Virtual Reality Simulation in Ear Microsurgery: A Pilot Study

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Abstract Classically, teaching of otological micro procedures is achieved by cadaveric dissection of the temporal bones, achieved by attending expensive temporal bone dissection courses. The difficulty in acquiring cadaveric specimens and the cost of courses has led to the development of alternative techniques. The aim of this study is to evaluate the efficacy of using virtual reality temporal bone simulation in training otolaryngology residents for mastoidectomy procedures. Four senior residents were evaluated during six canal wall down mastoidectomy procedures. Three of these procedures were done conventionally. The other three procedures were preceded by virtual reality simulation 1 day before the operation. In simulated cases, the residents scored higher on the global rating scale and task-based checklist, and were faster and more confident. Further, fewer instructions were required during the actual operation. This outcome is encouraging for the utilization of virtual reality simulation in otolaryngology residency training. Further studies should be performed on a larger number of simulators and surgical procedures to validate our results.

Keywords Mastoidectomy · Simulation

Introduction

Teaching surgical skills in training programs is always a challenging task. It is particularly difficult to teach ear

microsurgery procedures to otolaryngology residents. Patient safety and surgical competency are always our goals when teaching residents at all levels. Surgeons need to be familiar with the detailed temporal bone anatomy in a 3-dimensional way, and wide variations in anatomy need to be considered. Training on cadaver temporal bone dissections is the gold standard teaching technique, with the goal of familiarizing the surgeon with the 3-dimensional mental map of the temporal bone. However, ear microsurgery is quite challenging to perform in the operating room with different pathological conditions. Nowadays, it is almost impossible to obtain an adequate number of temporal bone specimens to adequately train residents. Hence, alternative and complementary methods should be considered. An alternative approach is the creation of artificial models of the ear, such as Pettigrew temporal bones [1]. These are plastic models of the temporal bone designed to allow the trainee to practice a number of surgical procedures and are an integral part of the Glasgow Temporal Bone Course.

Simulation techniques are part of a well-known system for training and teaching critical procedures outside the medical field. However, as of now, these techniques are underutilized while training surgical residents. Recently, simulation techniques have been used in the field of ear surgery and have become part of standard health-care training programs.

Methods

This was a prospective study evaluating the surgical skills of senior resident trainees. Four residents were observed while performing mastoidectomy procedures and evaluated by a senior faculty member and the head nurse of the operating room using the global rating scale and task-based

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checklist [2, 3]. Twenty four patients who required canal wall down mastoidectomy for the treatment of cholesteatoma were chosen for the study. The four final year residents included in the study provided verbal consent without an obligation to participate. Each resident was assigned two cases randomly. The first case was addressed by the conventional method of reviewing computerized tomography images of the case prior to the operation. For the second case, the procedure was practiced 1 day before the operation using a virtual reality simulation station (VOXEL-MAN TempoSurg simulator for middle ear surgery; Spiggle and Theis, developed by University Medical Center Hamburg-Eppendorf, Germany; Fig. 1), using volumetric high-resolution images of the temporal bone. This station uses volumetric high-resolution images of the temporal bone. That provides realistic representation of tissue in three dimensions. The operator specialized eye glasses to view in three dimensions and foot controlled hand drill that has haptic feedback (operator feels the sensation of the speeds, pressure and directions. The drill changes the appearance of the temporal bone in real time using volume cutting methods as its been drilled. Drill speed, size and type of burrs can be changed as well as magnifications.

Fig. 1 Virtual reality station

Attached software records the procedure for latter evaluation. Drilling mistakes are recorded as well. In the operating room, the two observers (the operating room head nurse with 10 year experience and the otolaryngology senior surgeon) performed the evaluation blindly. Residents were evaluated using the global rating scale (Table 1), which is based on a previously developed tool and has been validated for the assessment of technical skills in both the operating room and the simulated environment, and the task-based checklist (Table 2), which has been validated by previous researchers. The scales were adapted to the mastoidectomy procedure, and the average total scores were calculated. The operation time was also recorded and comments were obtained from both the residents and the observers (Table 2).

Results

As shown in Table 3, the average total score for the global rating scale and task-based checklist for the simulated cases was higher than that for the conventional cases. Further, the operating time was shorter and fewer instructions from the supervisors were necessary in the simulated cases. The residents thus felt much more confident when operating on the simulated cases.

Discussion

The results of this pilot study show that residents performed better and were more confident after practicing the surgical procedure using a simulation tool the day before the surgery.

Two assessment tools are used for the objective assessment of technical skills at the University of Toronto [4], namely, the global rating scale and task-based checklist. The global rating scale considers aspects of performance throughout a procedure, whereas the task-based checklist is a checklist specific to the procedure being evaluated [5]. In otolaryngology, an objective assessment of tonsillectomy has been developed and validated, and assessment of endoscopic sinus surgery skills on a virtual reality simulator has been validated [6]. Recently, these techniques were applied for the assessment of mastoidectomy skills in the operating room, as well as in a virtual reality simulator [1, 4].

