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ORIGINAL ARTICLE

Ventricular and skull base neuroendoscopy simulation in residency training: feasibility, cost, and resident feedback

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Abstract

Background: Shifting paradigms in neurosurgical education are promoting the development of different simulators in order to promote faster and safer surgical training. Neuroendoscopy simulators have been created with the intention of decreasing the learning curve of resident training in neuroendoscopy techniques. The objective was to study the potential usefulness of organized implementation of neuroendoscopy simulators in resident training, with particular attention to resident feedback and cost. **Methods:** A total of 19 residents from two separate academic institutions performed 83 simulated endoscopic procedures. These were classified as ventricular ($n = 49$) and skull base ($n = 34$). In turn, each procedure was classified into one of three difficulty levels (easy, medium, and hard). Evaluations regarding self-perceived performance were completed after each exercise in accordance with a Physician Performance Diagnostic Inventory Scale based on the Likert format. Subject identification was blinded to junior or senior resident. Wilcoxon rank testing was used to compare the self-perceived performance improvement within and between both groups. **Results:** Perceived improvement was statistically significant for all the ventricular and skull base/pituitary simulation procedures listed ($P < 0.001$) based on the Wilcoxon sign rank test. These results were not particularly influenced by simulation exercise group (ventricular vs skull base, $P = 0.48$), institution (United States vs Brazil, $P = 0.44$), resident training level (junior vs senior, $P = 0.48$), or the level of difficulty of the simulation procedure (easy, medium, hard, $P = 0.98$). The average cost of the ventricular and skull base/pituitary simulation modules was US$6367.50 and US$7065.50, respectively, per program. **Conclusion:** The use of neuroendoscopic surgery simulators in neurosurgical training is regarded favorably by trainees and should be considered as an adjuvant in neurosurgical simulation training curricula.

Keywords: *education; endoscopy; neurosurgery; simulation; training*

Introduction

In recent years, shifting paradigms in training have dramatically changed the traditional apprenticeship model of medical education.[1,2] In order to increase patient safety and improve treatment outcomes, simulation has been progressively introduced into neurosurgical curricula. The inherent need to surmount cost and other logistical difficulties of introducing this technology in a consistent and organized manner supported the necessity of curriculum development for assessing the simulated surgical skills of residents in an objective learning environment. As a result, the formal integration of simulation into neurosurgery residency training curricula is becoming a reality.[3,4]

Society demands a safer environment for patient care, a reduction in preventable errors and decreased rates of perioperative complications. These have led to dramatic hour regulation changes.[1,5] The number of procedures and instrumentation that neurosurgical residents have to learn during training has increased exponentially with the advent of highly technical subspecialties (neurointerventional, endoscopic pituitary and ventricular surgery, minimally invasive spine, etc.). Although mastery of basic traditional skills is always recommended and expected, these new technologies require a different set of skills that cannot be built entirely from prior traditional knowledge, i.e., ability to navigate in triplanar views, tactile feedback ability during interventional radiology procedures, endoscopic anatomy, etc. Additional motivation to introduce these simulators in training curricula is reinforced by their potential to create an effective interdisciplinary collaboration with other specialties (e.g., otolaryngology) as well as dedicated operating room personnel, developing working relationships that will result in a safer intraoperative environment.

Some of the challenges and necessary attributes of successful neuroendoscopic training involve understanding of proportionality, depth perception and angularity, mirror vision and minimum double vision.[6] Our work focuses on introducing neuroendoscopic simulation techniques in residency training and the residents' perception of their usefulness for training purposes, which remains unreported in the literature. Previous studies have reinforced the fact that attention to resident feedback regarding different simulators is critical for successful introduction to training curricula.[3,7,8] Medical simulation training is still in the early phases of development, therefore objective data on its ability to help improve operative skills are still lacking; hence, the trainees' self-perceived practical usefulness of this technology is the primary driving factor for the cost of implementing a complete curriculum of this technology, which can range up to $341,978.00 for initial outlay costs and $27,876.36 for annual operational expenses.[3]

The objective was to study the usefulness of neuroendoscopy simulators in resident training by looking at resident feedback and the cost of this technology.

Materials and methods

All simulation exercises were scheduled and conducted from January to December 2013. Equivalent methodology was used at two individual neurosurgery training programs: the Federal University of São Paulo (Brazil) and the University of Texas Medical Branch at Galveston (USA), institutionally approved under the scope of quality assessment and improvement of new teaching technologies.

