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Skills Transfer to Sinus Surgery via a Low-Cost Simulation-Based Curriculum

R. Alex Harbison, MD¹, Jennifer Dunlap², Ian M. Humphreys, DO¹, and Greg E. Davis, MD, MPH¹

¹Department of Otolaryngology-Head and Neck Surgery, University of Washington School of Medicine, Seattle, WA

²University of Washington School of Medicine, Seattle, WA

Abstract

Background—Surgical skill development outside the operating room aims to improve technique and subsequent patient safety. The purpose of this study was to evaluate the correlation between technical and cognitive skills with cadaveric endoscopic sinus surgery (ESS) performance and change in ESS performance before and after implementation of a dedicated ESS simulation- and knowledge-based curriculum.

Methods—A before-after study design was implemented among 10 medical students and 10 junior otolaryngology residents. Participants completed a knowledge-based, multiple-choice ESS pre-test and watched an ESS prosection video. Participants performed nine tasks on a previously validated low-cost, low-technology, non-biologic sinus surgery task trainer followed by cadaveric maxillary antrostomy and anterior ethmoidectomy. Participants then completed a simulation- and knowledge-based ESS curriculum followed by a repeat cadaveric maxillary antrostomy and anterior ethmoidectomy. Performance was graded with a 5-point global rating scale (GRS) and a 5-point ESS-specific checklist.

Results—We observed a stronger correlation between the multiple-choice, knowledge-based, ESS pre-test scores and cadaveric ESS GRS score ($r = 0.73$) than between task trainer performance and cadaveric ESS GRS score ($r = 0.43$). We also noted a significant increase in pre- vs post-curriculum mean (SD) cadaveric ESS checklist scores for both medical students (1.18 (0.25) vs 2.58 (0.57), p -value = 0.0002) and residents (2.09 (0.78) vs 2.88 (0.54), p -value = 0.023). The greatest improvements for residents were in performance of uncinctomy, enlargement of maxillary os, and identification of the bulla.

Conclusions—These findings provide evidence supporting the use of ESS training curricula outside the operating room.

Correspondence to: R. Alex Harbison, MD, Department of Otolaryngology-Head and Neck Surgery, 1959 NE Pacific St, Box 356515, Seattle, WA, USA, phone: 206-543-5230, fax: 206-543-5152, harbison@uw.edu.

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Keywords

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Introduction

Challenges imposed by duty-hour restrictions and patient safety initiatives combined with public demand for quality and value may impede surgical resident post-graduation preparedness and compromise skill attainment^{1,2}. Simulation strives to increase resident technical proficiency outside of the operating room in a controlled setting to increase patient safety. Training poses a unique challenge to the balance of patient safety as resident participation in the operating room may lead to longer operative times and increased complications^{3,4}. Moreover, data suggest that surgical performance is predictive of patient outcome⁵.

Learning from surgical textbooks, surgical videos, observation and graduated responsibility will continue to be the foundation for surgical training. However, the learning curve must be accelerated so that harm to patients is minimized and trainees can focus on advanced surgical concepts instead of the basics during valuable operating room time. Options for simulation include cadaveric dissection and virtual reality simulators. Cadavers provide a high-fidelity experience but are expensive, increasingly difficult to obtain, and dissected regions cannot be re-used⁶. High-fidelity virtual reality sinus surgery trainers such as the ES3 and the McGill simulator provide a standardized method for reinforcing anatomical knowledge and technical skills but are cost-prohibitive and inhibited by maintenance requirements⁷⁻¹⁰. In contrast, low-cost simulation options can increase fundamental skills early in the training years so that trainees can optimize operating room time and patient safety.

