Taking the Pulse on Pedagogy: Anesthesiology Training in Virtual and Augmented Reality

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Abstract

Anesthesiology represents a field where clinical precision cannot be compromised when it comes to procedural task performance. As such, better pedagogical approaches can be critical in ensuring a trainee is able to acquire mastery and refine technique for anesthesiologic interventions. Virtual reality (VR) and augmented reality (AR) technologies are one option that is growing in popularity due to its ability to enhance hands-on learning (albeit virtually), especially during disease outbreaks, such as the current COVID-19 pandemic. A large advantage to these forms of remote learning technology is the reduction of human resources required to run a training session. This commentary explores the current state of VR/AR in anesthesiology medical education.

Introduction

Simulation training in anesthesiology has evolved to mimic human responses with an astonishingly high fidelity and realism with mannequins that can replicate life-like functions from breathing to heartbeats to electrocardiograms (ECGs), it is possible to recreate a vast array of patient presentations (1). It would be ideal if every student could be provided an opportunity to practice on a dummy, but bandwidths on time, supply, and effort are rate limiting steps. This is where the unique opportunity of practicing anesthesia in virtual reality (VR) and augmented reality (AR) have the potential to revolutionize medical training, becoming especially relevant applications in this new reality presented by infectious disease. During times of social distancing and remote education delivery, a virtual modality that can engage students from the comfort of their homes can be an advantage for teachers and trainees alike. Here, our objective is to highlight the advancements and value of experiential, simulation-based learning offered through VR/AR in the field of anesthesiology. (2) For the purposes of this article, VR will refer to an experience that removes the user from the real-world experience with a simulated digital one while AR will refer to an experience that retains the user experience in the real world that has been digitally enhanced, and anesthesiology is defined as the medical discipline concerned with relieving pain before, during, or after surgical intervention.

Advances in VR

In VR, students are given an opportunity to recreate anesthesia procedures in an engaging and cost-effective way. Provided that educators invest in VR Headsets ($360.13 CAD per set for Oculus Rift headsets used in clinics),(3) trainees can practice and perfect their skills in a virtual environment in a manner that saves time, effort, and money. Educators can reduce the logistical burdens of setup and takedown while saving money on expensive simulation apparatus. Additionally, they are able to shift their focus exclusively to the development of trainees' procedural skills. Furthermore, the prevalence of VR can significantly increase the accessibility of education as students have to deal with pandemic restrictions that prevent them from in-person training. VR simulations also provide high-definition 3D graphics that allow for interactive user manipulation and construal.(4) With the integration of haptic feedback, perhaps the role of VR can even be enhanced to a greater degree.(5,6) Increased realism can foster positive effects on student confidence and in the larger context, patient safety.(7)

One great advancement in VR surgery and anesthesiology training comes from higher resolution x-ray

imaging.(8) For example, 3D anatomy models of the bile duct can be constructed in AR with high degrees of detail and used in VR for diagnostic training and exploration pre-operatively in common surgical anesthesia procedures such as cholecystectomy. (9,10) Anesthesiology residents will have to foster a good understanding of anatomy to manipulate software and work alongside technicians in interdisciplinary work environments to optimize models and carry out anesthesia in a seamless way during surgery.

I had the opportunity to work on a dental anesthesia VR simulation at the University of Alberta. To set the context, prior to the VR simulations, dental trainees would typically practice injections on chicken legs prior to practicing on their colleagues.(7) Perhaps conceivably, this was quite concerning for the safety of trainees and their peers. VR can represent a feasible intermediate step during this transition for healthcare students. Our lab, the University of Alberta Rehabilitation Robotics Lab, produced a learning object that can be used in VR and provide feedback to allow students to become better equipped to perform dexterous injections(11). If these types of pedagogical programming can be implemented in the classroom, it could change the landscape of learning. The VR experience still has several deficits when compared to patient mannequins. For example, essential nontechnical skills such as teamwork become much more difficult to assess in VR when completing a module in isolation. However, provided the current context of the COVID-19 pandemic, reducing one's contacts with peers, teachers, and others can actually be useful.

