Simulation-Based Neurosurgical Training for the Presigmoid Approach With a Physical Model

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BACKGROUND: In recent years, there has been growing interest in the use of simulation to supplement conventional surgical training. Simulation remains, however, in its infancy in neurosurgery.

OBJECTIVE: To report on and assess the utility of a simulation physical model for the presigmoid approach.

METHODS: The Congress of Neurological Surgeons created a Simulation Committee to explore and develop simulation-based models. The current model involves drilling of the presigmoid cranial base under image guidance. Each time the drill touches the dura, facial nerve, or sigmoid sinus, a beeping and a warning sound are emitted.

RESULTS: Nine neurosurgery residents participated in and completed the presigmoid approach simulation module. All residents successfully completed the simulation procedure within the allocated time period (20 minutes). The mean number of hits to the dura, facial nerve, and sigmoid sinus decreased from 4.2 in the first test to 3.1 in the second test ($P < .05$). The facial nerve was the most likely structure to be injured, followed by the sigmoid sinus and finally the dura. All 9 participants had an improvement in their technical scores.

CONCLUSION: The presigmoid approach simulation model is a useful tool in resident education that may improve surgical proficiency while minimizing risk to patients. More studies with standardized end points for technical proficiency and clinical outcomes are needed.

KEY WORDS: Drill, Neurosurgery, Presigmoid, Simulation, Training

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The implementation of the 80-hour work-week by the Accreditation Council of Medical Education in 2003 has potentially affected resident's surgical exposure and resulted in an urgent need to develop and integrate alternative modes of training outside the operating room.[1,2] This is particularly true for neurosurgery, a complex and delicate field in which minor errors can have disastrous consequences. In recent years, there has been growing interest in the use of simulation to supplement or even complement conventional surgical training. Simulators are designed to create a realistic, real-time environment to train surgeons on the requisite technical skills, with built-in objective feedback of performance. Although simulators have been used quite extensively in general surgery and obstetrics and gynecology,[3,4] simulation remains in its infancy in neurosurgery.[5,6] The Congress of Neurological Surgeons (CNS) has been leading efforts to advance and integrate simulation-based training into neurosurgery so as to promote surgical skill acquisition by trainees and to improve the quality of patient care. Several physical and virtual simulators were devised or obtained, and a free neurosurgical simulation course was organized for neurosurgery residents at the 2012 CNS meeting in Chicago. In this article, we report on the presigmoid approach educational module, consisting of a physical simulation model and a focused didactic component.

ABBREVIATION: CNS, Congress of Neurological Surgeons

METHODS

The presigmoid approach model is a physical model that was developed by Stryker in 2010 and initially tested by neurosurgery residents and faculty at Thomas Jefferson University Hospital in 2011 as part of a pilot program. The model involves drilling of the presigmoid cranial base of a prefabricated skull under image guidance (Figures 1 and 2). Each time the drill touches a critical structure, namely the dura, facial nerve, or sigmoid sinus, the model, equipped with sensitive detectors, emits a beeping sound and a voice warning mentioning the name of the structure injured. On the basis of the success of the pilot program, the CNS Simulation Committee decided to dedicate a simulation module and curriculum for the presigmoid approach. The module took place at the CNS simulation course held in the Chicago Convention Center at the CNS 2012 Annual Meeting. The education module was approximately 120 minutes long and consisted of 2 components, a didactic and a technical component. The didactic component consisted of 15 questions on cranial base anatomy (range of possible scores, 0-15) that were adapted and modified after being tested on neurosurgery residents as part of a pilot program. The residents were then asked to drill the presigmoid cranial base in 20 minutes (the technical component), and their initial performance was graded according to the number of hits (beeping sounds emitted) during the simulation procedure (The technical score consisted of the total number of hits during the procedure). This was followed by a didactic session during which the basic principles of cranial base anatomy and the presigmoid approach were emphasized. A detailed case presentation illustrating these principles was also given. Residents were then asked to perform the same procedure on the simulation model, and their performance was graded again. The simulation exercise was interactive, and emphasis was placed on instruments, techniques, and potential complications. A didactic posttest consisting of the same initial pretest questions reorganized in a random manner was subsequently performed. Finally, the faculty and participants reviewed and discussed the test questions.

RESULTS

Nine neurosurgery residents participated in and completed the presigmoid approach simulation module. Most of the participants (6 of 9) were from non-US residency programs.

