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RESEARCH ARTICLE

Development of a Low Cost, Renewable Endoscopic Sinus Surgery Skills Trainer (ESSST)

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ABSTRACT:
While otolaryngology (ORL) bootcamps are being increasingly utilized for resident education, many simulators are prohibitively expensive or complicated to construct. We constructed and validated a novel low cost and low fidelity endoscopic sinus surgery skills trainer (ESSST). After construction, participants were divided into 3 groups based on endoscopic sinus surgery (ESS) experience. The study participants were asked to perform 3 tasks. Their performance was videotaped and subsequently blindly evaluated by two rhinologists. Each task was scored based on performance and economy of motion using a standard scoring sheet. A one-way ANOVA and Post Hoc Tukey Tests were used to determine if there was a significant difference in performance of the 3 groups. The data suggests that skill and experience with ESS directly translates to the simulator, supporting that the ESSST is low cost, validated, renewable and a useful adjunct to higher fidelity simulators.

Introduction

Otolaryngology (ORL) simulation boot camps are being developed nationwide to augment education of surgical skills to trainees early in residency. Throughout the literature, it has been found that these training modalities help build trainee confidence, knowledge base, technical skill and overall clinical performance.[3] The modalities that have been utilized for otolaryngology trainees to teach surgical skills for endoscopic sinus surgery (ESS) include virtual simulators, cadaveric training courses, and low cost, reproducible models.[1]

Time and time again, research has shown that high quality, high repetition practice on an ESS simulator teaches skills that are transferrable to the operating room.[1] Virtual reality and cadaveric simulators are high fidelity simulators that offer a good training environment, however the cost of such trainers can make it difficult to reliably use for resident training. In addition, repetition is impossible with a cadaveric model.[1-2] Some ESS task trainers that have been developed are low cost, however, they are often time consuming and are difficult to construct.[3] While high-fidelity simulation is costly and may not be available in smaller institutions, low-fidelity simulation can provide similar experiences and fill assessment gaps with fewer resources.[4] In addition, the literature suggests that a low-fidelity simulation can offer more ideal training than high-fidelity simulators

After IRB approval was obtained through Montefiore Medical Center/Albert Einstein School of Medicine (#2017-8271), we sought to construct and validate a low cost, low fidelity, easily reproducible endoscopic sinus surgery skills trainer (ESSST) to enable ORL trainees to develop camera driving skills, triangulation, and a variety of two-handed endoscopic surgery techniques with high quality, high repetition task training.

Materials and Methods

Construction of the Model:

The ESSST **(Figure 1)** is constructed from a bell pepper and neoprene material with similar haptics to native tissues in the nose to provide a similar feel to the operative environment. To construct the neoprene additive, a 1.5mm thick piece of neoprene is glued to laminated paper to create a water tight seal and is then placed at a 45-degree angle through the side of the bell pepper. The pepper is secured to a wooden board for stability. The initial investment in materials was $20; however, the cost of renewability of the model was less than $1 per use (the cost of a bell pepper).

