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The Effect of 3-Dimensional Simulation on Neurosurgical Skill Acquisition and Surgical Performance: A Review of the Literature

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OBJECTIVE: In recent years, 3-dimensional (3D) simulation of neurosurgical procedures has become increasingly popular as an addition to training programmes. However, there remains little objective evidence of its effectiveness in improving live surgical skill. This review analysed the current literature in 3D neurosurgical simulation, highlighting remaining gaps in the evidence base for improvement in surgical performance and suggests useful future research directions.

DESIGN: An electronic search of the databases was conducted to identify studies investigating 3D virtual reality (VR) simulation for various types of neurosurgery. Eligible studies were those that used a combination of metrics to measure neurosurgical skill acquisition on a simulation trainer. Studies were excluded if they did not measure skill acquisition against a set of metrics or if they assessed skills that were not used in neurosurgical practice. This was not a systematic review however, the data extracted was tabulated to allow comparison between studies

RESULTS: This study revealed that the average overall quality of the included studies was moderate. Only one study assessed outcomes in live surgery, while most other studies assessed outcomes on a simulator using a variety of metrics.

CONCLUSIONS: It is concluded that in its current state, the evidence for 3D simulation suggests it as a useful supplement to training programmes but more evidence is needed of improvement in surgical performance to warrant large-scale investment in this technology. (J Surg Ed ■:■■■-■■■. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: 3-dimensional, neurosurgical, training, simulators

COMPETENCIES: Practice-Based Learning and Improvement

INTRODUCTION

As modern information technology becomes more advanced, the way we learn and teach is changing. Simulation technology is being used more widely, and in postgraduate surgical education it is now an important tool. With the advent of 3-dimensional (3D) simulators using haptic feedback, surgeons can practice techniques in a safe but realistic environment. The 3D simulators can measure variables that cannot be measured in live surgery, such as instrument angles and exact distances, which can be very useful for training in precision techniques. However, there is a lack of evidence that practice on a simulator leads to improvement in surgical performance. Most of the evidence is based on subjective ratings rather than objective performance metrics. Some objective studies measure performance

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improvement on the simulator, but do not compare this to live surgery. The perceived value of simulator training is high but more evidence of performance and patient outcomes is needed to justify the high-cost investment in such technology. Ethical constraints concerning patient safety also affect the possibility of conducting randomized trials.

This review concerns itself with 3D virtual reality (3D VR) simulation for various types of neurosurgery. There is a sizeable literature in this area, but a relative paucity of articles describes the effectiveness of simulation on surgical skills.

METHODS

An electronic search of the databases MEDLINE, EMBASE, and Cochrane Library Databases was conducted from inception to January 14, 2017 with restrictions to the English language. To identify studies investigating 3D VR simulation for various types of neurosurgery, the following key words were searched for: neurosurgery, neurosurgical, training, trainer, virtual reality, and simulator. This database search was supplemented by a search of the reference lists of included studies as well as using the related articles function provided by each database. Titles and abstracts were screened to include potential studies, with the full article being read to determine the suitability of the study.

Eligible studies were those that used a combination of metrics to measure neurosurgical skill acquisition on a simulation trainer. Studies were excluded if they did not measure skill acquisition against a set of metrics or if they assessed skills that were not used in neurosurgical practice.

Data extraction was reviewed independently by 2 authors (A.C. and N.C.) with any discrepancies being cross-checked at a consensus meeting. The following data were extracted from the included studies: sample size, study objective, study design, outcome measures, data type, and participant feedback.

Given that this was not a systematic review a formal quality assessment tool was not used. However, the data extracted from included studies were tabulated so comparisons between studies could be made and a quality assessment tool generated to assess the eligible studies.

RESULTS AND DISCUSSION

Endovascular Simulators

In 2004, Hsu et al.[1] conducted a trial ($n = 41$) of a computer simulator for endovascular carotid stenting, which projected 3D images constructed from computed tomography scans of patients, allowing patient-specific practice.[1] In both untrained and trained participants in this procedure, practice on the simulator was associated with significantly decreased time to perform the procedure in the final test compared to the initial test. There was also a nonsignificant trend in those who were not permitted to practice on the simulator. However, it is not possible to be certain that practice on the simulator would affect performance of the procedure in live surgery. The alternative explanation, that it may merely improve the participant's ability to use the simulator, still remains. This is a concern with all 3D simulation studies that can only be addressed by measuring surgical skill.

The Simbionix endovascular simulator was used in a pilot program involving catheterization of the internal carotid and vertebral arteries.[2] It was found that all participants improved over 5 trials on the simulator. Initially, Residents (more junior/novice trainees) were slower than Fellows (near "expert" level trainees), but by the fourth trial they performed the procedure in a similar time to the Fellows. However, this study only involved 10 Residents and 4 Fellows, and it is unclear how well performance on the simulator would relate to the live procedure. There is as yet still little objective evidence of improved surgical performance from endovascular 3D VR simulators, but the subjective evidence is certainly very encouraging and is worth further exploration.

Ventriculostomy Simulators

The 3D simulation of ventriculostomy has become far more popular with the advent of haptic feedback, which provides a more realistic experience for the surgeon, especially with regard to feeling the pressure change as the ventricle is entered. The ImmersiveTouch (ImmersiveTouch, Inc., Chicago, IL) VR platform, which involves haptic feedback, features in several studies. For example, Lemole et al.[3] used it to simulate ventriculostomy catheter placement. Neurosurgeons, trainees, and medical students reported that the simulator was very true to reality; however, no performance measures were taken in live surgery, so its usefulness for learning and improving this procedure was unknown. The ImmersiveTouch ventriculostomy simulator has been shown to improve anatomical identification, time to complete procedures, accuracy of burr hole placement, and catheter positioning as part of a course.[4] Performance on the simulator was also correlated with the experience level of the trainee, indicating it to be a good representation of live surgery. However, it is worth noting that this module does not realistically simulate either the burr hole wall, which may affect positioning of the catheter, or tunneling the catheter under the skin without moving the tip.[4]

It has also been shown by Yudkowsky et al.[5] that this simulator module does indeed improve Residents' ability to perform a ventriculostomy in live surgery. Competency indicators, such as correct placement of the catheter and number of attempts, were recorded from the participants in