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The Most Influential Innovation in Neurosurgery: The Perspective of a Medical Student

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Abstract

Neurosurgery is a constantly evolving field with many technological advances occurring over the past decades which have served to broaden our horizons regarding neurosurgical knowledge and capabilities. Of these many advancements, one particular innovation that stands out from the rest is the development of Augmented Reality (AR) and Virtual Reality (VR). While being a relatively new advancement and still in its infancy compared to other technological innovations, it has been demonstrated that AR and VR have a wide variety of applications ranging from improving training for neurosurgical trainees to pain management post-surgery. Furthermore, such applications can potentially be used in the field of global neurosurgery where the benefits can be reaped in Low- and Middle-Income Countries (LMICs) despite the numerous problems caused by the coronavirus pandemic. This article will discuss the current applications and benefits of AR and VR in neurosurgery as well as the potential uses in the future and why these reasons have cemented AR and VR as the technological innovation that arguably holds the most influence in advancing neurosurgical capabilities in the future and across the globe.

Abbreviations

AR: Augmented Reality; LMIC: Low- and Middle-Income Countries; MRI: Magnetic Resonance Imaging; VR: Virtual Reality; WHO: World Health Organisation; 2D: Two Dimensional; 3D: Three Dimensional

Introduction

Neurosurgery is a subspeciality that has developed leaps and bounds since its inception due to it being a high-stakes discipline where less-than-perfect results have devastating effects and demands technical development to enhance patient safety. As an ever-evolving field, the impact of new technological developments and understanding has served to have a major impact across the field [1], ranging from discoveries of treatment and furthering our understanding of different illnesses to implementing such knowledge and adapting this in the setting of Low- and Middle-Income Countries (LMICs) where resources are scarce. However, there is debate as to what the term 'innovation' entails as studies have found that the term 'innovation' has heterogeneous meanings according to neurosurgeons across the world, ranging from cost-effectiveness to modifications of existing procedures [2]. In turn, this lack of standardization could have various complications regarding care for future patients. Furthermore, what may be deemed 'innovative' can slow down how people choose to invest in different findings, which can hinder better care in the long term. However, one particular development that has the potential to address these different issues is the development of Virtual Reality (VR) and Augmented Reality (AR). Although comparatively new, AR/VR can potentially overtake other innovations and may be amongst the most influential developments in neurosurgical practice.

What are VR and AR?

Imaging has been a fundamental cornerstone in the history of neurosurgery, including the development and use of Magnetic Resonance Imaging (MRI) and Computerized Tomography (CT) scans to provide images beneficial for planning surgical operations and for navigation, which is especially important in a field renowned for its complexity and low margin for errors [3]. However, one of the most recent forms of neuronavigational imaging comes in the form of AR and VR. AR serves as a combination of both virtual and real objects to create a semi-virtual experience able to align synthetic constructs with real-life objects in real-time, whereas VR is entirely computer-generated. In theory, the development of such tools would help streamline the surgical process as the use of AR and VR would overcome the well-established shortcoming of traditional imaging, being that the constant switching of viewpoints from the surgical field to the computer screen would disrupt workflow and progress and would also help reduce cognitive load and stress duration.

The Current Applications

Currently, this technology has been used in a variety of different specialties and subspecialties within neurosurgery, ranging from neurovascular surgery to neuro-oncology and spinal surgery, producing a wide range of different results as to how the tools may provide benefits to surgery. For neurovascular surgery, particularly that of extracranial-intracranial bypass surgery, AR has not only provided accuracy comparable to that of current neuronavigational methods but has also served to have additional benefits as well. This includes being able to identify better skin vessels primed for resection and harvest but also led to minimizing craniotomy size, which could reflect a reduced likelihood of infection and complications in patients [4]. As well as better cosmesis, it has been found that AR could also have greater benefits in patients with aneurysms that are challenging to access [5]. For neuro-oncology, studies have investigated the use of AR/VR in preoperative planning, as AR can help determine the best trajectory for surgeons to employ in each case. A prime example of this is where CT and MRI scans can be blended to improve the surgeon's situational and spatial awareness [6]. This would demonstrate promising evidence that AR could provide a means to improve surgical and postoperative clinical outcomes.

Training neurosurgical trainees is another area in which AR and VR have been adopted and show a degree of promise. This can be made evident through the use of AR and VR in developing and using training modules to help enhance clinicians' knowledge and understanding of neuroanatomy and surgical procedures [7,8]. Furthermore, the use of VR and AR can also extend to a surgical environment, as there are many obstacles that neurosurgeons in training may face. A prime example of this is being able to carry out highly advanced complicated surgical procedures in small surgical windows. Furthermore, current neuronavigation fails to take into account the gradual brain shift that occurs throughout a surgical procedure, rendering them less accurate and making surgical mistakes and complications more likely. However, AR and VR systems can help overcome this by making use of haptic, sound, and visual feedback.

A key example can be highlighted in functional surgery, where AR had been used to help junior surgeons with the insertion of intracranial catheters regarding trajectory and the ability to avoid damage to eloquent cranial structures. Finally, data from AR systems can help provide feedback on neurosurgical trainees' performance and track their improvement rate. This would show that AR would not only serve as an impressive neuronavigational tool but would also double as an effective educational tool to provide feedback on trainee performance and highlight areas of improvement [9,10].