The SIMONT endoscopic simulators were used (Prodelphus, São Paulo, Brazil). These simulators are built with a synthetic thermo-retractile and thermo-sensible rubber called Neoderma®, which reproduces textures, consistencies and mechanical resistance similar to human tissues.[9,10] Both academic programs used these simulators under the same pathologic conditions and locations/sizes.

The SIMONT Otorhino and Skull Base Surgery model was used for simulated skull base/pituitary procedures (sinunasal anatomy identification, creation of a pedicle septal flap, and pituitary/skull base tumor resection) (Figs 1A–C and 2). The simulator recreates anatomic sinuses, turbinates, nasal septum, vessels, and sella and sphenoid bone with the possibility of including tumors such as macroadenomas or meningiomas in the skull base and pituitary. We used pituitary adenomas in all cases.

The SIMONT for Neuroendoscopy Surgery was used for neuroendoscopic simulation of ventricular procedures (anatomy orientation and structure identification, third ventriculostomy, colloid cyst resection, and septal ventricular tumor resection) (Figs 1C,D and 3).

The neuroendoscopic systems used were the Aesculap Minop Trend (Braun, Melsungen, Germany) by the USA group and the Gaab system (Karl Storz, Tuttlingen, Germany) by the Brazil group.

All the residents from both programs were invited to participate and a total of 19 residents, 7 in the USA group and 12 in the Brazil group, volunteered to participate. Due to operational logistics (e.g., limited time and resources), some residents were not able to participate in all exercises. A total of 83 endoscopic exercises were performed and were classified as ventricular ($n = 49$) or skull base ($n = 34$). Each exercise or simulated procedure was classified into one of three levels of difficulty (easy, medium, and hard) based on the relative complexity of the technical tasks involved, which was based on the authors' own expert judgment (Table 1). Procedures were conducted under careful observation by faculty proctors familiar with the systems. Sequential completion of the different designated technical tasks was required for each exercise. Multiple attempts were permitted until the simulator components were no longer usable and required replacement. No time limit was enforced.

Afterwards, each resident completed an online evaluation based on a Likert format, and self-rated their own performance based on what they thought it was before and after each exercise in accordance with a Physician Performance Diagnostic Inventory Scale (PPDIS): unsatisfactory, early learner, competent, proficient. Expert level was not included in the PPDIS because that category is reserved for practicing neurosurgeons. Medical experts at the Accreditation Council for Graduate Medical Education have reviewed this scale, which measures performance and learning progress. This online questionnaire requested feedback on the perceived reliability of the simulator and whether or not the participants would recommend its use to peers. Participants' responses and analyses were masked as either junior (PGY1–3, $n = 9$) or senior resident (PGY4–7, $n = 10$).

The Wilcoxon rank test was used to detect differences within (sign rank) and between groups (rank sum). Generalized linear mixed models with multinomial