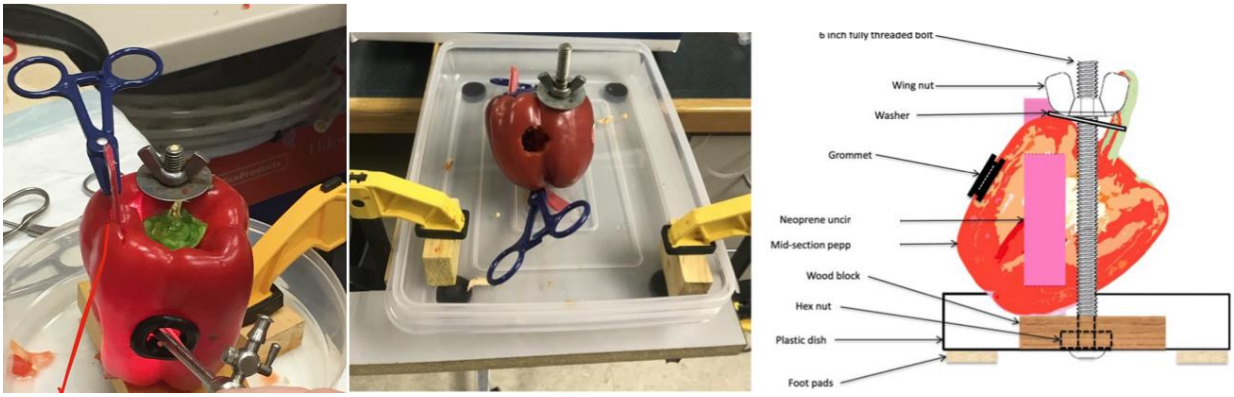

Figure 1: ESSST setup: Mounted bell pepper with reusable neoprene structure used for injection task.

Determination of Construct Validity

Study participants were divided into 3 groups based on skill level: 1) Medical students with no endoscopic experience(n=12); 2) ORL trainees who performed less than 30 ESS (n=20); 3) Experienced surgeons who performed more than 30 ESS (n=6).

Participants were instructed to perform 3 tasks (described below) on the ESSST using a 30-degree rigid nasal endoscope. These tasks were video recorded, blinded and evaluated by two experienced rhinologists based on overall performance and economy of motion using a scoring sheet developed for this study **(Figure 2)**.

Endoscopic Sinus Surgery Skills Trainer Scoring Sheet Participant Number: _____

First Task - Backbiter Task (1 Minute)			Score	Second Task - Removal of a partition (2 Minutes)			Scoring	Third Task - Targeted Injection (1 Minute)			Score
Poor Scope Rotation	Anything >45 degrees from horizontal	Yes / No	-2	Poor Scope Rotation	Anything >45 degrees from horizontal	Yes / No	-2	Poor Scope Rotation	Anything >45 degrees from horizontal	Yes / No	-2
Excellent visualization	User consistently dissects in center of field of view	Yes / No	1	Excellent visualization	User consistently dissects in center of field of view	Yes / No	1	Excellent visualization of needle tip throughout task	Does the needle tip remain in the view of the camera from insertion to injection?	Yes / No	1
Lack of Perspective	Camera is too close to or too far from target during the majority of the task	Yes / No	-1	Lack of Perspective	Camera is too close to or too far from target during the majority of the task	Yes / No	-1	Lack of Perspective	Camera is too close to or too far from target during the majority of the task	Yes / No	-1
Blind Dissection	User performs blind dissection outside the field of view from the camera	Yes / No	-5	Blind Dissection	User performs blind dissection outside the field of view from the camera	Yes / No	-5	Blind Injection	Injection performed outside of field of view	Yes / No	-1
Lack of progress	User fails to make progress with task after 30 seconds	Yes / No	-1	Lack of progress	User fails to make progress with task after 30 seconds	Yes / No	-1	Poor visualization of needle tip	Does the needle tip repeatedly leave the field of view of the camera	Yes / No	-1
Repetitive Scope Collision	Contact between the instrument/scope >3 times	Yes / No	-3	Repetitive Scope Collision	Contact between the instrument/scope >3 times	Yes / No	-3	Poor Aim	Were any injections performed outside of the dot?	Yes / No	-1
Repetitive Scope Insertion	Removes scope every time with instrument	Yes / No	-1	Repetitive Scope Insertion	Removes scope every time with instrument	Yes / No	-1	Repetitive Scope Collision	Contact between the instrument/scope >3 times	Yes / No	-3
Aggressive movements		Yes / No	-1	Aggressive movements		Yes / No	-1	Past pointing	Instrument goes beyond the intended target more than 3 times	Yes / No	-1
Unsteady/Drifting Scope	Unsteady scope while performing task, drifting view	Yes / No	-1	Unsteady/Drifting Scope	Unsteady scope while performing task, drifting view	Yes / No	-1	**Target 1 Executed**	Was the first injection within the center of the dot?	Yes / No	5
Was the task completed in less than 30 seconds?		Yes / No	1	**Was the task completed in less than 30 seconds?**		Yes / No	1	**Target 1 Injection Quality**	Was the injection in the correct plane?	Yes / No	1
Was the task completed in less than 45 seconds)		Yes / No	1	**Was the task completed in less than 1 minute?**		Yes / No	1	**Target 2 Executed**	Was the second injection within the center of the dot?	Yes / No	1
Was the task completed in the allotted time?		Yes / No	1	**Was the task completed in less than 1:30 seconds?**		Yes / No	1	**Target 2 Injection Quality**	Was the injection in the correct plane?	Yes / No	5
Was the target field at least 75% cleared?		Yes / No	1	**Was the task completed in the allotted time?**		Yes / No	1	**Were both injections correctly performed within 30 seconds?**		Yes / No	1
Did the participant demonstrate economy of motion?	User exhibits intentional movements that lead to progress	Scale 1 to 5	____	**Wrong tool choice**	User fails to switch to better suited instrument for the task	Yes / No	-1	**Were both injections correctly performed within the allotted time?**		Yes / No	1
				Did the participant demonstrate economy of motion?	User exhibits intentional movements that lead to progress	Scale 1 to 5	____	Did the participant demonstrate economy of motion?	User exhibits intentional movements that lead to progress	Scale 1 to 5	____
Total Score				**Total Score**				**Total Score**			