In addition to technical skills, cognitive skills are tantamount to safe surgery as they independently affect surgical performance¹¹. In one study, the majority of errors performed by trainees during simulation were caused by a knowledge gap in understanding the correct sequence of steps of a given task¹². Teaching both technical and cognitive skills has a greater impact on surgical performance than either alone as illustrated in a randomized controlled trial of resident technical performance during colectomy¹³. In a recent study, we evaluated the face, content, and construct validity of a low-cost, low-technology, non-biologic sinus surgery task trainer and knowledge-based curriculum¹⁴. We sought to extend the results of our prior work and assess skill transfer to endoscopic sinus surgery with deliberate practice and cognitive training using a knowledge- and simulation-based endoscopic sinus surgery (ESS) curriculum.

In the current study, we aimed to test the association between task trainer performance and cognitive skills with cadaveric ESS performed by medical students and junior otolaryngology residents. We also tested baseline and post-sinus surgery curriculum ESS performance in cadaver specimens. We hypothesized that technical skills, as measured by task trainer performance, and cognitive skills would be associated with ESS performance.

Additionally, we hypothesized that post-curriculum ESS performance would be higher than pre-curriculum (baseline) ESS performance.

Materials and Methods

Subjects

Subjects enrolled in this study included medical students and first through second year otolaryngology residents at the University of Washington. Subjects were required to be over 18 years of age, able to read and speak English, and have dexterity appropriate for someone entering a surgical field. Exclusion criteria included the inability to give informed consent or to complete surveys written in English because of cognitive impairment, language barriers or severe medical conditions. The University of Washington Human Subjects Division Institutional Review Board approved this study.

Subjects were approached to complete a survey assessing baseline characteristics regarding gender, level of training, handedness (right, left or ambidextrous), previous sinus surgery simulation and intra-operative experience, as well as past participation in activities requiring coordination (e.g., sports, dance, sewing, video games, music) ^{14–16}. The training and testing curricula are outlined in Figure 1.

Task Trainer Protocol

Tasks were performed on a previously described, low-cost, low-fidelity endoscopic sinus surgery task trainer ¹⁴. Briefly, subjects were asked to perform a set of nine tasks. These include two endoscopic visualization tasks with a 0° nasal endoscope, a straight suction maneuver, an injection task, and pin removal tasks from the nasopharynx, maxillary sinus, and middle meatus.

Pre-Curriculum Protocol

Participants were instructed to view a video illustrating an expert performing an uncinectomy, maxillary antrostomy, and anterior ethmoidectomy prosection (video provided in supplemental material online ¹⁴). The participants were administered a multiple-choice, knowledge-based, sinus surgery pre-test (also provided in supplemental material ¹⁴). Participants completed the set of nine tasks on the task-trainer. Participants then performed the baseline surgical procedure in a fresh cadaver specimen including a unilateral uncinectomy, maxillary antrostomy, and anterior ethmoidectomy. The side of surgery was chosen based on the hand dominance of the surgeon with the assumption that operating on the contralateral side would attenuate technical difficulty from the side of operation as a confounding variable on the baseline cadaveric ESS (e.g. a right-handed surgeon would perform left sided ESS). Participants had a 20-minute time limit. Participants were only instructed about the available instruments and recommended to perform the procedures as close as possible to the expert prosection that they viewed ahead of time. Endoscopic video of the task trainer and unilateral cadaveric ESS performance was recorded using equipment at the Harborview Medical Center surgical simulation lab (WWAMI Institute for Simulation in Healthcare).

Curriculum Protocol

After the pre-curriculum task trainer and unilateral cadaveric ESS were completed, participants were instructed to complete a previously described endoscopic sinus surgery curriculum including the instructional endoscopic sinus surgery video and a written text¹⁴. Briefly, participants read through the manual including steps of basic ESS adapted from Wormald 2008¹⁷, illustrations of instruments used in ESS, common errors in technique, and description of complications plus their management. Cognitive skills were evaluated via a multiple-choice, knowledge-based, endoscopic sinus surgery post-test¹⁴. Subjects could move on to the repeat ESS once they achieve a score of at least 90% on the post-test. Those participants not achieving proficiency on the post-test were required to repeat until the 90% threshold correct score was achieved. In addition, subjects completed the task trainer module three times on the day of repeat ESS with real-time, standardized coaching.