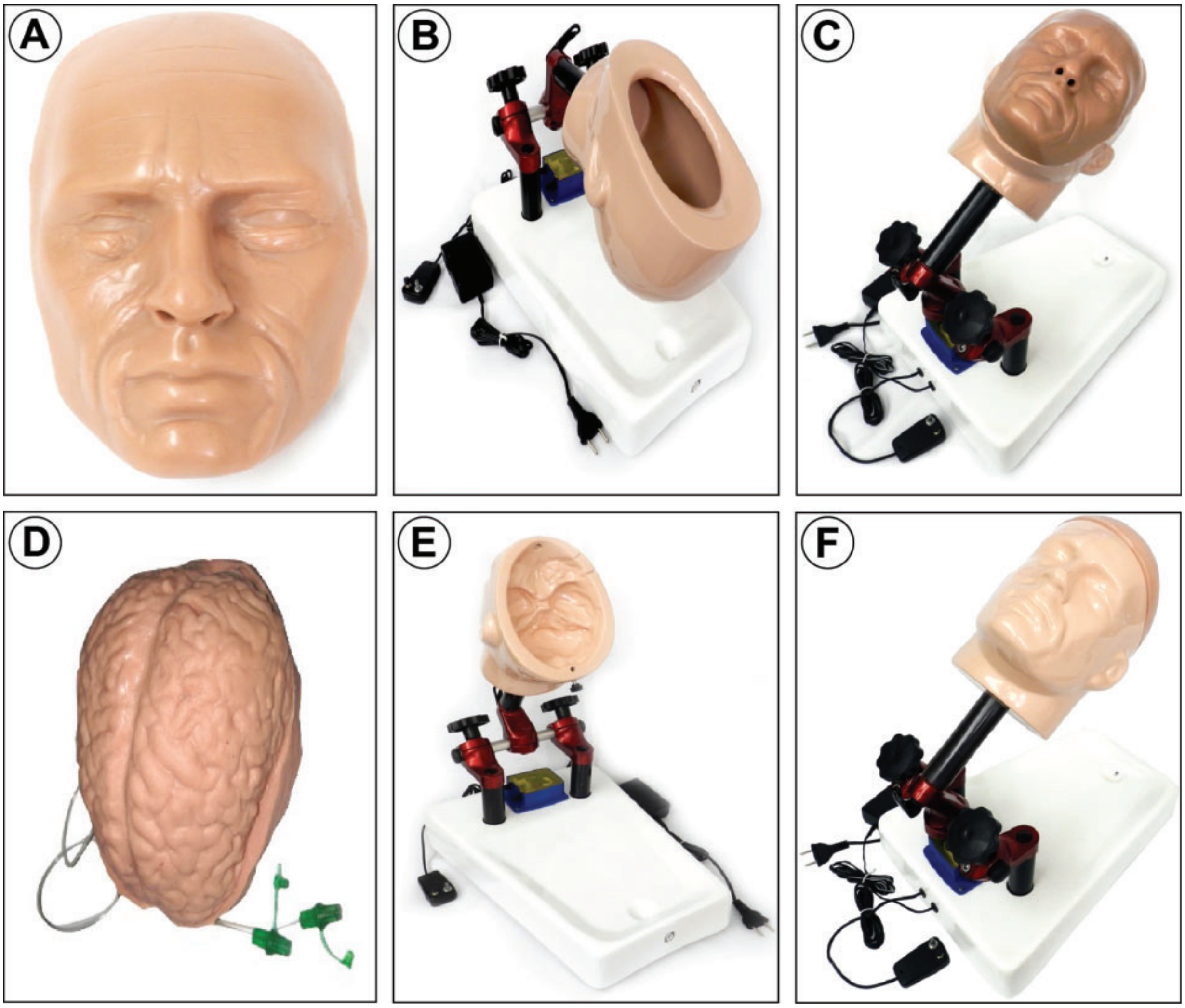

Figure 1 Physical simulators. (A) Endonasal surgical unit. (B) Endonasal fiber base. (C) SIMONT Otorhino and Skull Base Surgery simulator ready for use. (D) Ventricular Surgical unit with connectors for a fluid pump. (E) Ventricular base skull. (F) SIMONT for Neuroendoscopy Surgery simulator ready for use.

distribution and cumulative logit link were built to assess the overall difference across training levels and type of simulations. All analyses were performed using SAS software version 9.3 (SAS Institute, Inc., Cary, NC) based on the two-sided significance level of $P < 0.05$.

Results

Perceived improvement in the PPDIS was statistically significant for all the ventricular and skull base/pituitary simulation procedures listed ($P < 0.001$) based on the Wilcoxon sign rank test.

Endoscopic ventricular simulations

Overall, 57.1% of residents reported an improvement beyond baseline of at least one PPDIS level after the training sessions on the SIMONT for Neuroendoscopy Surgery ($P < 0.001$). We observed a similar trend of reported improvement by junior and senior residents in this group ($P = 0.41$). There was no difference when comparing PPDIS improvement between the USA and Brazil groups ($P = 0.99$). Improvement of one or more levels in the PPDIS was reported with statistical significance at all levels of difficulty (easy 57.2%, $P < 0.001$; medium 56.5%, $P < 0.001$; hard 58.4%, $P = 0.01$) (Table 2).