Figure 2: Scoring sheet used to rate ESSST user

Task 1: Backbiter task (1 minute)
Participants were instructed to remove 100% of a pre-marked area on a natural septation in the pepper using a backbiter. Participants were evaluated for percentage removed in allotted time and ability to center instrumentation in their camera view. Points were deducted for hitting the camera with the instrument, inflicting "injury" to surrounding tissue, using the scope as an instrument, and instrumenting outside of the field of view.

Task 2: Removal of a Partition (2 Minutes)
Participants were instructed to select a natural septation within the pepper model and remove it fully, within 2 minutes, utilizing an instrument of their choice. Participants were evaluated in an identical manner to the previous task.

Task 3: Targeted Injections (1 Minute) **(Figure 3)**
Participants were instructed to perform injections at two pre-marked targeted locations on the neoprene structure. For a full score, the needle must be clearly visualized with the endoscope as it is introduced into the model, the injection must be performed within the center of the field of view, in the center of the target and in the correct plane. Points were deducted for injuring adjacent "tissue," losing view of the needle tip and hitting the camera with the needle.

Figure 3: Perform Targeted Injection using 25-gauge spinal needle

Results/Statistical Analysis

One-way ANOVA and Post Hoc Tukey Tests were used to determine significant differences in scores between the 3 groups **(Figure 4)** based on the final score from the scoring sheet described in figure 2. A statistically significant difference was noted when comparing economy of motion and overall performance score between that of novice medical students with no previous ESS training and ORL trainees or experienced surgeons. Although experienced surgeons had higher average scores than ORL trainees in performance and economy of motion, this difference was not found to be of statistical significance. A Likert scale survey of the participating attendings was used to assess the face validity of this skills trainer as a training module for residents. The mean score of each item on the questionnaire was calculated.. Across all metrics in the Likert survey, the mean score was >4.0, indicating the model was positively received and thought to be helpful for novice trainees early on in their training.