Task Trainer and ESS Coaching Protocol and Post-Curriculum ESS

Coaching of the deliberate practice on the task trainer included verbal, real-time feedback regarding speed of instruments, torqueing on the model's septum, orientation of the endoscope, crossing and angulation of instruments, and endoscope-instrument depth and position relationship. Subjects then performed a unilateral ESS on the contralateral side using the same cadaver specimen they used for the pre-curriculum ESS. Endoscopic video was recorded. A coaching protocol was implemented in real-time during the repeat ESS with standardized feedback as for the task trainer in addition to feedback as follows: 1) entering the nasal cavity with instrument tips in a closed state, 2) avoidance of inadvertent soft tissue trauma, 3) request for participant to point out key structures (i.e., uncinate, bulla ethmoidalis, and middle turbinate), 4) assessment of participant's goals during uncinectomy, 5) assessment of the participants goals during maxillary antrostomy (i.e., plan to identify natural os), 6) assessment of participants endpoint of maxillary antrostomy, 7) assessment of participant's goals during anterior ethmoidectomy, and 8) assessment of participant's understanding of posterior boundary of the anterior ethmoid air cells. Affirmative responses were provided. If a participant was unsure of specific steps of ESS upon being asked as above, they would be reminded of the objective. For example, they would be told that the posterior boundary of the anterior ethmoid air cells is the basal lamella. They would be allowed to point out the structure they believed to be correct, but the structure would not be specifically pointed out for them. If they were uncertain, they would be asked to continue the procedure to the best of their abilities.

Video Grading Protocol

Endoscopic video was recorded and de-identified for grading by three independent reviewers (G.E.D., I.M.H., and R.A.H.). Reviewers were blinded to whether endoscopic video was from a medical student or resident and whether it was from a pre- or post-curriculum attempt. A previously validated endoscopic sinus surgery global rating scale (GRS) was used for evaluating endoscopic video performance¹⁸. The GRS was used to evaluate overall technical performance for both the task trainer and ESS performance, and is scored on a one to five scale with one representing inadequate performance, three representing competent performance, and five representing mastery. Domains evaluated from the GRS included *Use*

of Endoscopes, Instrument Handling, Respect for Tissue, Time and Motion, Flow of Operation, and Overall Surgical Performance. Additionally, ESS performance was graded using the Endoscopic Sinus Surgery Task Specific Checklist (“Checklist”) ¹⁸. The *Uncinectomy*, *Maxillary antrostomy*, and *Anterior ethmoidectomy* domains were evaluated, each containing subdomains specific to aspects of the procedure. Under *Uncinectomy*, there are three subdomains including a) “identification of the uncinate and boundaries”, b) “incision of uncinate with backbiter or sickle knife”, and c) “removal of uncinate with forceps or debrider”. For *Maxillary antrostomy*, there are two domains including a) “identification of natural ostium of maxillary sinus” and b) “when indicated, enlargement of ostia by removal of posterior fontanelle.” For *Anterior ethmoidectomy*, there are three subdomains including a) “identification of bulla”, b) “removal of bulla with mucosal preservation with forceps or debrider”, and c) “removal of anterior cells with identification of boundaries”. For both the GRS and checklist, domains were scored using a 5-point Likert-type grading system ranging from “Unable to perform” to “Performs easily with good flow”. Average scores were calculated for the three raters and an overall score was determined by taking the total score divided by the number of items evaluated for a final score ranging from one to five with three representing competence.

Statistical Analysis

Univariate linear regression was performed to assess the association between task trainer performance and multiple-choice pre-test scores with baseline ESS performance. Multivariate linear regression was used to control for potential confounding by training level (medical student vs resident) and multiple-choice pre-test score. *T-tests* were used to compare pre- and post-curriculum ESS performance scores. An α -level of 0.05 was used for hypothesis testing with 95% confidence intervals (CI). False Discovery Rate correction was applied to adjust p-values for multiple hypothesis testing when necessary, and an α -level of 0.1 was used to determine statistical significance in these cases. Statistical analyses were performed using R statistical programming software ¹⁹.