Skull base and pituitary simulations

Considering all residents who worked with the SIMONT Otorhino and Skull Base Surgery simulator, 47.1% reported improvement of one level on the PPDIS scale, 8.8% two levels, and 8.8% three levels ($P < 0.001$). In this group, we observed that the junior residents did not report an

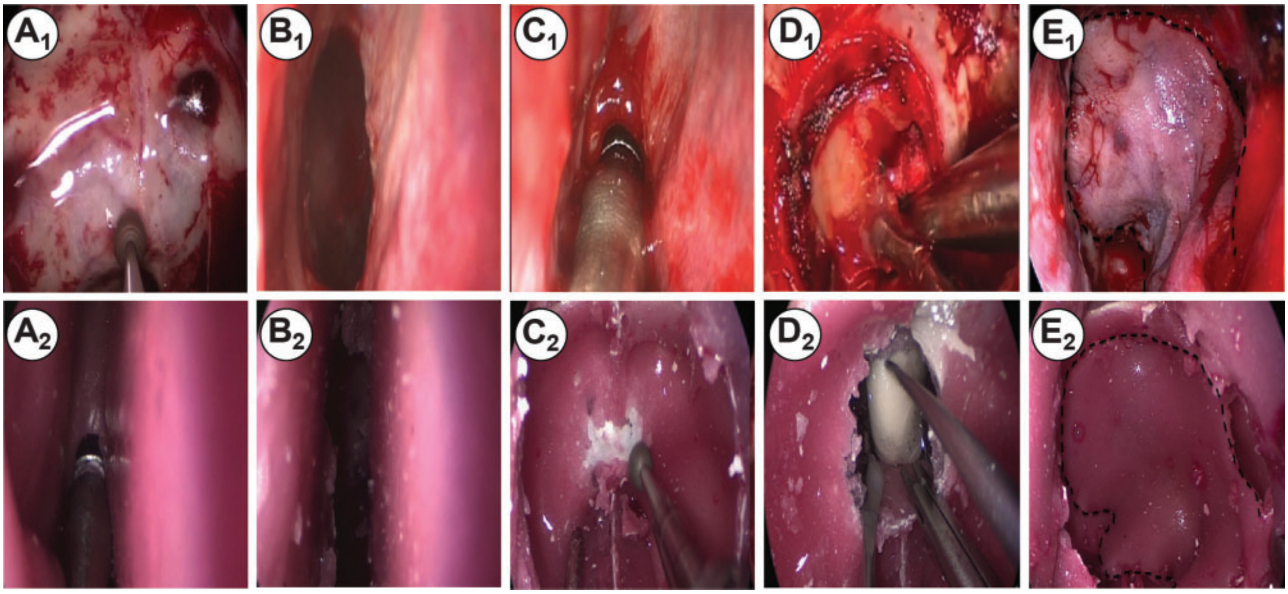

Figure 2 Surgical pictures of the Otorhino Trainer. Approach to the sella turcica, sphenoidotomy and nasoseptal flap construction. (A_1,B_1,C_1,D_1,E_1) Real surgery. (A_2,B_2,C_2,D_2,E_2) Simulated surgery with the SIMONT Otorhino and Skull Base Surgery simulator. (A) Identification of the sphenoid sinus ostium. (B) Sphenoidotomy. (C) Drilling the sellar floor. (D) Pituitary tumor resection. (E) Pedicle nasoseptal flap placement.