Results

	Performance Score	Economy of Motion
Medical Students	0.54 +/- 0.05**	0.39 +/- 0.05**
ORL Trainees	0.79 +/- 0.04**	0.67 +/- 0.04**
Experienced Surgeons	0.83 +/- 0.04**	0.72 +/- 0.03**
ANOVA*	p < 8.3 x 10-5^^	p < 1.6 x 10-5^^

*ANalysis Of VAriance Test

** Mean +/- Standard Deviation of the Mean

	Performance Score ^	Economy of Motion^
Medical Students vs. ORL Trainees	p = 0.001^^	p = 0.001^^
Medical Students vs. Experienced Surgeons	p = 0.001^^	p = 0.001^^
ORL Trainees vs. Experienced Surgeons	p = 0.73	p = 0.66

^PostHoc Tukey Test HSD (Honestly Significant Difference) Test

^^ Statistically Significant p Value

Figure 4: Results from one-way ANOVA and Post Hoc Tukey Tests

Discussion

Medical simulation offers residents and other trainees the opportunity to learn procedural skills in a controlled environment without serious risk to the patient.[5,6-11,16] Simulation can be utilized to develop appropriate knowledge, enhance skills and self-confidence, and gain surgical fluency.[3] While duty hour restrictions have decreased the time period in which a resident can learn procedural and surgical skills, there has been a stronger push for the implementation of an educational environment that can offer the technical skills training outside of the traditional Operating Room education. [7,12,13,16]. While other low cost endoscopic sinus simulators have been validated in the literature[15], this simulator allows for an alternative practice media, offers different practice opportunities and has the advantage of a shorter set up time.

Simulation has repeatedly proven to be an effective means of surgical resident education.[1,17-18] Many studies have repeatedly shown that simulation in different formats can help trainees develop the appropriate knowledge, skill set and self-confidence [1,7] to be a successful clinician and, equally as important, that these skills translated to real clinical procedures. Repetition in a safe and controlled environment with feedback helps facilitate a quicker and safer learning curve that the traditional method that is offered[19]

With the advancement of technologies, some simulators offer a simulation that is close to

reality. It is often assumed that a higher fidelity simulator offers a larger degree of learning opportunity and training, however, many studies have in fact shown that there is no advantage of high fidelity simulators over low fidelity simulators in regards to knowledge and skills acquisition.[20-22] In a study comparing the use of high fidelity and low fidelity simulation for Advanced Life Support training in medical students, Massoth et al, found that "Participants in both groups showed significant improvement in theoretical knowledge in the post-test as compared to the pre-test, without significant intergroup differences."[23] Interestingly, the paper suggested that the students who used the high-fidelity simulator displayed higher level of overconfidence compared to their actual training level when it came to an advanced life support scenario, interpreting this as a possible adverse outcome of high-fidelity simulation. Norman et al proposed that the use of high-fidelity simulators often has no or little benefit compared with low-fidelity simulators. They argued that if the skill that a simulator is intended to teach is a basic motor skill, and if the high cost of high-fidelity simulators are taken into consideration, the use of low-fidelity simulators may even be of advantage for novice learners, likely due to accessibility and repetition.[24]

Due to the proven success of simulation-based-learning, we developed a low-cost, low fidelity highly renewable and effective endoscopic skills trainer that can be easily adopted into any Otolaryngology training curriculum. As can be noted in the above-mentioned data, a statistically significant difference was noted when comparing economy of motion and overall performance score between that of novice medical students with no previous ESS training and ORL trainees or experienced surgeons. Although experienced surgeons had higher average scores than ORL trainees in performance and economy of motion, this difference was not found to be of statistical significance. We believe this is due to the fact that fluency with the skills tested with the ESSST is achieved early on in residency. We believe this trend in the performance testing is suggestive of construct validity. A Likert scale survey of the experienced surgeons (N=6) was used to assess face validity. Across all metrics in the Likert survey, the mean score was >4.0, indicating the model was positively received and thought to be helpful for novice trainees early on in their training.

Conclusion

The mean scores among the 3 test groups and the Likert scale data suggests that the endoscopic sinus surgery skills trainer (ESSST) is a validated, low cost, renewable and useful adjunct to higher fidelity simulators in training residents early in their experience in endoscopic surgery.

Conflicts of Interest:

The authors have no conflicts of interest to declare.

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