Results

Baseline participant characteristics are illustrated in Table 1. Participants included 10 first and second year medical students and 10 first and second year otolaryngology residents. Among the medical students, one had prior experience with sinus surgery simulation while all residents had prior experience with sinus surgery simulation (including prior cadaver dissection). Most medical students and residents had some level of prior sports participation. Video game experience was prevalent in both the medical students and residents.

We observed a weak to moderate correlation between task trainer performance as measured by the global rating scale (GRS) and pre-curriculum cadaveric ESS performance as graded by both the GRS and endoscopic checklist (Fig. 2A, *left and right panels*, respectively). Data from a total of 17 of 20 participants were included due to incomplete data from three participants. In contrast, we observed a strong correlation between the multiple-choice pre-test score and ESS performance (Fig. 2B, *left and right panels*, respectively). In the univariate analysis, we did not observe a statistically significant association between the pre-

curriculum task trainer GRS score and the pre-curriculum ESS GRS score (p -value = 0.086; Table 2A). However, training level (p -value = 0.0026) and pre-test score (p -value = 0.0009) were independently associated with the baseline cadaveric ESS GRS and endoscopic checklist scores. When controlling for training level and pre-test score, we did not observe a significant association between the pre-curriculum task trainer GRS score and ESS performance based on GRS or endoscopic checklist (Table 2B).

Figure 3 illustrates the comparison between pre- (baseline) and post-curriculum cadaveric ESS performance as graded by the GRS and endoscopic checklist. A total of eight sets of pre- and post-curriculum videos for each of the medical student and resident groups were included in this analysis. Example medical student pre- and post-curriculum videos are available in the Supplementary Materials (Supplemental Video 1 and Supplemental Video 2). Medical students exhibited a significant increase in performance between the baseline and post-curriculum ESS performance with respect to both the GRS and endoscopic checklist scores (Fig. 3A, *left and right panels*, respectively; Table 3). Two medical students even passed the competence threshold (GRS and checklist score = 3) on their post-curriculum cadaveric ESS. Example resident pre- and post-curriculum videos are available in the Supplementary Materials (Supplemental Video 3 and Supplemental Video 4). Residents also experienced gains in ESS performance (Fig. 3B; Table 3). Half of the residents reached competence on their post-curriculum cadaveric ESS (Fig. 3B).

Medical students experienced improvement across all domains of the GRS and endoscopic checklist scores between baseline and post-curriculum ESS performance (*FDR adjusted p -value* < 0.1; Table 4). Residents also experienced improvements in multiple domains. For the GRS, residents primarily experienced statistically significant gains in *Time and Motion* and *Flow of Operation* domains (*FDR adjusted p -value* < 0.1; Table 4). For the endoscopic checklist, residents experienced gains in the *Uncinectomy* subdomains uncinete incision and removal of the uncinete, *Maxillary antrostomy* subdomain assessing removal of the posterior fontanelle, and the *Anterior ethmoidectomy* subdomains of identifying and removing the bulla (Table 4).

Lastly, we assessed change in pre- and post-curriculum task trainer GRS scores. Medical student GRS scores improved from a mean (SD) 2.21 (0.66) at baseline to 2.71 (0.49) post-curriculum. Resident scores increased from a mean (SD) 3.08 (1.03) at baseline to 3.81 (0.52) post-curriculum.