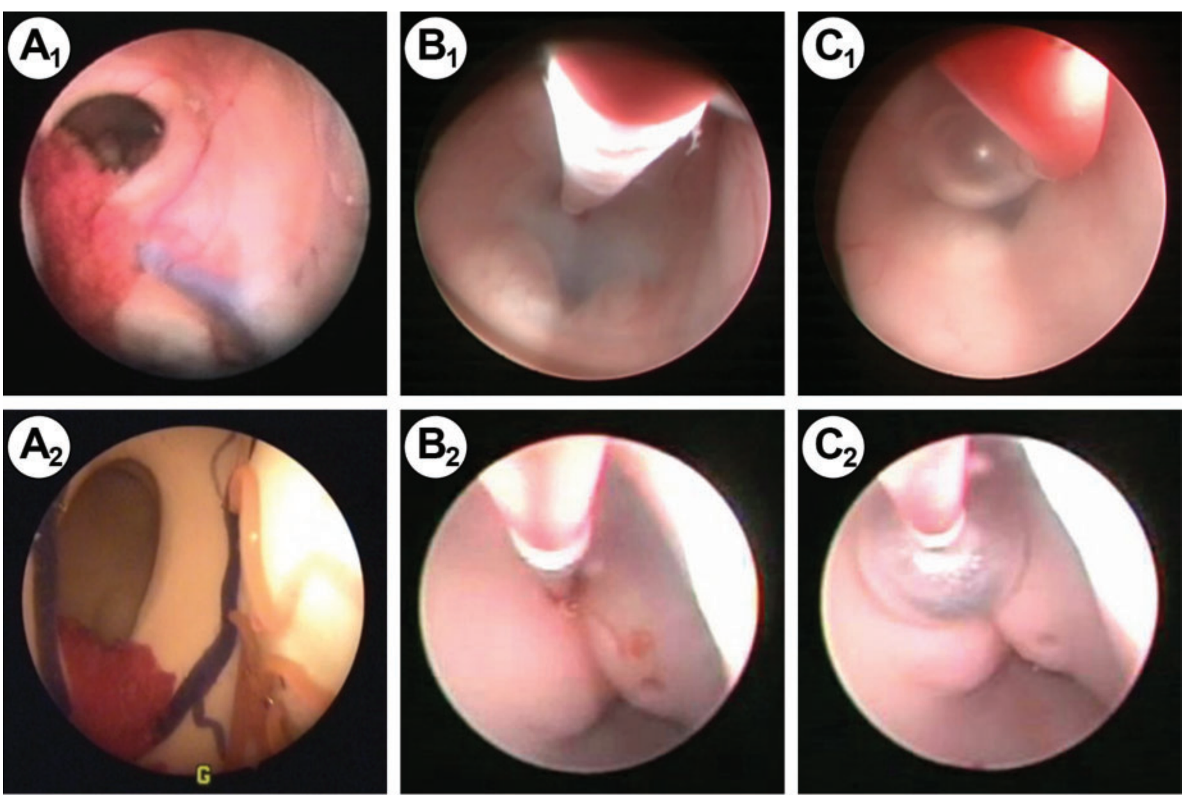

Figure 3 Surgical pictures of the Neuro Trainer; endoscopic third ventriculostomy. (A_1,B_1,C_1) Real surgery. (A_2,B_2,C_2) Simulated surgery with the SIMONT for Neuroendoscopy Surgery simulator. (A) Right lateral ventricle with view of the foramen of Monro. (B) Fogarty 4 French catheter at the ventriculostomy point anterior to the mammillary bodies. (C) View of an insufflated balloon.

Table 1 Technical tasks and evaluation according to level of difficulty

Easy	Medium		Hard
Technical tasks: ventricular simulation			
Ventricular anatomy orientation	Third ventriculostomy	Colloid cyst resection	Septal ventricular tumor resection
Correctly positions head height and tilt; pays attention to entry angle into ventricle; secures plastic cannula prior to use of endoscope; uses irrigation system appropriately	Correct selection of entry point, insertion of trocar/canula and instrument; identifies fornix, protecting it from inadvertent damage	Orients him/herself prior to addressing cyst; localizes colloid cyst attachment points and related vascularity	Correctly identifies the septal ventricular tumor position
Correctly identifies the septum pellucidum, plexus, foramen of Monro, fornix, mammillary bodies, infundibulum and recesses of third ventricle	Identifies mammillary bodies, infundibulum, and recesses; adequate targeting of Fogarty balloon with judicious inflation technique	Performs the cyst resection. Judicious use of traction during procedure	Correctly identifies the septum pellucidum and the arterial and venous anatomy
Identifies and names the most relevant venous anatomy (septal, thalamostriate)	Avoid injuries during the entire procedure in particular to basilar artery/branches	Avoid inappropriate traction of cyst if poorly visualized. Uses proper dissection technique	Avoid injuries throughout the procedure
Technical tasks: pituitary and skull base simulation			
Sinunasal anatomy orientation	Creation of pedicle septal flap		Sphenoid/sellar approach and tumor resection
Correctly places head angle and orientation. Places the scope in the superior aspect of the nostril and the dissecting instruments in the inferior aspect	Identifies ostium and choanae; outfractures turbinates; removes middle turbinate; considers free flap from the turbinate; applies adequate field of view at each step during dissection		Removes posterior 2 cm of nasal septum and exposes the rostrum of the sphenoid; resects the rostra and removes septations; identifies the sella and recesses (opticocarotid, clivus, and planum)
Identifies turbinates, choana, middle meatus, and uncinate process; identifies the sphenoid ostia bilaterally relative to the superior turbinate	Elevates the mucosal flap preserving the vascular pedicle; adequately pushes the flap down to the nasopharynx		Opens sellar floor; cruciate dural incision; adequate use of curettes during tumor resection; closure includes hemostasis check, positioning of septal flap ± use of sealant

improvement beyond one PPDIS level ($P < 0.001$). Senior residents from the Brazil group were able to improve two and three PPDIS levels ($P < 0.001$). The improvement percentage was very similar across exercises of all difficulty levels (easy 66.6%, $P < 0.001$; medium 66.6%, $P < 0.001$; hard 60.0%, $P = 0.03$) with a positively skewed distribution. There was no difference when comparing PPDIS improvement between the USA and Brazil groups ($P = 0.14$). The USA group reported higher reliability ratings with this simulator ($P = 0.003$) (Table 3).

