factors that contribute to achieving higher levels of performance along the novice-expert continuum include knowledge, experience, and innate characteristics. Improvement in performance due to accumulation of knowledge and experience has a ceiling effect [5]. Ceiling effect refers to the level beyond which an independent variable (e.g., experience and knowledge) no longer has a significant effect on a

dependent variable (e.g., performance).

Innate characteristics that have an obvious influence on surgical performance include basic manual dexterity, stress resilience, and self-esteem. Innateness does not imply heritability. Innate characteristics are not immutable. Although they have psychological and physiological basis, and have significant resistance to change, they could be improved through a deliberate practice program. Both genetic and environmental factors contribute to development of these innate characteristics. Surgeons differ in these characteristics, and those less endowed are likely to struggle more during surgical training and thereafter in surgical practice. The ultimate level of surgical skill and performance that surgeons can achieve is probably determined by their innate characteristics.

Manual Dexterity

Some surgical procedures require a high degree of manual dexterity. Surgeons differ in underlying manual dexterity aptitude. This might be predictive of the speed with which they progress through the novice-expert continuum or the ultimate level of performance that they could achieve. Surgeons with initially poor manual dexterity may have difficulty in acquiring some surgical skills. However, evidence shows that manual dexterity can be improved by means of deliberate practice [6,7]. Manual dexterity is closely related to physiology. It has been shown that improvement in manual dexterity corresponds to increased concentration of testosterone [35].

Stress Resiliene

Excessive stress has a potential negative impact on surgical performance and outcomes, most notably in novice surgeons [8,9]. Intraoperative stressors trigger a complex cascade of physiological and behavioral changes in surgeons. A stressor can significantly perturb the surgeon's physiological system from an optimal utility state toward a lower utility state [10]. Stress has been shown to negatively influence surgeons' fine motor skills and dexterity [11,12]. Intraoperative stress is associated with increased time required for task completion, poorer economy of motion, and an increased number of errors [13].

A surgeon's stress latitude and resilience greatly contribute to the ability of the surgeon to perform a surgical task successfully in the face of an intraoperative stressor. Latitude refers to the maximum amount of stress a surgeon can tolerate before losing its ability

to remain within his or her high utility state. A surgeon's latitude is the ability of the surgeon to tolerate stress without a decline in surgical performance. Resilience refers to how effectively and quickly a surgeon returns to his or her previous high utility state after being perturbed by a stressor [10]. A resilient surgeon has a greater capacity to recover from and overcome a stressful situation (e.g., sudden hemorrhage) intraoperatively.

From a physiological perspective, resilience is mediated by numerous hormones, neurotransmitters, molecular pathways, and neural circuits. Differences in the function, balance, and interaction of these factors underlie inter-individual variability in stress latitude and resilience. For example, it has been suggested that downregulation of corticotropin-releasing hormone (CRH) and adaptive changes in CRH receptor activity might promote resilience [14]. Stress resilience is associated with the capacity to limit stress-induced increases in CRH and cortisol levels through a negative feedback system, involving optimal function and balance of glucocorticoid and mineralocorticoid receptors [15]. Another striking example is the finding that higher plasma dehydroepiandrosterone (DHEA) to cortisol ratio in individuals undergoing military training is associated with higher stress resilience and better military performance [16]. DHEA has antiglucocorticoid effects in the brain and has an influence on GABA (γ -aminobutyric acid)-ergic system. Brain-derived neurotrophic factor (BDNF), an important nerve growth factor that is expressed at high levels in the brain, represents another molecular pathway underlying stress resilience. Animal studies have shown that increased expression of BDNF is causally related to the degree to which rodents are susceptible versus resilient to deleterious effects of stress, with resilient animals showing no increase in BDNF levels [17]. The results of another study also suggest that regional differences in BDNF levels and dendritic spine density in the rat brain confer a stress-resilient character to rats [18].