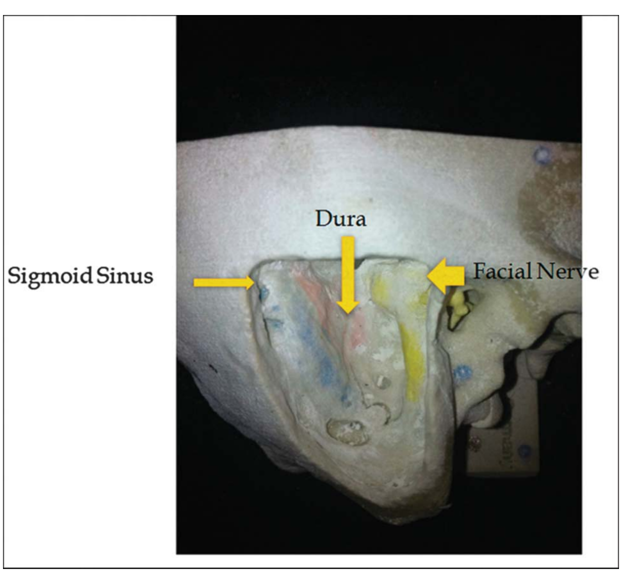

FIGURE 1. *Picture showing the 3 critical structures (facial nerve, sigmoid sinus, and dura) to avoid during presigmoid skull base drilling.*

The didactic pretest scores ranged from 53% (9 of 15) to 100% (15 of 15). An improvement in individual didactic scores was noted in 88% of participants (8 of 9). All residents successfully completed the simulation procedure within the allocated time period (20 minutes). The mean number of hits to the dura, facial nerve, and sigmoid sinus decreased from 4.2 in the first test to 3.1 in the second test ($P < .05$). The facial nerve was the most likely structure to be injured, followed by the sigmoid sinus and finally the dura. All 9 participants had an improvement in their technical scores.

DISCUSSION

With the increasingly hostile medicolegal environment and the recent duty hour restrictions, resident education has become more complex and problematic. In addition to increasing the overall risk to the patient, teaching residents in the operating room results in longer operative times and higher costs. The limited number of cases and/or instructors also adds to the complexity of the problem. In light of the success of flight simulation in the airline industry, surgical simulators have been developed to provide a realistic no-risk environment in which technical skills can be acquired through harmless repetition.[7,8] In some fields such as laparoscopy and endovascular surgery, simulation has been shown to improve operating room performance, thus supporting the integration of simulators into training curricula.[3,4,9,10]

Although simulation is still underdeveloped in neurosurgery, there is a growing interest in the neurosurgical community for simulation. Ganju et al[6] surveyed the program directors of US neurosurgery programs regarding the role of simulation in neurosurgical education and found that 72% of respondents believed that simulation would improve patient outcome and 74% believed that it could supplement conventional training. Interestingly, the majority of program directors were willing to invest time and money in simulation and would make simulator training mandatory if available. With most neurosurgery program directors receptive to incorporating simulation into training curricula, efforts should be directed toward the development and validation of simulation models.

We have reported on a new physical simulator for the presigmoid approach, a commonly used approach for resection of tumors or vascular lesions of the posterior fossa. Drilling of the presigmoid cranial base may cause injury to the facial nerve, sigmoid sinus, or dura. The present model was specifically designed to train residents on avoiding injury to these critical structures during skull base drilling. All participants successfully completed the presigmoid drilling within the allocated time period and had a significant improvement in their didactic and technical scores after the simulation module. These results suggest that simulator-based training with the present model may optimize resident education and improve surgical proficiency while minimizing risk to patients. The simulator is also portable and requires only ordinary computer equipment, which facilitates its use. In addition, as the present study shows, the simulation

