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Chapter 16: Technology and Simulation To Improve Patient Safety

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Abstract/Summary:

Improving the quality and efficiency of surgical techniques, reducing technical errors in the operating suite, and ultimately improving patient safety and outcomes through education are common goals to all surgical specialties. Present day surgical simulation programs represent an effort to enhance and optimize the training experience, to overcome the training limitations of a mandated 80 hour work week, and the overall goal of providing a well-balanced resident education in a society with a decreasing level of tolerance for medical errors. Incorporation of technical procedural based simulators is just the first step. Full integration into residency requires a scientific objective structured assessment tool and a method of independent testing and grading. One proposed method is through a video-based assessment of simulator performance. Surgical simulators represent one key attempt at maximizing the efficiency of resident education during an era of limited resources.

Key Points (3-5):

1. Neurosurgical education is increasingly looking to integrate surgical procedural based simulators as a tool for preoperative training and interim evaluation of skills.
2. Repetitive surgical training provides-helps the resident to-develop a mental rehearsal of steps. Simulation allows for that mental rehearsal to begin prior to the first operative experience. This process is particularly useful/beneficial with infrequently encountered pathologies and procedures.
3. Using simulation as an interim evaluation tool requires a validated and reliable scoring system, which poses a unique challenge in grading technical skills.

Introduction to Simulation in Neurosurgical Education

Improving the quality and efficiency of surgical education, reducing technical errors in the operating suite, and ultimately improving patient safety and outcomes are common goals to all surgical specialties.¹ Modern medical education at the turn of the 20th century emphasized graduated levels of responsibility through successive years of training.² Modern day simulation measures-tools represent an effort to enhance the training experience due to the limitations of a government-mandated 80 hour work week, as well as the task of providing a well-balanced resident education in a society with a decreasing level of tolerance for medical errors.^{2,3}

Early simulator use in medical training has been focused on the rehearsal of clinical scenarios, such as those required in advanced cardiac life support resuscitation training.⁴ The use of simulators has expanded rapidly after positive reports correlating technical simulator proficiency with increasing measures of technical expertise in the operating suite.⁵ One prospective randomized trial evaluating the use of simulation in laparoscopic inguinal hernia repair found significantly shorter operative times,

decreased complication rates, and shorter hospital stays compared to those who had no prior simulation training.⁶

Organized Presurgical Training Models

In a recent survey of neurosurgery program directors, 72% felt that simulation would improve patient outcome, and that nearly half of the respondents felt that residents should reach an agreed upon standard of simulation proficiency prior to intraoperative training.⁷ One formal implementation of simulator training could be in the form of annual objective assessments of resident operative skills. At the very least, since the direct effects of work hour restriction is the decrease in operative time for the resident, practice runs using a simulator would help the resident develop a mental 'script-based rehearsal' to optimize the time spent in the operating suite.⁸

Comment [SH1]: IS this US? If so authors should state

Simulation in Neurosurgery

Simulators can be divided into physical simulators, haptic/computerized simulators, or cadaveric dissection.³ Cadaveric simulation was the first educational tool to provide anatomic education with preserved three-dimensional relationships. As a result, this modality has provided the majority of education to the present time. Improvements in computer and engineering technology have seen the recent growth of computerized simulators. Eventually, computer graphics technology and passive three-dimensional optics became affordable for implementation in neurosimulation. Lastly, techniques of three-dimensional fabrication have allowed for realistic physical simulators to be developed at a cost affordable for medical education training institutions.

Initial Use of Simulation in Neurosurgery Residency

Surgical 'boot camps' for postgraduate first year residents have been adopted and implemented in the past several years across a variety of surgical specialties, including cardiothoracic surgery⁹, orthopedics¹⁰, otorhinolaryngology¹¹ and neurosurgery.¹² Surveys conducted in neurosurgery found a high level of satisfaction and knowledge retention of the skills that were emphasized at the neurosurgical boot camp.¹² Appropriate simulators found at postgraduate year one training events have included central line placement, ventriculostomy catheter placement, and trauma craniotomy models.

Expansion of Training Aspects Addressed by Simulators

With the rapid growth in simulators available, interest in incorporating these into formal training has been rising. In the past year alone, results of several efforts have been published with haptic feedback devices demonstrating the various aspects of microsurgical technique that can be taught outside of the operating room, ranging from tumor handling, volumetric resection, to anatomical accuracy (Table 1). These technologies are ideal for techniques such as endovascular treatment of vascular pathologies,⁵ craniotomies,^{13,14} and endoscopic approaches.¹⁵ In spinal surgery, new simulations are being introduced such as the durotomy repair¹⁶, posterior cervical laminoforaminotomy,¹⁷ and anterior cervical discectomy models.¹⁸ These have been a welcome

addition to prior established simulators for percutaneous pedicle screw fixation.¹⁹ Arguably these skills should be practiced prior to the entry of the operating room, and textbook knowledge alone is insufficient.

