Neuroenhancement in surgeons: benefits, risks and ethical dilemmas

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Background: Surgeons traditionally aim to reduce mistakes in healthcare through repeated training and advancement of surgical technology. Recently, performance-enhancing interventions such as neurostimulation are emerging which may offset errors in surgical practice.

Methods: Use of transcranial direct-current stimulation (tDCS), a novel neuroenhancement technique that has been applied to surgeons to improve surgical technical performance, was reviewed. Evidence supporting tDCS improvements in motor and cognitive performance outside of the field of surgery was assessed and correlated with emerging research investigating tDCS in the surgical setting and potential applications to wider aspects of healthcare. Ethical considerations and future implications of using tDCS in surgical training and perioperatively are also discussed.

Results: Outside of surgery, tDCS studies demonstrate improved motor performance with regards to reaction time, task completion, strength and fatigue, while also suggesting enhanced cognitive function through multitasking, vigilance and attention assessments. In surgery, current research has demonstrated improved performance in open knot-tying, laparoscopic and robotic skills while also offsetting subjective temporal demands. However, a number of ethical issues arise from the potential application of tDCS in surgery in the form of safety, coercion, distributive justice and fairness, all of which must be considered prior to implementation.

Conclusion: Neuroenhancement may improve motor and cognitive skills in healthcare professions with impact on patient safety. Implementation will require accurate protocols and regulations to balance benefits with the associated ethical dilemmas, and to direct safe use for clinicians and patients.

Introduction

Human errors within surgery can have grave consequences. Advancing societal age and increasing population growth rates with relative lack of financial investment are a strain on healthcare systems. This environment emphasizes the importance of reducing errors to a minimum for cost-containment. Both the American College of Surgeons’ Curriculum Committee and the Royal College of Surgeons’ Improving Surgical Training Committee stress the importance of innovation in surgical education to advance the acquisition of trainee skills. Unsurprisingly, recent times have witnessed significant technological advances aiming to overcome the challenge of delivering safe and high-quality care to patients worldwide. Artificial intelligence and robotic innovations are accumulating a research base in the hope that they will offset some of the burdens facing the provision of surgical services. Surgeons can relieve some of these strains by maximizing their potential through performance-enhancing intervention. Aspects of these innovations are explored here.

A decade of research examining dynamic learning-related changes in surgeons found that activation of the prefrontal cortex is integral to the development of surgical skills, to enable surgeons to cope with day-to-day challenges. Stressors jeopardize these neural systems, resulting in deterioration of function that manifests externally as overt errors and inwardly as disordered cognition (such as poor decision-making, reduced stress resilience and impaired working memory). Greater engagement of the neural mechanisms underlying attention and concentration may prevent this decline in cognitive performance through improved neural efficiency.

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Neuroenhancement by neurostimulation

Neurocognitive enhancement, the practice of improving the neurological function of disease-free individuals, has gained momentum with recent developments in transcranial direct-current stimulation (tDCS). It is a safe, non-invasive method of neurostimulation by passing a weak current between two scalp electrodes to increase underlying cortical excitability. Neurocognitive-enhancing effects of tDCS in the healthy population improve a broad span of cognitive abilities, including working memory, attentional function, language acquisition, knowledge application and decision-making. Studies in elite athletes have demonstrated that tDCS (compared with sham) increases the time to exhaustion in a whole-body cycling task (from 723.7 s to 751.4 s, \( P = 0.05 \)), along with increased power output (from 301.0 W to 313.2 W, \( P = 0.04 \)). A recent systematic review suggested enhanced motor tasks (reaction time, task execution time and strength) in the general population too.

Correlating this to surgical technical tasks, there are currently three published studies investigating the impact of tDCS in laparoscopic skills tasks and simulated neurosurgical resection tasks in medical students. Compared with sham, tDCS improved performance in pattern-cutting scores during a laparoscopic skills task (207.6 versus 186.0; \( P = 0.022 \)), and there were significant improvements in resection efficiency during the neurosurgical task. Furthermore, tDCS can improve early open knot-tying skills in medical students, and may increase robotic suturing accuracy and knot-tensile strength (unpublished observations). Consistent reductions in subjective temporal stress were observed in these studies, an interesting finding given the well-documented role of the prefrontal cortex in temporal stress resilience; this may account for some of the technical performance. This is supported by evidence that tDCS leads to better working memory performance of cognitive tasks under stress. The possibility of augmenting technical skills in this manner is all the more pertinent in an era of complex surgical approaches and yet decline in training opportunities. The potential to enhance multitasking capabilities represents a key component required of the modern surgeon. Coping better with significant pressures could help to avoid or reduce mistakes induced by the strain of busy clinical duties. Surgeons are susceptible to omissions when reviewing clinical images and, instead, tDCS could augment accurate identification of subtle pathology on laparoscopy or radiological images, for example. Similarly, tDCS could assist with the detection of small polyps on colonoscopy, where the use of artificial intelligence technology is imminent.

Other cognitive advantages with tDCS include better information-processing capability in Air Force cadets. In addition, further studies have demonstrated increased performance accuracy and perception with tDCS during detection tasks (for example, Clark et al.). Military personnel performing a vigilance task showed a significantly higher overall hit rate and significantly lower false alarm rate with tDCS. The benefit of sustained attention is obvious over the course of tiring and complex operations. Extrapolating to all surgical grades, greater vigilance could prove paramount when susceptible to diagnostic and pattern-mapping mistakes due to fatigue.