It has been shown that differences in brain anatomy underlie individual differences in stress susceptibility and resilience. For example, stress-susceptible mice have smaller cingulate cortex volume [19] and larger hippocampal volume [20] compared to resilient mice. The brains of individuals with stress disorders exhibit decreased levels of glucocorticoid receptors in various brain areas, and subjects with higher baseline parasympathetic activity in general are likely to be more resilient to stress [12].

Stress-induced performance deficits might be rooted in a surgeon's personality. Evidence clearly shows that there is a relationship between an individual's resilience and personality. Resilience has a strong inverse relationship with neuroticism and positive relationships with extraversion and openness [21]. Individuals with high neuroticism scores perceive events and problems as being more stressful than individuals with lower scores [22]. Vulnerability to stress is one facet of neuroticism, and individuals with low neuroticism scores are very likely to obtain high scores on measures of resilience. Certain psychosocial factors such as positive emotions, optimism, humor, spirituality, social competence, and openness to social support have stress buffering effects and promote resilience [23].

To improve stress latitude and resilience, surgeons should evaluate themselves and determine their current level of latitude and resistance. Awareness of a weakness is the first step toward overcoming that weakness. Resilient individuals exhibit lower levels of denial and avoidant behaviors [14]. Practice can attenuate stress-induced physiological changes (e.g. increased heart rate), and reduce the likelihood of stress-induced performance deficit during surgery [8]. Neural and chemical pathways of stress response are highly adaptive to surgical training and such adaptations contribute to improvement of surgical skills [24].

Exposure therapy is a psychological tool that helps improve resilience. If a surgeon is repeatedly exposed to a tolerable dose of an intraoperative stressor, the surgeon's resilience will be improved [10]. Stress inoculation (exposure to manageable stressors) during development of a surgical skill might reduce the possibility and severity of stress-induced performance deficit in the future. Exposure therapy has been used successfully in treatment of a variety of clinical disease and conditions including allergy and post-traumatic stress disorders.

Meditation [25] and cognitive reappraisal are other psychological tools that can improve resilience. Cognitive reappraisal refers to reinterpreting the meaning of negative stimuli, with a resulting reduction in emotional responses. By reevaluation and reframing adverse experiences in a more positive light, cognitive reappraisal allows an individual to perceive stressful events in less threatening ways. Resilient individuals are better at reappraisal and use this strategy more frequently [14].

Another popular strategy to reduce the negative effects of stress is mental practice. Mental practice is a system-

atic form of mental rehearsal in which people imagine themselves performing an action without engaging in the actual physical movements involved. Research shows that a short period of mental practice training can attenuate the psychological, neuroendocrine, and cardiovascular response to acute stress in novice surgeons [26]. Apart from its effectiveness in reducing stress, mental practice has positive effects on technical aspects of surgery. In fact, mental practice injects the benefits of experience to novice surgeons.

“Stop and stand back” is a stress management strategy that some experienced surgeons have used successfully in the face of a sudden intraoperative stressor [11]. If an unexpected complication such as sudden hemorrhage occurs, an expert surgeon stop what he or she is doing and try to gain time (e.g., by putting pressure on the bleeding site). Putting pressure on the site may not be the best solution to the problem but is necessary for the surgeon to reduce the stress, regain self-control, and get back to a more stable physiological and behavioral state. Taking deep breathes and waiting for a few seconds until the heart rate decreases are effective methods of relaxation. The surgeon stands back emotionally, reassesses the situation, makes a decision, and prepares for the next step. It is important to avoid overfocusing on the task and to break the vicious circle of anxiety and pressure of the stressor leading to poor judgment and decision-making problems.

Self-talk is another stress management strategies that experienced surgeons have reported to be effective intraoperatively [11]. Self-talk consists of a positive inner dialogue that helps the surgeon to calm down and regain self-confidence. There is a lot of evidence in sport sciences showing that the use of self-talk strategy could enhance performance [27].

