Simulation-based training

The recent emphasis on simulation-based training in neurosurgery has led to the development of many simulation models and training courses.

Simulation-based training is increasingly being used for the assessment and training of psychomotor skills involved in medicine. The application of artificial intelligence and machine learning technologies has provided new methodologies to utilize large amounts of data for educational purposes. A significant criticism of the use of artificial intelligence in education has been a lack of transparency in the algorithms' decision-making processes.

A study aimed to 1) introduce a new framework using explainable artificial intelligence for simulation-based training in surgery, and 2) validate the framework by creating the Virtual Operative Assistant, an automated educational feedback platform. Twenty-eight skilled participants (14 staff neurosurgeons, 4 fellows, 10 PGY 4-6 residents) and 22 novice participants (10 PGY 1-3 residents, 12 medical students) took part in this study. Participants performed a virtual reality subpial brain tumor resection task on the NeuroVR simulator using a simulated ultrasonic aspirator and bipolar.

<html><iframe src=“https://player.vimeo.com/video/190588397” width=“640” height=“360” frameborder=“0” allow=“autoplay; fullscreen” allowfullscreen></iframe> <p> </html>

Metrics of performance were developed, and leave-one-out cross validation was employed to train and validate a support vector machine in Matlab. The classifier was combined with a unique educational system to build the Virtual Operative Assistant which provides users with automated feedback on their metric performance with regards to expert proficiency performance benchmarks. The Virtual Operative Assistant successfully classified skilled and novice participants using 4 metrics with an accuracy, specificity and sensitivity of 92, 82 and 100%, respectively. A 2-step feedback system was developed to provide participants with an immediate visual representation of their standing related to expert proficiency performance benchmarks. The educational system outlined establishes a basis for the potential role of integrating artificial intelligence and virtual reality simulation into surgical educational teaching. The potential of linking expertise classification, objective feedback based on proficiency benchmarks, and instructor input creates a novel educational tool by integrating these three components into a formative educational paradigm [1].

Patel et al. aimed to identify the currently available simulators and training courses for neurosurgery, assess their validity and determine their effectiveness.

Both Medline and EMBASE were searched for English language articles that validate simulation models for neurosurgery. Each study was screened according to Messick's validity framework, and rated in each domain. McGaghie's model of translational outcomes was then used to determine a level of effectiveness (LoE) for each simulator or training course.

Upon screening of 6006 articles, 114 were identified either validating or determining a LoE for 108 simulation-based training models or courses. Achieving the highest rating for each validity domain were: six models and training courses for content validity; 12 for response processes; 4 for internal structure; 14 for relations to other variables and none for consequences. For translational outcomes, 6 simulators or training achieved a LoE of greater than 2 and thus demonstrated skills transfer beyond the simulation setting.

With the advent of increasing neurosurgery simulators and training tools, there is a need for more validity studies. Further attempts to investigate translational outcomes to the operating theatre when using these simulators are particularly warranted. Finally, more training tools incorporating full immersion simulation and non-technical skills training are recommended [2] [3].

The current simulation technology used for neurosurgical training leaves much to be desired. Significant efforts are thoroughly exhausted in hopes of developing simulations that translate to give learners the “real-life” feel. Though a respectable goal, this may not be necessary as the application for simulation in neurosurgical training may be most useful in early learners. The ultimate uniformly agreeable endpoint of improved outcome and patient safety drives these investments [4].

Medicine and surgery are turning towards simulation to improve on limited patient interaction during residency training. Many simulators today utilize virtual reality with augmented haptic feedback with little to no physical elements.

To optimize the learning exercise, it is essential that both visual and haptic simulators are presented to best present a real-world experience. Many systems attempt to achieve this goal through a total virtual interface.

Bova et al., approach has been to create a mixed-reality system consisting of a physical and a virtual component. A physical model of the head or spine is created with a 3-dimensional printer using deidentified patient data. The model is linked to a virtual radiographic system or an image guidance platform. A variety of surgical challenges can be presented in which the trainee must use the same anatomic and radiographic references required during actual surgical procedures.

Using the aforementioned techniques, they have created a ventriculostomy simulators, percutaneous stereotactic lesion procedure for trigeminal neuralgia, and spinal instrumentation.

The system has provided the residents an opportunity to understand and appreciate the complex 3-dimensional anatomy of the 3 neurosurgical procedures simulated. The systems have also provided an opportunity to break procedures down into critical segments, allowing the user to concentrate on specific areas of deficiency [5].

Multiple simulators have been developed for neurosurgical training, including those for minimally invasive procedures, vascular, skull base, pediatric, tumor resection, functional neurosurgery, and spine surgery.

Advances in imaging and computer technology have led to the development of different simulation models to complement traditional surgical training. Sophisticated virtual reality (VR) simulators with haptic feedback and impressive imaging technology have provided novel options for training in neurosurgery. Breakthrough training simulation using 3D printing technology holds promise for future simulation practice, proving high-fidelity patient-specific models to complement residency surgical learning [6].

Shakur et al., developed a real-time augmented reality simulator for percutaneous trigeminal rhizotomy using the ImmersiveTouch platform. Ninety-two neurosurgery residents tested the simulator at American Association of Neurological Surgeons Top Gun 2014. Postgraduate year (PGY), number of fluoroscopy shots, the distance from the ideal entry point, and the distance from the ideal target were recorded by the system during each simulation session. Final performance score was calculated considering the number of fluoroscopy shots and distances from entry and target points (a lower score is better). The impact of PGY level on residents' performance was analyzed.