Advances in AR

Beyond VR, AR applications can be pursued to superimpose models onto cadavers. With markers and overlays, it is possible to practice intubations and insertions with greater precision. In having these 'handrails' on anatomical landmarks, students would be given a chance to explore specific techniques involved in surgical anesthesia(12). AR also can play a role in surgical planning as students and educators can discuss possible courses of anesthesia administration as a team or class(13). For example, one of the innovations being developed are AR guidance systems for combining tracked needles with non-invasive ultrasound and patient-specific geometric models to create phantom paths that anesthesia residents can use to practice nerve block(14). Understanding the technical skill to place needles within submillimetre targets takes practice, failure, and repetition for residents to acquire this expertise. An equally pertinent application has been developed in our lab. As spinal needle injection procedures such as lumbar epidurals are becoming more and more prevalent, needle placements are of utmost importance as trainees could unintentionally damage sensitive spinal cord tissue. An educational intervention study showed that manual palpation can correctly identify spinal levels 30% of the time, but additional training, with ultrasound guidance, greatly improved this success rate to 78.7% (15). Our lab has a vertebral AR model that can be used in applications like this to identify lumbar spinal levels(11). Beyond the clinical value of these technologies, it also has a vital pedagogical value as students can recognize their mistakes and allow for correction.

AR is currently being used in real-life robotic surgical interventions and as we evolve our technologies, it might start becoming more commonplace in routine surgeries as well(16). If this is the case, anesthesiology trainees may need to start acquiring skills that enable them to use AR while performing anesthesia.

Future Directions

The future of VR/AR is ripe with possibilities. If current trends for VR and AR equipment costs continue, it is conceivable that there will be a time when households no longer have any financial barriers to afford VR/AR systems that permit interactive student learning from home. In this future, remote education can look completely different with learning objects or modules specialized towards different procedures and skills that could be assessed and monitored remotely by an evaluator.

Alternatively, it may even be possible to tap into machine learning algorithms that can increase the challenge required for practicing maneuvers and injections. (17) Combining VR/AR 3D models with artificial intelligence can transform clinical decision making. For example, a machine learning model can predict difficult intubations from using appearance or alternatively, control anesthesia depth based off electroencephalograms of the brain. (17) With added functionality like this, students would be given an opportunity to make even more

realistic decisions to prepare them for real patients.

Limitations and Caveats with VR/AR

Translation of VR/AR technologies into healthcare pedagogy is teeming with potential and data, but there are still pitfalls and limitations that prevent it from being fully embraced by institutions. Currently, although VR/AR headsets are something that lab grants and medical training institutes devote their resources towards, they are not readily available in homes. Limitations in bandwidth also exist as computational paradigms can only model anatomical intricacies so well.(18) It is also integral to consider the legal, ethical, and social implications that can arise from errors and misrepresentations of experience.

Significance in the Current Context

In these times of social distancing, companies have greater incentives to develop VR/AR educational tools for medical specialties like anesthesiology to better support trainees. However, engineers and developers believe there may be long-lasting implications to adoption of these tools even after the pandemic is over.(19) Perhaps, the landscape of anesthesiology pedagogy will be altered permanently with these novel developments.

The COVID-19 pandemic has also presented a brand-new period of challenges for medical educators. With the growing expansion of telehealth applications, there is more pressure on medical curricula to match these changes. As remote patient monitoring technologies have gained momentum, remote trainee monitoring technologies could be the next step. I believe this is the question we should ask ourselves. Can we outsource education via AR and VR just as we do with telemedicine applications? If so, how can we best support infrastructure for remote learning and what types of learning objects can be implemented while retaining accessibility?

Conclusion

In conclusion, advances in VR/AR are valuable advances that can reimagine the way we provide education to anesthesiology students. As a constantly growing and rapidly evolving field, there is a need for educators and students alike to stay up-to-date and provide these opportunities for learning, if feasible. Providing opportunities for experiential learning in VR/AR can help reduce medical student error in clinical situations and enhance the delivery of anesthesiology care provided.