Future Possibilities and Combinations

AR and VR also have the potential to be used as an adjunct alongside other tools to not only compensate for the shortcomings that current AR/VR technology has but also help provide even greater improvement to neurosurgical care. One particular example would be the combination of AR and ultrasound to take into account brain shift which dramatically reduces the effectiveness of preoperative planning and imaging [11]. A pilot study looking into the combination of AR and ultrasound showed that not only did the combination of AR and ultrasound accurately visualize pathology and the patient's anatomy, but it also was an enhancement compared to imaging with AR alone [12]. The combination of AR and robotics is also a promising field, as the integration of AR would provide invaluable data regarding feedback from auditory, visual, and tactile cues, which would help streamline the surgical process and enhance robotic function. Furthermore, as the use of robotics become more commonplace in the surgical theatre, VR can act as a form a trainer to allow neurosurgical trainees to learn and become more confident with using robotics to carry out complicated procedures [13].

Benefits for the Patient

VR and AR have been shown to not only assist in imaging and strengthening the skillset of surgeons but will also benefit patients as well. An example is this is explaining the procedure to patients and gaining their consent. A randomized trial had shown that patients who had been informed about their procedure using Three Dimensional (3D) imaging and VR had a greater appreciation for this and had a greater understanding of the procedure compared to those who had been informed using traditional Two Dimensional (2D) imaging [14,15]. The effects of this may also be profound as neurosurgery is known to be a specialty with one of the highest number of litigations and medicolegal issues [16]. Improving the patient's understanding may help alleviate patient concerns about upcoming procedures and may even impact the number of legal issues that may arise with the patient. Educating patients using VR and AR can also bring psychological benefits, such as improving patient anxiety and improving their understanding of MRI scans. Simulating such experiences may also have a profound impact on patient's well-being by providing reassurance and may even help streamline the process of getting patients ready for operations [17].

Another area in which VR and AR may have an impact is in the form of pain management and rehabilitation after surgery. VR can be used to assess and quantify the abilities of patients with injuries or learning difficulties in a variety of different areas, including balance, motor recovery, and psychological benefits [18]. A systematic review consisting of 8 randomized control trials and 732 patients had shown that VR was successful in significantly reducing post-operative pain in those who had received VR post-operatively and intraoperatively, and this effect could be seen for both major and minor surgeries [19].

The Effect of AR and VR on Global Neurosurgery

However, the impact of such innovation will be seen most predominantly in the developing world. While neurosurgery is a field that has benefitted greatly from technological advancement, there is a present disparity in healthcare across the globe. It is predicted that across LMICs, over 5 million people will continue to suffer from treatable neurological conditions without access to surgical intervention. The cause of this disparity is due to a culmination of multiple factors, such as a reduced surgical workforce and a lack of resources [20]. In response to this, major organizations have sought to address this disparity, including both the World Health Organisation (WHO) with the 17-goal action plan [21] and the Lancet Commission seeking to identify the unmet neurosurgical burden in LMICs and identify the key areas of improvement by 2030 [22]. However, with only seven years remaining until the 2030 deadline and COVID-19 serving to disrupt neurosurgical care and highlight disparities across the globe, it has been predicted that, even with the use of successful training schemes and the implementation of task shifting and sharing to address the deficit, approximately 58% of LMICs will fail to address the targets set for 2030 [23].

As such, further efforts are necessary to address this gap, a key factor being that of novel technology, which has been viewed as a key way to strengthen surgical capacity across the world. The development of novel technology, including AR and VR, would not only allow for surgical trainees and surgeons to practice high-risk operations in low-risk settings but would also preserve current resources and provide an affordable tool that can improve neurosurgical care. The use of affordable technology has already been used in LMICs, including low-cost mobile devices, and the use of AR would only serve to build upon devices already made accessible and available to neurosurgery specialists across LMICs. Furthermore, AR and VR have also provided the opportunity for experienced surgeons to pass on their knowledge and experience remotely, a key example being carried out in Brazil and Paraguay, where live operations were broadcasted and demonstrated [24]. The use of telemedicine has especially become more common with the COVID-19 pandemic, and this, once again, proves AR/VR to be versatile tools as these can be used alongside schemes that have built up neurosurgical capacity in the developing world. This would include international training camps and using this to train as many non-surgical specialists to carry out surgical tasks and increase the workforce available through task-shifting and task-sharing.

Conclusion

In conclusion, neurosurgery is a specialty known for its technological advancements over the years, each revolutionizing the field and changing the way neurosurgical care is provided to its patients. However, in the past ten years, AR and VR have stood out in terms of their current applications and the potential it holds in the future across various uses from diagnosis and imaging to education. While AR and VR still serve as novel tools with room for development and improvement, the versatility and accessibility that AR and VR possess over other innovative technology serves as a strength, not only revolutionizing imaging and teaching for surgical students even in the setting of a global pandemic but such improvements to neurosurgical care would be seen even in LMICs. The development and adoption of AR and VR technology in neurosurgery have not only served to be arguably the most important advancement in neurosurgical practice in the last ten years but may also be amongst the most influential forms of innovation over the next ten years.

Conflict of Interest

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Informed consent was obtained for this publication.

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