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Clinical Study

Resident simulation training in endoscopic endonasal surgery utilizing haptic feedback technology

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ABSTRACT

Simulated practice may improve resident performance in endoscopic endonasal surgery. Using the NeuroTouch haptic simulation platform, we evaluated resident performance and assessed the effect of simulation training on performance in the operating room. First- (N = 3) and second- (N = 3) year residents were assessed using six measures of proficiency. Using a visual analog scale, the senior author scored subjects. After the first session, subjects with lower scores were provided with simulation training. A second simulation served as a task-learning control. Residents were evaluated in the operating room over six months by the senior author—who was blinded to the trained/untrained identities—using the same parameters. A nonparametric bootstrap testing method was used for the analysis (Matlab v. 2014a). Simulation training was associated with an increase in performance scores in the operating room averaged over all measures ($p = 0.0045$). This is the first study to evaluate the training utility of an endoscopic endonasal surgical task using a virtual reality haptic simulator. The data suggest that haptic simulation training in endoscopic neurosurgery may contribute to improvements in operative performance. Limitations include a small number of subjects and adjudication bias—although the trained/untrained identity of subjects was blinded. Further study using the proposed methods may better describe the relationship between simulated training and operative performance in endoscopic Neurosurgery.

1. Introduction

Although surgical practice using cadavers has had a strong presence in Neurosurgery [1–4], a scarcity of anatomic specimens, difficulty in terms of practicing repetitive tasks, and costs associated with this mode of training pose challenges to its implementation [4]. Despite a high rate of utilization among residency training programs (93.8% of training programs reported using cadaveric training with a 65% survey respondent rate), only about half use cadavers for endoscopic simulation and training [4]. Endoscopic endonasal surgery requires the development of a unique skill set through dedicated practice. Operative practice and experience may improve performance as demonstrated by outcomes seen in high-volume operative centers [5–7]. Residency training, even at such centers, can be variable.

With surgical tasks that require the use of unique instrumentation, visualization methods, and ergonomics, simulation training should be beneficial in terms of improving resident operative performance. Furthermore, simulation affords an environment without time constraints and repercussions of error relating to surgery [8–10]. Haptic technology enhances virtual reality simulation by allowing for tactile sensation and feedback, which are critical elements relating to endoscopic endonasal surgery [3,8]. Because the surgeon is observing a screen and performing surgery, endoscopic endonasal procedures requires a developed coordination between the visual senses and tactile/proprioceptive feedback mechanisms. Studies to date have described a virtual reality haptic (VRH) simulator in detail and posited its use in training, but have not been done to specifically evaluate its utility in training residents in endoscopic endonasal surgery [11–13].

Using the NeuroTouch VRH simulation platform, we evaluated resident performance and specifically assessed the effect of simulation training on performance in the operating room. This study is the first to examine the effect of resident training using an endoscopic VRH simulator on operative performance in endonasal surgery.

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2. Methods

The central hypothesis tested was whether simulation training could independently improve resident performance according to a blinded assessment made in the operating room.

2.1. Simulator/endoscopic module

Testing was carried out via the NeuroTouch VRH simulator (NeuroTouch, Quebec, Canada) using the endoscopic endonasal surgery module (Fig. 1). The VRH simulator includes a screen dedicated for endoscopy, irrigation/drill pedals, and tools (endoscope, drill) that are used in completing the task. The tools can be arranged to accommodate for left- and right-handed subjects. The user stands throughout the task as is done commonly in the operating room.

2.2. Experimental design

The Institutional Review Board (IRB) at the University of Pennsylvania (IRB#8) approved this study and was granted IRB exemption: #820938. Written consent was obtained from each of the study's participants and this procedure was approved by the IRB. Six neurosurgical residents (three first-year, three second-year) at our institution were recruited for participation in the study. Residents/faculty (with the exception of the first and last author) have been blinded to performance scores. Each subject performed tasks as a baseline using an endoscopic endonasal surgery module on the VRH simulator (Fig. 1).

2.3. Task

The subjects were asked to identify the right sphenoid ostium using the endoscope, retreat from the nasal passage, reintroduce the drill along with the endoscope, and create an opening into the sphenoid sinus. As a final element, the user was asked to introduce the endoscope into the sphenoid sinus (Fig. 2). Subject performance during this initial session ("session 1") was evaluated by an expert neurosurgeon (the senior author) using six measures on a visual-analog scale (VAS). These measures were chosen to assess fundamental aspects of subject performance in the given tasks (Fig. 2, see "Scoring/Visual Analog Scales," below).

2.4. Evaluation and training

Subjects were then divided into two groups based on their mean VAS scores from session 1. Subjects with the lowest three scores were assigned to the experimental group that would undergo several simulation-based training sessions ("trained group," see "Training protocol," below), whereas those with the highest three scores were assigned to the control group that would not undergo simulated training ("untrained group"). Throughout the study, the evaluator was blinded to the randomization procedure and the trained/untrained assignment.

Each subject underwent two subsequent evaluations. First, a second session ("session 2") on the simulator was performed after the subjects in the trained group completed training. Second, the senior author evaluated each subject in the operating room in performing a similar task over a 6-month period. The same VAS criteria were used in all evaluations. Because the evaluator was blinded to the assignment of each subject into the trained and untrained groups, he was unaware of which subjects were undergoing simulated training, and which subjects were not.

Fig. 1. NeuroTouch and User. The user is holding the endoscope in the left hand and the drill in the right hand. Pedals are positioned. The endoscopic view is demonstrated on an adjustable screen.

2.5. Scoring/visual analog scales

Refer to Fig. 3. Subjects were scored on a continuous scale from 1 to 5 according to criteria that were developed by the first and senior authors. These criteria as outlined demonstrated what was felt to be important for training a junior resident in endoscopic endonasal surgery.

2.6. Training protocol

For the residents assigned to training, each was provided a set of instructions with supervision to complete an alternate task. The residents were advised to position the pedal prior to starting the module. Instruction was provided on how to hold the instruments, maneuver them keeping the endoscope at the correct orientation, and how to introduce the accompanying instrument. Residents underwent 2–3 simulation-training sessions until an expected minimum score of 3 ("satisfactory") was achieved (Fig. S2–S4). The user was allowed to practice during this session and did not practice at other times (the NeuroTouch VRH simulator requires a specific log-in that was queried and verified).

2.7. Data analysis and statistical methods

To assess whether the training protocol resulted in a specific improvement in subjects' endoscopic abilities (task-related improvement), we computed three difference scores. First and second, we compared the subjects' mean VAS scores during simulation session 2 to those from simulation session 1 for both the trained group, and the untrained group. We hypothesized that the trained group should demonstrate an improvement in performance, but that the untrained group should not. Third, to