Challenges to Designing a Formal Curriculum Using Simulation in Residency Education

The initial introduction of simulators has already been successfully incorporated into residencies as well as national meetings such as the Congress of Neurological Surgeons.²⁰ In an attempt to fully incorporate neurosurgical simulators into resident education, an educational curriculum and evaluation tool is needed. There are several challenges to grading surgical skills not encountered with typical testing of one's fund of knowledge. The first challenge is identifying a participant's knowledge of all skills,¹⁶ so that when repeated examination of the same participant occurs, a frame of reference is established. The second challenge is choosing the right objective structured assessment (OSAT) to quantitatively measure a resident's interim performance. This OSAT needs to be consistent across all examiners and would have to be demonstrated in future study through validation, as well as interobserver and intraobserver reliability studies.

Comment [SH2]: Tool? (OSAT)

Proposal for Validation of Neurosurgical Simulation Skills

One proposed pathway to a more reliable and consistent grading scheme would be a video-based OSAT scoring system, rather than a traditional text-based scoring system that purely describes certain techniques on a 10-point scoring scheme. This way, the participant can videotape their examinations, following scripted instructions either independently or with a faculty instructor. This way, formal grading can be done and can be graded by an examiner. One way to validate this method would be to have multiple examiners review and grade a submitted video, using the video-based OSAT to confirm interobserver reliability. Interobserver reliability is felt to be the most important component of implementing an interim grading scheme that limits bias from having different examiners grading annual performance.

The Durotomy Repair Simulator As A Model Residency Training Tool

Unintended repair of durotomies can be frustrating, adding significant morbidity to a spine Procedure. Dural closure of an unintended durotomy is often in a technically difficult location such as the lateral recesses of the lumbar spinal canal. Occurring at a relatively infrequent rate of 1-13%²¹ leaves the resident with little case practice. Furthermore, at the time of dural repair, it would be ideal for residents to have had prior experience due to the innate difficulties of closure. In a durotomy repair model,¹⁶ residents can practice dural closure with a variety of suture materials and sizes. While at the present stage this model does not simulate the difficulties of obscured vision by epidural bleeding or the risk of nerve root injury from suturing, it provides valuable time for the resident to practice watertight dural closure and knot placement (Figure 1). Residents take a multiple-choice pretest and undergo a didactic skills session prior to closure. Each closure is graded on timeliness, the presence of a watertight closure, and the consistency of suturing in terms of distance between bites as well as even apposition of the edges of the durotomy. The current steps in improving the value of this tool in

interim education is to provide a video-based OSATs where the resident can review a video of ideal techniques and emulate that in independent self-guided study and testing.

Summary/Discussion:

Modern residency education is looking forward to the number of newly developing simulators. Incorporation of these simulators is just the first step. Full integration into residency requires a scientific objective structured assessment tool and a method of independent testing and grading. One proposed method is through a video-based assessment of simulator performance. These simulators represent one key attempt at maximizing the efficiency of resident education in the era of limited duty hours.

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Table 1: Selected Simulation Efforts Using Haptic Feedback/Software in 2014.

Author	Title (year)	Journal	Purpose	Design	Metric
Patel ²²	Neurosurgical tactile discrimination training with haptic-based virtual reality simulation (2014)	Neurol Res	To determine if computer simulation w/ haptic feedback devices improved handling with surgical instruments	Group A: Computer training with haptic stim superior handling demonstration compared to Group B w/o prior training.	Ability to correctly identify brain lesions in a black box using instrumented tactile response
Hooten ²³	Mixed Reality Ventriculostomy Simulation: Experience in Neurosurgical Residency	Neurosurgery	To assess if simulation can improve ventriculostomy placement	Physical simulator measuring accuracy	Comparison to controls, distance to Foramen of Munro

	(2014)				
Azarnoush ²⁴	Neurosurgical virtual reality simulation metrics to assess psychomotor skills during brain tumor resection (2014)	Int J Comput Assist Radiol Surg	Software/Haptic feedback To develop tumor handling	Use of NeuroTouch™ Software.	Tier 1 metric: Volumetric resection (%), normal brain resected (%), Tier 2 tip path, OR time, pedal activation, Tier 3, sum of applied forces (estimating force of manipulation)

Figures

Figure 1. Lumbar Durotomy Repair Model. A Sawbones™ model of the lumbar spine is seen with the spinal canal filled with a latex tube distended by a set hydrostatic pressure. Residents are instructed to make a set durotomy (1cm) and are evaluated by their technique and timeliness under instruction. These simulators are simple that they can be used in a self-directed manner.