Discussion

To our knowledge, this is the first study to assess skill transfer to ESS performance with implementation of a technical and cognitive skills-based ESS curriculum. The overarching goals of the study were to 1) test the relationship between a low-cost, low-technology, non-biologic sinus surgery task trainer and multiple-choice, knowledge-based, pre-test with pre-curriculum ESS performance and 2) assess the pre- vs post-curriculum change in ESS performance. Our principal findings were that the correlation between training level and pre-test score were strongly associated with pre-curriculum ESS performance whereas pre-curriculum task trainer performance was weakly associated with pre-curriculum ESS

performance. We also observed a significant difference in pre- vs post-curriculum ESS performance based on the endoscopic checklist evaluation. Medical students also experienced an increase in general endoscopic performance as judged by the GRS between pre- and post-curriculum ESS performance whereas residents experienced less gain in overall performance. Thus, cognitive skills as measured by the knowledge-based ESS pre-test appear to have a greater association with ESS performance than technical skills on a low-fidelity task trainer, and ESS performance improves to a near competent level on a second attempt coupled with implementation of a technical and cognitive skills-based ESS curriculum that includes live coaching

One of the important findings of this study was the increase from below competence to near competence during cadaveric ESS experienced by residents before and after completion of the curriculum. While it is unknown whether ESS performance at the competence threshold level of the grading instrument used to evaluate participants in this study is associated with surgical outcomes, several studies suggest a safety advantage in accelerating resident technical and cognitive skills outside the operating room. For instance, Zendejas et al.²⁰ evaluated a mastery learning simulation-based curriculum for laparoscopic, inguinal hernia repair. They observed a decrease in intraoperative complications, postoperative complications, and a reduced need for overnight stay in patients undergoing total extraperitoneal inguinal hernia repair when residents randomized to the mastery learning intervention were involved in the case. Technical and cognitive learning outside the operative room are especially important given concerns associated with resident participation in cases such as increased operating time⁴.

The finding that medical students improved their ESS performance with this surgical simulation and cognitive training program is of crucial importance. Anyone who has taught medical students and junior otolaryngology residents is aware of the challenges of the inexperienced surgeon trying to perform basic tasks such as placing instruments into the nasal cavity without traumatizing the nasal and septal mucosa or keeping the camera in the proper orientation. The results of this study show that these basic tasks can be taught, and learned, outside the operating room in a safe, controlled environment, thus leaving the precious operating room time for mastery of more advanced skills. Moreover, supervised practice is a critical factor in acquisition of the skill set required to operate deliberately and safely. Real-time feedback in and out of the operative theatre promotes deliberate learning *en route* to mastering ESS.

An interesting finding was the difference in relationship between task trainer performance and pre-test scores with pre-curriculum ESS performance. Task trainer performance had a weak correlation with pre-curriculum cadaveric ESS performance. This highlights the importance of cognitive skills in surgical training which forms a framework by which to build experience. On the other hand, this does not obviate the need for technical skill development outside the operative theater. It is possible that the task trainer incorporates only a subset of the skills utilized in ESS performance. For example, the task trainer tasks range from simple to more complex grasping maneuvers in a less challenging anatomic context. Whereas, in the cadaver, the nasal cavity is narrower and the technical challenge is greater than simple grasping. Skills that likely correlate between the task trainer and

cadaveric ESS include scope positioning, instrument to scope relationship, and efficiency. Overall, technical skill acquisition is intended to accelerate the learning curve which may translate to more efficient use of teaching time in the operating room. Technical and cognitive skills in combination may have a greater impact on surgical performance than either alone as illustrated in a previous randomized controlled trial of resident technical performance during colectomy¹³. Additionally, simulation decreases operative time^{20,21}.

Along the lines of the technical skills component of this low-cost, low-fidelity system, a question arises for future investigation whether the deliberate practice with coaching was the key to improved ESS and task trainer performance versus rote repetition. We believe that the opportunity to receive immediate feedback with a standardized coaching protocol during the task trainer practice sessions allowed residents and medical students to hone their performance in a deliberate fashion. Ericsson illustrates how deliberate practice, not just repetition differentiates expert from novice performers²². Thus, future work could evaluate the gain in performance and efficiency in training with deliberate practice via one-on-one coaching vs repetition without one-on-one coaching.