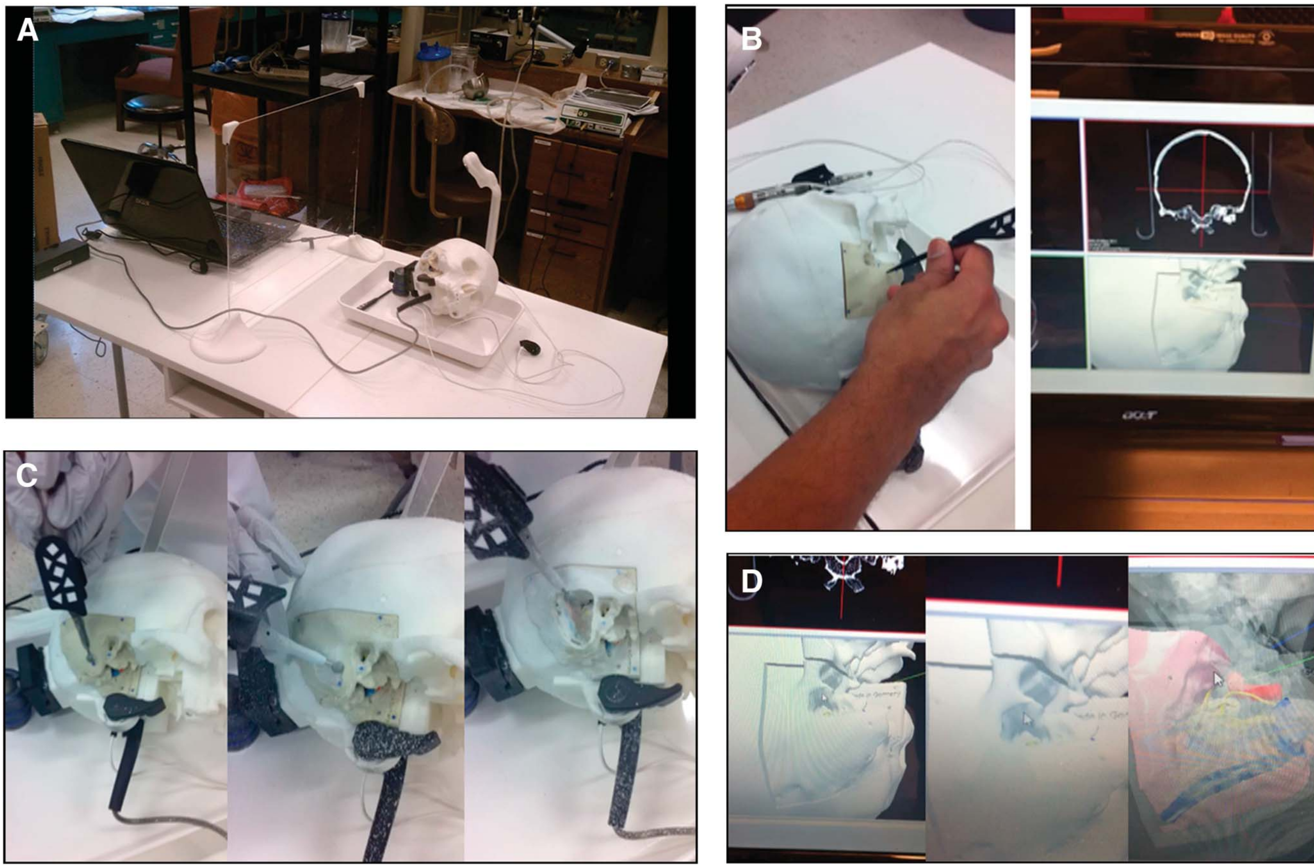

FIGURE 2. **A**, *picture showing the presigmoid approach simulation model.* **B**, *the simulator is equipped with image guidance.* **C**, *the skull base is drilled in the presigmoid area, and each time the drill touches the facial nerve, sigmoid sinus, or dura, a beeping sound and a voice warning are emitted.* **D**, *3-dimensional renderings showing the anatomy of the presigmoid area.*

session can be combined with a didactic session and delivered through a structured training curriculum for optimal results. Future improvements in the presigmoid approach model should focus on increasing the sensitivity of the detectors to mechanical and thermal injury and integrating a more efficient neuro-navigation system.

Although the present model is the first physical simulator for the presigmoid approach, other virtual reality simulators for skull base dissection are also available, but most have only otolaryngology applications.[5] In 2003, Bernardo et al[11] from the Barrow Neurological Institute developed a 3-dimensional surgical simulator (called the interactive virtual dissector) designed to teach surgeons the visuospatial skills required to navigate through a transpetrosal approach. The dissector is constructed from stereoscopic photographic source data obtained sequentially during cadaveric dissections and allows the user to drill the petrous bone and to identify critical structures. In the field of otolaryngology, several graphically advanced models have been developed to simulate tactile haptic feedback in cranial base surgery.[12,13]

The present study is limited primarily by the small sample size. Still, a statistically significant improvement in resident evaluation scores before and after simulation training was noted. It is also unclear whether the improvements in test performance were due to focused didactics or to simulation-based dissection, both of which could contribute to improved scores. The simulator appears to have good face and content validity; the construct validity, however, needs to be ascertained in a future study because we did not formally assess whether the device can differentiate between expert and novice during standardized simulated tasks. Further studies are needed to assess the durability and clinical improvement of simulation training.

CONCLUSION

The presigmoid approach simulation model is a useful tool in resident education that may improve surgical proficiency while minimizing risk to patients. This portable and easy-to-use simulator offers the advantage of allowing as much training on presigmoid skull base drilling as is required before the resident is allowed to operate on a patient. More studies with standardized end points for technical proficiency and clinical outcomes are needed.

Disclosures

Dr Jabbour has been a consultant for ev3, Codman, and Mizuho. Dr Chalouhi has no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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