All studies to date, both published and unpublished, have investigated single sessions of tDCS, whereas experimental paradigms exploring repeated sessions might reflect training and practice more accurately. All studies have compared tDCS with sham stimulation to ensure that effects are not simply placebo in nature, but should be evaluated against traditional training approaches including team-based scenarios and human factors sessions. Encouragingly, greater technical performance can be demonstrated in aspects of surgery in a simulated environment. It is not known whether these benefits will translate into faster achievement of technical competence in trainees or better clinical outcomes in practice.

Teamwork in surgery has been investigated widely, commonly using the Observational Teamwork Assessment for Surgery (OTAS) and the Non-Technical Skills Assessment (NOTECHS) scales. These formal assessment tools contain many domains that have been improved with tDCS outside of surgery, including coordination, situational awareness and decision-making. Augmenting the performance of anaesthetic, surgical and scrub team members in these domains could well translate into more efficient teamwork for optimal care. One of the greatest barriers to translating tDCS and other neurocognitive enhancement techniques in medicine is cultural, one that often values doctor intuition and natural ability over evidence-based solutions. Relatively unknown to the healthcare population, reservations may also exist over what may be initially perceived as a hazardous and unconventional technique. However, although the timing may be unclear, neuroenhancement has the potential to disrupt the healthcare landscape, and a number of ethical questions need to be addressed (Fig. 1).

Ethical considerations

Safety

tDCS is non-invasive and has been conducted on thousands of participants in research laboratories without adverse
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Events, suggesting that it is safe. Common immediate side-effects are minor, and include headache (11–15 per cent), itching (40–70 per cent) and tingling (22–75 per cent). However, questions remain over long-term side-effects, which are relatively unexplored given the recent rise of tDCS to prominence. Furthermore, as it gains further acceptance with the ‘promise’ of cognitive enhancement, there is potential for misuse and abuse of tDCS with an unknown risk profile. The implications of an adversely affected clinician going on to treat patients is of undeniable concern. Despite this, tDCS has an excellent safety profile and, when coupled alongside strict regulations and with any implementation overseen by a regulatory body, its safety can realistically be maintained in the workplace.

**Coercion**

Is it immoral for a workforce not to undergo the intervention, if it enables clinicians to work optimally and potentially reduces errors? Implicit coercion arises through social pressure as patients ‘expect’ their caregivers to function at their best with the use of neuroenhancement. Explicit coercion complicates this further through an expectation from higher or governing authorities if they feel patients would be safer with the use of the neuroenhancement measures. At what point do we draw the line between necessity and an individual’s autonomy to decline an intervention? Although it is important to investigate novel options to help offset pressures faced by surgeons, we must not detract from the core issue, which is to address sources of increasing demands on surgeons in the first place. We must not enter a situation whereby enhancing our ability to cope with pressures leads to more impositions and a greater burden on surgeons, simply because they can ‘cope better’. This would undermine the benefits of such technologies and potentially lead to a vicious circle of greater innovations to tackle increasing pressures. If an individual chooses to utilize the benefits of neurostimulation, they should retain the right to decide on its use; through guidance from expert surgeons and individual supervisors, we believe surgeons can avoid coercion through
the exploration of all available opportunities of training enhancement.

Distributive justice

As desirability for neuroenhancement develops, so does the commercial value of the technology. Equitable distribution throughout a workforce with varied financial and socioeconomic statuses becomes a concern, with those of a lower standing conceivably missing out on benefits afforded to others. This has implications for reinforcing and widening the gap in socioeconomic backgrounds and creating an adverse environment amongst a workforce where outcomes are so often contingent upon a multidisciplinary teamwork ethic. If benefits of neuroenhancement of the surgeon are established and evidence-based improvements in patient care are achieved, this may allow for expansive integration of neuroenhancement for all, regardless of location, reputation or financial status. However, the latter must be considered against the cost-effectiveness of widespread application of the technology. Although research-grade tDCS devices are available for under €2000, it is challenging to appreciate the true cost of wide implementation. Nonetheless, it would appear to be cost-effective if it was able to offset some of the widely recognized costs associated with errors and litigation.

Fairness

The sporting community continues to debate whether neurocognitive enhancement is simply a form of ‘cheating’. For healthcare, on the one hand, if the aim is to raise the standards of patient care and safety, it would be fair to use methods to gain an advantage. However, we live in a time where outcomes are reported and rewarded whilst mistakes are punished with compensation claims and litigation. To avoid the latter, attempting to gain a competitive edge over others with neuroenhancement creates a certain degree of moral uncertainty. Nevertheless, with patient care and safety being our primary concern as caregivers, it is reasonable that methods to enhance performance and patient safety should take precedence over concerns of competition.

Conclusion

Neurocognitive enhancement may have the potential to improve dexterity, accuracy and decision-making in healthcare professions. It represents a desire to expand our conventional training methods by adding a new dimension in the ability to cope with work-based pressures and continuously excel in delivering high-quality patient care. Barriers to implementation will rightly necessitate strict and rigorous regulations and protocols to offset many of the surrounding ethical dilemmas, and to oversee safe use and protection of patients.

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