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COVER EDITORIAL

The role of simulation in neurosurgery

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It is increasingly apparent that the standards for surgical training are shifting from time-based to criterion-based parameters that emphasize obtaining and maintaining competencies [24]. The formation of a surgeon demands significant dedication and effort, in addition to time [54]. Current, well-established methods of surgical training are being challenged as the environment becomes increasingly competitive and litigious with greater scrutiny of patient outcomes [14, 17, 40, 44, 50]. In order to increase patient safety and improve treatment outcomes, several strategies such as problem-based learning and objective structured clinical examinations have promoted the development of new curricula in surgical education [13, 15, 35, 51, 52].

Some of these changes have been driven by events in the 1980s and 1990s such as medical misconduct and overworked, unsupervised resident staff that contributed to patient morbidity and mortality. This also coincided with a growing medical malpractice crisis. As a result, regulatory bodies began to initiate new standards of work hour restrictions and supervision for residents in training. The New York Health Code of 1989 compiled regulations restricting resident work hours (80 h per week) and one day free a week and placed limits on the number of calls [24, 32]. Concerns arose about the long-established methods of training surgical residents, and solutions were sought to reduce preventable errors and perioperative complications [24, 9].

The airline industry, with the development of flight simulators and pilot coaching methods, proved to be an excellent precedent for innovation in surgical education. Many surgical educators believe such methods are keys to accelerating the acquisition of fundamental skills and the rate of performance improvement among surgical residents. A Yale University study demonstrated that criterion-based simulator training decreased operating time by 30 % and operative errors by 85 % [47, 48].

Neurosurgical trainees in particular face great challenges in learning to plan and perform increasingly complex procedures in which there is little room for error [10]. The educator's task becomes ever more daunting as the number and complexity of neurosurgical procedures continue to increase in parallel with technological developments such as minimally invasive spine surgery and instrumentation, interventional neuroangiography, image-guided navigation, and endoscopic surgery.

The necessity of innovative surgical curriculum development that incorporates safe learning environments and objective skill assessments is thus obvious and needs to be led by trained surgical educators [5].

Adjuvant, non-clinical, surgical training can be grouped into four broad categories:

1. Cadaver training
2. Animal models
3. Training with synthetic physical models
4. Computerized and virtual reality simulators

Practice with each of these models has particular advantages and disadvantages that are still being elucidated in various validation processes. The choice of the most appropriate training model should take into consideration, among other qualities, efficacy, validity, cost-effectiveness, and versatility [60]. The demand for new, non-clinical, paradigms for surgical skills training has led to the development of a variety

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of surgical simulation models and methods that refine technique while objectively assessing performance [2, 20, 42, 45, 56, 58]. Simulation may be defined as a pool of techniques used in conjunction to recreate specific aspects of the real world, thus providing experience in a riskless situation. This concept has gained popularity over the last 20 years, and its broad applicability is exemplified in neuroendoscopy training.

Neuroendoscopy has reemerged as an appealing option in the management of intraventricular lesions and the treatment of hydrocephalus in children and adults. The use of cadaveric specimens for developing neuroendoscopy skills is expensive and increasingly difficult logistically. There are problems with the potential toxicity of chemicals used for fixation as well as logistic limitations related to preservation, storage, and viable utilization time for the specimens [36, 41, 43, 55]. In addition, cadavers do not recreate a realistic environment for ventriculoscopic work due to unnatural brain and ventricular compliance and consistency. Likewise, although laboratory animals are useful for surgical training, cost, ethical issues, and the lack of similarity with the human are problematic. The development of alternative realistic training methods is vital (Cover figure). The challenge is to provide not only realistic simulation of various pathologies but also standardized training milestones that allow a gradual progression in technical difficulty in concert with objective assessments of performance [61].

The use of 3-D renderings and virtual reality settings is still in the development phase and are quite costly for widespread use [11, 19]. Examples in neurosurgery include simulators for ventriculostomy [27, 30, 38], spine needle biopsy [28], pedicle screw placement [26, 31], diagnostic cerebral angiography [53], and aneurysm clipping. However, there may be limitations in the ability to transfer these “virtual skills” to physical reality [20, 39]. Further development and evaluation is needed in regard to touch, tactile, and force feedback (which vary among simulators) and the complex task of reproducing an appropriate tridimensional environment for visuospatial task training [4, 5, 20, 22].

Despite ongoing investment in virtual reality simulator development, synthetic physical simulators are still generally considered the most reliable, effective, and cost-efficient [3, 8, 12, 21, 23, 25]. The employment of physical simulators, designed specifically for surgical training, has become a promising method for neurosurgery training that provides effective results at a reasonable cost [1, 34, 57, 59]. Many permit multiple uses of repetitive practice in order to reach the desired level of performance. They also provide the opportunity to obtain CT and MRI imaging to incorporate image-guided navigation into the training program [6]. Moreover, there is the possibility of developing various surgical environments (tumor appearance, consistency, bleeding, cystic content) that require the practice of different tasks with more realism and unquestionable safety [6, 61]. A very important feature is the potential for high-fidelity haptic feedback that is not thus far supported by computer models. In general, these synthetic surgical simulators are reported to be interesting and appealing for participants to use [50], can serve as surrogate patients, and have the potential to enhance the quality of education in surgical anatomy and the teaching of basic and advanced open or endoscopic technical skills [24, 61].

It is important to emphasize that there is significant level I evidence demonstrating that technical skills acquired on simulated models directly transfer into performance improvements in the operating room, reinforcing their value in surgical training programs [29, 37]. The ideal simulator has to be realistic in multiple dimensions. Simulation physics, optical properties, haptic feedback, and suitability for the required surgical tasks must be tested to ensure the quality of surgical training [29, 33]. It is also mandatory to validate the ability of the simulation exercise to teach the desired skill set or technique [24]. The identification and measurement of errors permit assessment of the effectiveness of training that is specifically intended to reduce their incidence. Additionally, to be considered a useful tool for training, a simulator should be further evaluated regarding its overall quality. Despite a variety of ways to do it, every simulator should meet three major criteria: validity, reliability, and feasibility [16, 6].

Chopra et al. and Filho FV et al. showed that synthetic physical simulators can improve surgical performance [7,16]. Satava has suggested that a standardized simulator curriculum should include metrics specific to the skill being taught, common errors for the skill set, a specific curriculum for training the surgical skill, a method to capture outcomes, and a validation methodology [24, 49]. It has been suggested that when adopting a new training paradigm such as a simulator-based curriculum, it is important to utilize the same language and terminology in order to preserve the standards of assessment [24, 18].

The development of effective surgical simulators is a milestone in the evolution of surgical education. Realistic simulators provide a safe and non-threatening learning context that not only promotes the development of skills but also allows for objective risk-free testing of a trainee’s abilities prior to entering the operating room. Beyond pure technical proficiency, the cognitive skills of anatomical recognition, decision-making, and contingency planning can also be developed. And, independent learners can practice without constant supervision [50]. Additionally, these same models can be used in the process of initial certification as well as recertification of existing practitioners similar to performance assessment standards in the airline industry [24, 46].

Although the science of simulation for surgery, and more specifically pediatric neurosurgery, is still under development, the potential is very promising. New skill sets, such as those required for efficient and safe use of flexible endoscopy for neurosurgeons already adept with rigid endoscopes, will be more safely and efficiently transferred without the costs, risks, and logistical difficulties of learning new techniques in living patients.

Cover figure: Dr Giselle Coelho and her realistic model, a mimic of an infant with craniosynostosis

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