Seventy-one residents provided their PGY-level and simulator performance data; 38% were senior residents and 62% were junior residents. The mean distance from the entry point (9.4 mm vs 12.6 mm, P = .01), the distance from the target (12.0 mm vs 15.2 mm, P = .16), and final score (31.1 vs 37.7, P = .02) were lower in senior than in junior residents. The mean number of fluoroscopy shots (9.8 vs 10.0, P = .88) was similar in these 2 groups. Linear regression analysis showed that increasing PGY level is significantly associated with a decreased distance from the ideal entry point (P = .001), a shorter distance from target (P = .05), a better final score (P = .007), but not number of fluoroscopy shots (P = .52).

Because technical performance of percutaneous rhizotomy increases with training, they proposed that the skills in performing the procedure in there virtual reality model would also increase with PGY level, if this simulator models the actual procedure. The results confirm this hypothesis and demonstrate construct validity [7)].

Simulation technology identifies neurosurgical residency applicants with differing levels of technical ability. These results provide information for studies being developed for longitudinal studies on the acquisition, development, and maintenance of psychomotor skills. Technical abilities customized training programs that maximize individual resident bimanual psychomotor training dependant on continuously updated and validated metrics from virtual reality simulation studies should be explored [8)].

Surgical education is moving rapidly to the use of simulation for technical training of residents and maintenance or upgrading of surgical skills in clinical practice. To optimize the learning exercise, it is essential that both visual and haptic cues are presented to best present a real-world experience. Many systems attempt to achieve this goal through a total virtual interface.

To demonstrate that the most critical aspect in optimizing a simulation experience is to provide the visual and haptic cues, allowing the training to fully mimic the real-world environment.

Bova et al approach has been to create a mixed-reality system consisting of a physical and a virtual component. A physical model of the head or spine is created with a 3-dimensional printer using deidentified patient data. The model is linked to a virtual radiographic system or an image guidance platform. A variety of surgical challenges can be presented in which the trainee must use the same anatomic and radiographic references required during actual surgical procedures.

Using the aforementioned techniques, they have created simulators for ventriculostomy, percutaneous stereotactic lesion procedure for trigeminal neuralgia, and spinal instrumentation. The design and implementation of these platforms are presented.

The system has provided the residents an opportunity to understand and appreciate the complex 3-dimensional anatomy of the 3 neurosurgical procedures simulated. The systems have also provided an opportunity to break procedures down into critical segments, allowing the user to concentrate on specific areas of deficiency [9].

Simulation center

Simulation Centers

References

1)
Mirchi N, Bissonnette V, Yilmaz R, Ledwos N, Winkler-Schwartz A, Del Maestro RF. The Virtual Operative Assistant: An explainable artificial intelligence tool for simulation-based training in surgery and medicine. PLoS One. 2020 Feb 27;15(2):e0229596. doi: 10.1371/journal.pone.0229596. eCollection 2020. PubMed PMID: 32106247.
2)
Patel E, Aydin A, Cearns M, Dasgupta P, Ahmed K. A Systematic Review of Simulation-based Training in Neurosurgery, Part 1: Cranial Neurosurgery. World Neurosurg. 2019 Sep 18. pii: S1878-8750(19)32430-1. doi: 10.1016/j.wneu.2019.08.262. [Epub ahead of print] PubMed PMID: 31541755.
3)
Patel E, Aydin A, Cearns M, Dasgupta P, Ahmed K. A Systematic Review of Simulation-based Training in Neurosurgery, Part 2: Spinal and Paediatric Surgery, Neurointerventional Radiology and Non-Technical Skills. World Neurosurg. 2019 Sep 18. pii: S1878-8750(19)32442-8. doi: 10.1016/j.wneu.2019.08.263. [Epub ahead of print] PubMed PMID: 31541754.
4)
Konakondla S, Fong R, Schirmer CM. Simulation training in neurosurgery: advances in education and practice. Adv Med Educ Pract. 2017 Jul 14;8:465-473. doi: 10.2147/AMEP.S113565. eCollection 2017. Review. PubMed PMID: 28765716; PubMed Central PMCID: PMC5524176.
5) , 9)
Bova FJ, Rajon DA, Friedman WA, Murad GJ, Hoh DJ, Jacob RP, Lampotang S, Lizdas DE, Lombard G, Lister JR. Mixed-reality simulation for neurosurgical procedures. Neurosurgery. 2013 Oct;73 Suppl 1:138-45. doi: 10.1227/NEU.0000000000000113. PubMed PMID: 24051877.
6)
Rehder R, Abd-El-Barr M, Hooten K, Weinstock P, Madsen JR, Cohen AR. The role of simulation in neurosurgery. Childs Nerv Syst. 2016 Jan;32(1):43-54. doi: 10.1007/s00381-015-2923-z. Review. PubMed PMID: 26438547.
7)
Shakur SF, Luciano CJ, Kania P, Roitberg BZ, Banerjee PP, Slavin KV, Sorenson J, Charbel FT, Alaraj A. Usefulness of a Virtual Reality Percutaneous Trigeminal Rhizotomy Simulator in Neurosurgical Training. Neurosurgery. 2015 Sep;11 Suppl 3:420-5; discussion 425. doi: 10.1227/NEU.0000000000000853. PubMed PMID: 26103444.
8)
Winkler-Schwartz A, Bajunaid K, Mullah MA, Marwa I, Alotaibi FE, Fares J, Baggiani M, Azarnoush H, Zharni GA, Christie S, Sabbagh AJ, Werthner P, Del Maestro RF. Bimanual Psychomotor Performance in Neurosurgical Resident Applicants Assessed Using NeuroTouch, a Virtual Reality Simulator. J Surg Educ. 2016 Jul 6. pii: S1931-7204(16)30026-5. doi: 10.1016/j.jsurg.2016.04.013. [Epub ahead of print] PubMed PMID: 27395397.