Multivariate analysis

The results were not influenced by the simulation exercise group (ventricular vs skull base, $P = 0.48$), institution (USA vs Brazil, $P = 0.44$), resident training level (junior vs senior, $P = 0.48$), or the level of difficulty of the simulation procedure (easy, medium, hard, $P = 0.98$) in the multivariate analysis. Although both simulators were considered useful by the residents, the SIMONT Otorhino and Skull Base Surgery simulator was perceived as more reliable and likely to create a technical improvement in the PPDIS compared with the SIMONT for Neuroendoscopy Surgery simulator ($P = 0.04$).

Cost and logistics

The cost associated with the simulators including bases and disposable surgical units was US$12,735.00 for the ventricular endoscopic simulation (mean US$6367.50 per program, SD US$1938.20) and US$14,131.00 for the skull base/pituitary endoscopic simulation (mean US$7065.50 per program, SD US$3728.57). The estimated cost of the endoscope systems ranges between US$10,000.00 and US$15,000.00. Additional costs may apply depending on the instrumentation requested. Total time spent in the didactics was 18 hours for both locations (mean 9 hours for each location, SD 1.41) with a total of four sessions, two in Brazil and two in the United States.

Table 2 Ventricular group descriptive results

	% improvement after simulation					Perception simulator is reliable (%)				Would recommend to a peer			
	None	1 PPDIS level	2 PPDIS levels	P^{wsr}	P^{wrs}	Neutral	Agree	Strongly agree	P^{wrs}	Neutral	Agree	Strongly agree	P^{wrs}
Training level													
Overall ($n = 15$)	42.9	40.8	16.3	< 0.001		4.1	67.3	28.6		4.1	49	46.9	
Senior ($n = 10$)	52.9	23.5	23.5	< 0.001	0.4	–	67.5	32.4	0.16		52.9	47.1	0.65
Junior ($n = 5$)	20	80	–	< 0.001		13.3	66.7	20		13.3	40	44.7	
Location													
Brazil ($n = 8$)	50	38.9	5.6	< 0.001	0.99	–	73.3	26.7	0.85		50	50	0.39
USA ($n = 7$)	8.3	66.7	25.0	< 0.001		10.5	57.9	31.6			47.4	42.1	
Difficulty of exercise													
Easy ($n = 14$)	42.9	42.9	14.3	< 0.001		7.1	64.3	28.6		7.1	50	42.9	
Medium ($n = 23$)	43.5	39.1	17.4	< 0.001	0.99	4.4	65.2	30.4	0.59	4.3	52.2	43.5	0.59
Hard ($n = 12$)	41.7	41.7	16.7	0.01		–	75	25		41.7	58.3		

A total of 49 exercises were completed. Percentages are relative to the number of procedures performed by each subgroup or category. No participants reported a decrease in performance after the simulations or chose "disagree" or "strongly disagree" for any of the questions. Within-group comparisons were statistically significant for all simulations. All within-group distributions were statistically significant for this category. P^{wsr}, Wilcoxon sign rank used for within-group comparisons; P^{WRS}, Wilcoxon rank sum for between-group comparisons. There were no statistically significant differences found between groups.

Discussion

The introduction of any simulator into our residency training programs involves three major steps: validation, resident/faculty feedback, and cost analysis. Previous studies have explored the validation aspects of the SIMONT neuroendoscopic simulators.[9–11] Our work focuses on resident feedback regarding the usefulness of simulators in terms of their cost, fidelity and self-perceived improvement at two different neurosurgery training programs.

