Immersive Technologies in Neurosurgery: Challenges and Opportunities

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I enter the operating room to see my patient lying on the table sedated by a miraculous safe cocktail of drugs honed over years of development, and under the stewardship of my anaesthetic colleague. I give her a wave – her head nods in my direction before it dips back down to her smartphone screen. I look to the right at the bank of monitors and remind myself of the brain scans – a large tumour on the left side of the brain, invading the speech area. It's going to be tricky. In addition to this is the pressure of knowing my patient is young, has worked hard to turn his business profitable and has a family with kids not much older than my own. I put on my glasses and look at his head. I can see the clear imprint of the tumour, glowing green and slightly transparent, overlying his hair. Around it are blood vessels in red, nerve fibres in blue and the fluid filled spaces of the brain in yellow. Calculating my best angle of approach, I turn my head slightly to one side and then to the other, while all the time the green glow takes on a slightly different shape, and new strings of red and blue appear and disappear. I take my right index finger and trace a large hole on my patient's head. The surgical noose encircles the green enemy. I place my thumb and forefinger into the middle of the space and spread them apart. Suddenly I'm immersed in green glow, I'm right in the middle of the battle zone. My biggest anxiety is not the tumour itself however, but what's just beyond it – areas of the brain responsible for speech and language. Leaving little or no surgical footprint in this area, whilst removing as much tumour as possible will be crucial to a positive result for this brave young man. My ability to achieve this could determine the number of years before his tumour comes back – next time it will be nastier, more invasive and will ultimately claim his life. Happy with my planning and understanding of the surrounding anatomy, I proceed with the operation.

Thankfully, all goes well and the post-op scans show a great result. What's most remarkable however, is that I haven't left home yet. Or even got dressed. I haven't even had my first coffee of the day. And no surgeon in the history of surgery has ever done an operation before their first coffee of the day. See (pun intended), I have just 'performed' this operation from the comfort of my own home using immersive technology. A virtual reality world, in which I was even able to use augmented reality. A dream within a dream. A modern day neurosurgical Christopher Nolan.

I do eventually get dressed, eat my breakfast, kiss my family goodbye, have that coffee, battle the traffic, drive around relentlessly looking for a parking space, get to my office, groan at the number of letters on my desk, groan even louder at the number of unread emails in my inbox and then finally get changed to go and see my patient. Despite the chaos, I'm blanketed in a sense of calm. It feels like I've done this operation before. And that's a new luxury. Every patient is unique, every case is unique. Every blood vessel has its own twists and turns. In reality, every operation, and every patient is a 'first-time' case for surgeons. This is probably the area in which immersive technologies can revolutionise surgery the most. The ability to 'rehearse' an operation, the ability to 'make mistakes' and push the boundaries, all in the safety of a virtual environment, is the holy grail. En-route, there are several incremental gains to be made with the use of immersive technologies.

Neuro-navigation and Pre-Operative Planning

Use of navigation has been commonplace for many years in neurosurgery. It is used in the pre-operative planning stage, and intra-operatively. As the technology has become more sophisticated, additional modules such as auto-segmentation (whereby the computer identifies structures on scans and assigns them a unique colour), nerve fibre-tracking overlay, head-up display within the operating microscope field and pinless-registration (the lack of need to fix the head to facilitate system registration) have evolved the systems to be more useful and integrated into the surgery. The addition of intra-operative imaging (getting an 'update' on the surgical progress and allowing for comparison to the original images) has made these systems even more complementary to the physical tools of surgery and the abilities of the operator. However, the equipment remains cumbersome, and economically challenging to update/replace due to the initial capital outlay. Perhaps most importantly however, from the surgeons' perspective, it is not possible to use these systems outside of the theatre environment. This makes the scenario described above impossible.

The development of immersive technology solutions could revolutionise the usability and portability of these systems. Certainly, in the initial phases, it does not appear to require a reinvention of the wheel or massive step change; rather an integration of the already well validated and commonly used software algorithms into more modern devices. For example, augmented-reality (AR) glasses that a surgeon could wear would facilitate overlay of the very same computer-generated images of the tumour, vessels and other critical structures that we already have, onto the patient's head. It is a simple change from looking at a screen to looking at the actual patient to 'see' the tumour. Simple, but infinitely more natural. It would also make the intra-operative use more innate. Coupled with virtual-reality (VR), it would be possible to be completely immersed in the operating room environment, anatomy room or surgical wet-lab. Furthermore, the relative portability of such devices would potentially make this planning and 'rehearsal' possible in the office, or at home, and has significant implications for training.

Training

Immersive technologies potentially have a huge role to play in the training of future surgeons. As an apprentice specialty, it is a true mantra that there is no substitute for training than actual operating. Reading books, watching videos and even watching someone else doing the operation in theatre all eventually have their knowledge transfer limitations. In recent years, the imposition of the European Working Time Directive and the increased pressures on trainees to deliver service (clinics, on-call) have resulted in reduced 'cutting time.' Educational bodies and commercial entities have responded by developing physical simulation models and making 'bootcamps' mandatory. However, these endeavours fail to recreate the theatre environment and the physical models are still a poor representation of the tissue characteristics encountered in real patients. Moreover, they are disposable by nature and therefore expensive. Human cadaveric (embalmed or fresh-frozen) and live anaesthetised animal surgery (not allowed in the UK) courses go some way to address these issues but costs make it extremely prohibitive to attend repeatedly and there are very high regulatory barriers to overcome.

Immersive technologies will face similar challenges in engineering the haptic feedback required to represent the physical characteristics of human tissue – not only in handling but also in cutting, stopping bleeding and manipulating. However, all the other current challenges could be relatively easily addressed. For example, VR could be used to recreate the noise and distraction of a theatre environment. This would enable trainees to 'interact' with colleagues, deal with unexpected logistical challenges and allow assessors to objectively evaluate trainees in the same scenarios, over time and between trainees. Moreover, the ability to 'reboot' simulated scenarios and operations offers huge cost savings. Finally, a system that enables trainees to 'rehearse' any operation, using real patient images and anatomical data will be invaluable in a similar fashion to the advantages offered to the more established surgeon. As a final training opportunity, the ability to watch 'the boss' do the operation, and even pre-select 'alternative endings' would be a great insight for trainees into the decision-making mindset of experienced mentors.

Translating Virtual- and Augmented-Reality into Real-Life Reality

Surgeons are notorious for having a 'Dorothy-mindset.' We expect to click our heels three times and be transported to an alternative dimension. Most surgeons believe the translation of real-world challenges can easily be met by maths and engineering. This both flatters and insults our computer science and engineering colleagues all at once. The algorithmic calculation and computer programming required to achieve even the simplest of immersive scenarios is colossal. Converting programming languages across systems, recapitulating tissue characteristics, integrating the movement characteristics of existing surgical tools, creating virtual theatre environments, registering real-world physical objects in immersive worlds – these are just some of the significant barriers to overcome. Perhaps most crucially, it is important that surgeons, computer scientists and engineers work together at every stage, to understand the vagaries of each other's' working domains, but also to make sure that a huge amount of effort (and money) are not invested into pursuing avenues that do not reveal themselves to be ultimately useful. Immersive technologies have significant research and development investment from all the major global technology players – Google, Apple, Samsung, HTC, Microsoft. It is therefore a unique opportunity for us in a publicly funded healthcare system to ride the wave of this commercial investment and use it to enhance our service delivery, and ultimately improve patient outcome. For real.