Advanced radiological imaging assists in the development of precise 3D reconstructions for virtual reality simulators. The familiarity of the residents with a navigation system that is used mainly in rhinological and some otological procedures helped us to apply the simulation technique in the otolaryngology training described here. During

Table 1 Global rating scale

	1	2	3	4	5	N/A
1. Understanding of indications/objectives of surgery	Deficient understanding of indications/objectives of surgery	Understands most indications/objectives of surgery			Fully understands indications/objectives of surgery	N/A
2. Interpretation of preoperative test	Unable to interpret and/or relate to surgical objectives	Able to interpret and/or relate to surgical objectives most of the time			Able to interpret and/or relate to surgical objectives easily	N/A
3. Use of otologic drills	Chooses inappropriate bur and/or repeatedly awkward use of drill	Chooses appropriate bur and occasionally awkward use of drill			Uses appropriate bur and uses drill effortlessly	N/A
4. Knowledge of instruments	Frequently asks for wrong instrument or uses inappropriate instrument	Knows names of most instruments and uses appropriate instrument			Extremely familiar with instruments and their names	N/A
5. Use of microscope	Repeatedly inappropriate position, magnification, or focus	Competent use of microscope, but occasional inappropriate position and magnification			Optimal visualization and appropriate microscope use	N/A
6. Respect for surgical limit	Uses unnecessary force on tissue or causes damage by inappropriate use of instruments	Careful handling of tissue, but occasional inadvertent damage to tissue			Consistently handles tissues appropriately with minimal damage	N/A
7. Time and motion	Many unnecessary moves	Efficient time/motion, but some unnecessary moves			Clear economy of movement and maximum efficiency	N/A
8. Knowledge of specific procedure	Deficient knowledge and needs instruction at most steps	Knows all important steps of operation			Demonstrates familiarity with all aspects of operation	N/A.
9. Flow of operation	Frequently stops and is unsure of next move	Some forward planning with reasonable progression			Obviously planned course of operation with effortless flow	N/A
10. Overall performance	Poor	Acceptable			Outstanding	N/A
N/A Not applicable						

Table 2 Task-based checklist

		Unable to perform		Performs with minimal prompting		Performs easily with good flow	N/A
		1	2	3	4	5	
1	Initial bone cuts						
a	Placement of superior cut	1	2	3	4	5	N/A
b	Placement of canal cut	1	2	3	4	5	N/A
2	Defining anatomical landmarks						
a	Identification of the tegmen	1	2	3	4	5	N/A
b	Sharpening the posterior EAC cortex	1	2	3	4	5	N/A
c	Defining sigmoid sinus and sinodural angle	1	2	3	4	5	N/A
3	Opening antrum						
a	Deepening dissection at sinodural angle	1	2	3	4	5	N/A
b	Opening antrum	1	2	3	4	5	N/A
c	Atraumatic exposure to short process of incus	1	2	3	4	5	N/A
4	Digastric dissection						
a	Defining cephalic edge of digastric	1	2	3	4	5	N/A
b	Following to stylomastoid foramen	1	2	3	4	5	N/A
5	Thin posterior EAC cortex						
a	Viewing posterior EAC en face	1	2	3	4	5	N/A
b	Using side/front of appropriate bur	1	2	3	4	5	N/A
c	Saucerization	1	2	3	4	5	N/A
6	Facial recess						
a	Even removal of the infralabyrinthine bone	1	2	3	4	5	N/A
b	Medial thinning of EAC cortex	1	2	3	4	5	N/A
c	Identifying VII and chorda tympani	1	2	3	4	5	N/A
d	Identifying middle ear anatomy	1	2	3	4	5	N/A
e	Decompressing facial nerve	1	2	3	4	5	N/A
7	Posterior atticotomy						
a	Thin superior EAC cortex	1	2	3	4	5	N/A
b	Thin anterior tegmen	1	2	3	4	5	N/A
c	Removing intervening bone	1	2	3	4	5	N/A
d	Identifying epitympanic anatomy	1	2	3	4	5	N/A

N/A Not applicable, EAC external auditory canal

Table 3 Average scores of residents in three cases of mastoidectomies in each group

	Mastoidectomy			Mastoidectomy preceded by simulation		
	Task-based checklist	Global rating scale	Average operation time (min)	Task-based checklist	Global rating scale	Average operation time (min)
Resident 1	50	34	189	52	35	187
Resident 2	57	35	219	58	37	190
Resident 3	55	36	225	55	37	200
Resident 4	54	36	180	56	34	168

simulation, the trainee is allowed to practice, but is not evaluated on their performance. However, performance tools can be used for assessment during simulation and to record progression, as well as for feedback. Technical

simulator training can separate skills acquisition from clinical care. Thus, simulator training allows trainees to try new techniques and make mistakes, which helps us to define the resident's ability and to improve surgical quality.

However, the high costs of the tools and the developing technology are still limiting the use of surgical simulation techniques universally.

Conclusion

This pilot study demonstrates that simulation is an essential tool for the training of surgical procedures such as ear microsurgery and that simulation is a complementary tool for training and assessing residents in training. Simulators are useful if there is a clear understanding of the purpose of the simulation experience. Simulation methods also have the potential to offer the practicing surgeon the opportunity to maintain skill levels by regular practice. It is necessary to extend this approach to other aspects of otolaryngological practice, so that potential ear, nose, and throat surgeons can be fully trained. Further studies should be performed on a larger number of simulators and surgical procedures to validate our results.

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Conflicts of Interest The author declares that there are no conflicts of interest.

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