Recognizing the potential sources of intraoperative stress helps surgeons to prepare themselves to confront them or prevent them from arising altogether. Potential intraoperative stressors include unexpected bleeding, difficulty finding the source of a problem, no progress, time pressure, equipment problems. Fear of failure in surgical outcomes is another potential source of intraoperative stress. Some individuals are endowed with greater fear extinction capabilities. It has been demonstrated in human subjects that endogenous cannabinoid system is involved in fear extinction, and the genetic variability in this system underlies individual differences in this innate ability [28]. Cognitive behavioral therapy may help keep anxiety and fear of failure at a low level.

Self- esteem

It is not enough for surgeons to possess the required knowledge and skills to perform a surgical procedure; they also must have the conviction that they can successfully perform the task under typical and, more importantly, under challenging circumstances. Self-esteem and a related characteristic, self-efficacy, may contribute more than actual competence to successful completion of a task. Implicit self-esteem has an influence on behaviors that are not normally subject to conscious control. Self-efficacy is defined as the individual's belief in and perception of his or her capability to perform a particular task [29]. In fact, self-efficacy is task-specific self-esteem. High self-efficacy in one surgical procedure does not necessarily mean high self-efficacy in another.

Self-efficacy is a belief about one's capability, and as such, does not necessarily match one's actual capability in performing a task successfully. Research shows that most individuals actually overestimate their self-efficacy [30]. However, it seems that a modest overestimation of self-efficacy can actually improve task performance, particularly under difficult circumstances [31]. Surgeons who have low self-efficacy for performing a surgical procedure may avoid it or show less persistence in skill acquisition, and this limits their progression in the novice-expert continuum. Individuals with higher self-efficacy persist longer in the face of difficulties, and are more likely to perform at a higher level during a surgical procedure.

Two sources that help a surgeon to raise his or her self-efficacy for performing a surgical procedure include past successes in performing the procedure and observing other surgeons performing the operation [31].

Deliberate practice

Deliberate practice is a task-specific structured training activity that plays a key role in the development from novice to expert. The concept of deliberate practice has been applied successfully in various domains including musical performance and sports [32]. Deliberate practice is a tool that enables circumvention of performance limitations associated with innate characteristics [33].

In order to improve performance in a surgical procedure, surgeons should decompose the whole procedure into its constituent tasks and then find their weaknesses in each task. Surgeons then need to active-

ly engage in a deliberate practice program, in which they concentrate on improving performance in a specific surgical task [2]. A deliberate practice program requires that the surgeons

- 1) Perform the intended task repeatedly.
- 2) Carefully monitor and evaluate their performance in each procedure (e.g., by video recording) to make necessary adjustments and refinements in subsequent procedures
- 3) Seek advice and informative feedback from experts and colleagues.
- 4) Observe other surgeons doing the same task in order to find clues for better performance.
- 5) Keep their knowledge up to date.

Deliberate practice requires a supportive environment. It is typically effortful and not enjoyable. However, learning from deliberate practice obviously goes beyond the unintentional and implicit learning from experience [34]. Deliberate practice is particularly useful for those surgeons who suffer plateaus in their skill development.

Conclusion

The rate of progression through the novice-expert continuum and the ultimate level that a surgeon can achieve in this continuum are largely dependent on innate characteristics such as stress resilience and self-efficacy. Innate characteristics that have potential impacts on surgical performance are not rigid and can be improved by a variety of psychological tools including mental practice and self-talk. Stress management training programs and courses would be beneficial for surgeons with limited stress latitude and resilience. Another powerful and efficient strategy to improve surgical performance is deliberate practice. The value and effectiveness of explicit experience gained through deliberate practice goes beyond implicit experience that is accumulated passively through simple repetition of a surgical procedure. Even such innate characteristics as manual dexterity can be improved by deliberate practice.

Conflict of Interest

The authors declare no conflict of interest.

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