References

1. Green M, Tariq R, Green P. Improving patient safety through simulation training in anesthesiology: Where are we? Vol. 2016, Anesthesiology Research and Practice. Hindawi Limited; 2016.
2. Cleave-Hogg D, Morgan PJ. Experiential learning in an anaesthesia simulation centre: Analysis of students' comments. Med Teach [Internet]. 2002 [cited 2021 May 21];24(1):23–6. Available from: https://pubmed.ncbi.nlm.nih.gov/12098453/
3. Oculus Rift S PC-Powered VR Gaming Headset | Phone pop case holder for iphone samsung pop socket [Internet]. [cited 2021 May 21]. Available from: https://popisocket.com/product/oculus-rift-s-pc-powered-vr-gaming-headset/?utm_source=Google Shopping&utm_campaign=Popi USA&utm_medium=cpc&utm_term=19428
4. Ming Tang Y, Ho HL. 3D modeling and computer graphics in virtual reality. In: mixed reality and three-dimensional computer graphics [Internet]. IntechOpen; 2020 [cited 2021 May 21]. Available from: www.intechopen.com
5. Kim M, Jeon C, Kim J. A study on immersion and presence of a portable hand haptic system for immersive virtual reality. Sensors (Basel). 2017 May 17;17(5).
6. Collaço E, Kira E, Sallaberry LH, Queiroz ACM, Machado MAAM, Crivello O, et al. Immersion and haptic feedback impacts on dental anesthesia technical skills virtual reality training. J Dent Educ [Internet]. 2020 Apr 1 [cited 2021 May 21];85(4). Available from: https://pubmed.ncbi.nlm.nih.gov/33274441/
7. Poyade M, Lysakowski A, Anderson P. Development of a haptic training simulation for the administration of dental anaesthesia based upon accurate anatomical data [Internet]. 2014 [cited 2021 May 21]. Available from: http://www.openscenegraph.org/
8. Peters TM. Image-guided surgery: From X-rays to virtual reality. Comput Methods Biomech Biomed Engin [Internet]. 2001 [cited 2021 May 21];4(1):27–57. Available from: https://pubmed.ncbi.nlm.nih.gov/11264860/
9. Simone M, Mutter D, Rubino F, Dutson E, Roy C, Soler L, et al. Three-dimensional virtual cholangioscopy: A reliable tool for the diagnosis of common bile duct stones. Ann Surg [Internet]. 2004 Jul [cited 2021 May 21];240(1):82–8. Available from: https://pubmed.ncbi.nlm.nih.gov/15213622/
10. Tang R, Ma L, Li A, Yu L, Rong Z, Zhang X, et al. Choledochoscopic examination of a 3-dimensional printing model using augmented reality techniques: A preliminary proof of concept study. Surg Innov [Internet]. 2018 Oct 1 [cited 2021 May 21];25(5):492–8. Available from: https://pubmed.ncbi.nlm.nih.gov/29909727/
11. Alberta researchers combine X-rays, virtual reality for new medical treatmens | CTV News [Internet]. [cited 2021 May 21]. Available from: https://www.ctvnews.ca/health/alberta-researchers-combine-x-rays-virtual-reality-for-new-medical-treatments-1.4326679
12. Molina CA, Phillips FM, Colman MW, Ray WZ, Khan M, Orru' E, et al. A cadaveric precision and accuracy analysis of augmented reality–mediated percutaneous pedicle implant insertion. In: Journal of Neurosurgery: Spine [Internet]. American Association of Neurological Surgeons; 2021 [cited 2021 May 21]. p. 316–24. Available from: https://pubmed.ncbi.nlm.nih.gov/33126206/
13. Thomas RG, John NW, Delieu JM. Augmented reality for anatomical education. J Vis Commun Med [Internet]. 2010 Mar [cited 2021 May 21];33(1):6–15. Available from: https://pubmed.ncbi.nlm.nih.gov/20297908/