The SIMONT simulators were selected primarily due to the elastic properties of the tissue and the capability to simulate bleeding and recreate neurosurgical pathologies (e.g., pituitary tumor/colloid cyst). Additional advantages are the feasibility of undergoing preoperative computed tomography or magnetic resonance imaging for tumor identification and intraoperative navigation.[11] Both programs in this study have integrated these simulators in their respective curricula for resident simulation training.[3] Some of the current alternatives that can be used in the world of physical simulators are the Phacon Sinus System (Phacon, Leipzig, Germany), which incorporates a dedicated optoelectric navigation system, or the Kezlex endoscopic models for the hydrocephalus and pituitary gland (Ono & Co., Tokyo, Japan), both of which contain detachable surgical units with holders derived from rapid prototyping techniques.[12] Despite being well-developed simulators, none of them offer the unique combination of deformable tissue, simulated bleeding and incorporated neurosurgical pathology (e.g., tumors/cysts) and their cost surpasses the budget we have presented here.[3] Recent virtual reality three-dimensional simulators such as the Neurotouch Endo-VR (National Research Council, Canada) are an attractive alternative for repeated practice and cognitive task analysis, limited by the significant cost and disparity of eye–hand coordination required or instrumentation used compared with the real physical world.[13,14]

Overall, resident feedback was positive and both simulators were well accepted, generating a subjective technical improvement in most cases regardless of the training level, difficulty of the procedure, ventricular vs skull base group, or training program. One would expect residents at different training levels to report different levels of improvement. This may be due to relatively low clinical training exposure to these types of cases at both training programs. Another factor is the subjective bias in reporting

Table 3 Skull base and pituitary simulation descriptive results

	% improvement after simulation						Perception simulator is reliable (%)			Would recommend to a peer of their level		
	None	1 PPDIS level	2 PPDIS levels	3 PPDIS levels	P^{wsr}	P^{wrs}	Agree	Strongly agree	P^{wrs}	Agree	Strongly agree	P^{wrs}
Training level												
Overall (n = 12)	35.3	47.1	8.8	8.8	< 0.001		64.7	35.3		32.3	67.7	
Senior (n = 7)	31.6	36.8	15.8	–	< 0.001	0.15	73.7	26.3	0.24	42.1	57.9	0.19
Junior (n = 5)	40	60	–	–	< 0.001		53.3	46.7		20	80	
Location												
Brazil n = 7	57.1	14.3	14.3	14.3	< 0.001	0.14	85.7	14.3	0.003	28.6	71.4	0.57
USA (n = 5)	–	100	–	–	< 0.001		30.8	69.2		38.5	61.5	
Difficulty level												
Easy (n = 12)	33.3	50	8.3	8.3	< 0.001		66.7	33.3		33.3	66.7	
Medium (n = 12)	33.3	50	8.3	8.3	< 0.001	0.98	66.7	33.3	0.93	33.3	66.7	0.98
Hard (n = 10)	40	40	10	10	0.03		60	40		30	70	

A total of 34 exercises were completed. Percentages are relative to the number of procedures performed by each subgroup or category. We found no subjects reported a decrease in performance following the simulations or chose "disagree" or strongly disagree" for any of the questions. All participants either agreed or strongly agreed with regard to the perceived reliability of the simulators (fidelity) and recommending its use to peers. The USA group reported a greater perceived reliability of this model compared with the Brazil group (P = 0.003). P^{wsr}, Wilcoxon sign rank used for within-group comparisons; P^{wrs}, Wilcoxon rank sum for between-group comparisons. Within-group comparisons were statistically significant for all simulations. There were no statistically significant differences found between groups.

self-improvement. Having an independent proctor objectively evaluate a participant's performance can minimize this subjective or cognitive bias. Although this measure was not used in this pilot study, future studies can reduce such bias by adapting this methodology. Some recognized limitations include the fact that the number of participants and exercises performed by both groups differed slightly. Also, because these simulation modules are relatively new, validation and objective measures for evaluating surgical performance remain undeveloped and therefore could not be used. Therefore, the PPDIS was used, which required the participants to use their personal judgment based on their previous surgical experience for self-evaluation. The perceived realism and likelihood of recommending the simulation exercises to one's peers is also subject to personal experience.

Each program has unique characteristics and it cannot be inferred from this study that everyone will benefit equally from the use of these simulators. Improvement from their use is also influenced by many factors including real clinical experience, prior repeated simulated practice and resident seniority, among others.[3] Nevertheless, certain simulation exercises may be of use to different residents depending on their previous surgical experience.

Conclusion

The use of neuroendoscopic simulators in neurosurgical training, both for skull base and ventricular navigation, is an innovative approach to adjuvant training that may be considered within the particular needs of each individual program. Further multi-institutional studies would help to elucidate the benefit of these simulators.

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Conflict of interest

No personal or institutional financial conflicts of interest (drugs, materials, or devices) apply to this study.

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