While we observed a greater change in pre- vs post-curriculum ESS performance for medical students, more residents reached a competence threshold after completion of the curriculum. This may have been due to a natural and expected trend in improvement after gaining comfort with the tasks and sinus surgical procedures. The same trend may be observed after a junior resident completes their first maxillary antrostomy and anterior ethmoidectomy in a live patient, although the stakes are much greater. This study was not designed to evaluate specific components of the curriculum, but we postulate that standardized coaching during the post-curriculum cadaveric ESS was integral to better performance. However, we also believe that the combination of coaching, technical skills practice, cognitive training, cadaver ESS practice, and observation of ESS video accelerated the observed performance gains more than any component alone. The increase in junior resident performance to near competent following one cadaveric ESS dissection and implementation of the curriculum supports the value of focused training experiences outside the operating room.

Another limitation of this study is that we used cadavers to test ESS performance while results in a live patient may have been different due to patient factors including bleeding and added stress of operating on a live patient. However, we felt it would be unethical to have medical students perform these procedures in the operating room on actual patients, and the same degree of freedom to err would not be tolerated in the live operative setting.

Conclusion

This study showed that both medical students and otolaryngology residents significantly improve their endoscopic sinus surgery performance when participating in a focused surgical simulation and cognitive training program. We also observed a strong correlation between performance on the knowledge-based pre-test and cadaveric ESS performance. While there was weak to moderate correlation between performance on the task trainer and cadaveric ESS, we believe that honing basic technical skills in a controlled setting outside of the

operating room preserves precious time in the operative theatre for advanced learning. In summary, the combination of a knowledge-based and technical-skills training program offers a platform for residents to acquire critical experience outside of the operating room with the ultimate goals of optimizing patient safety and training efficiency.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Flow diagram of study participant steps

Study participants completed the pre-curriculum objectives including a baseline cadaveric ESS (*Pre-curriculum*). The ESS-specific knowledge- and skills-based curriculum was completed (*Curriculum*). Participants then completed a repeat cadaveric ESS (*Post-curriculum*).

Figure 2. Technical and cognitive association with cadaver functional endoscopic sinus surgical (ESS) performance

A, Correlation between global rating scale average score on endoscopic sinus surgery task trainer and cadaver ESS average score rated with a sinus surgery-specific global rating scale (*left panel*) and ESS-specific checklist (*right panel*). B, Correlation between knowledge-based multiple-choice sinus surgery pre-test score and cadaver ESS average score rated with a sinus surgery-specific global rating scale (*left panel*) and ESS-specific checklist (*right panel*). Dashed line, competent ESS performance threshold. r , correlation coefficient.

Figure 3. Pre- versus post-simulation-based endoscopic sinus surgery curriculum cadaver ESS performance

A, Medical student pre- vs post-curriculum cadaver ESS rated with a sinus surgery-specific global rating scale (*left panel*) and ESS-specific checklist (*right panel*). *B*, Resident pre- vs post-curriculum cadaver ESS rated with a sinus surgery-specific global rating scale (*left panel*) and ESS-specific checklist (*right panel*). *Dashed line*, competent ESS performance threshold.

Table 1

Baseline participant characteristics.

Category	Medical Students n (%) N = 10	Residents n (%) N = 10
Sex		
Female	6 (60)	3 (30)
Male	4 (40)	7 (70)
Previous Sinus Surgery Simulation experience		
0 times	9 (90)	0 (0)
1–2 times	1 (10)	6 (60)
3–5 times	0 (0)	4 (40)
Previous Sports		
No history of participation	1(10)	2 (20)
1 – 9 hours per week	6 (60)	3 (30)
>9 hours per week	3 (30)	2 (20)
Unknown	0 (0)	3 (30)
Previous Dance		
No history of participation	5 (50)	6 (60)
1 – 9 hours per week	5 (50)	1 (10)
>9 hours per week	0 (0)	0 (0)
Unknown	0 (0)	3 (30)
Past Sewing		
No history of participation	9 (80)	5 (50)
1 – 9 hours per week	1 (10)	2 (20)
>9 hours per week	0 (0)	0 (0)
Unknown	0 (0)	3 (30)
Past Video Games		
No history of participation	6 (60)	2 (20)
1 – 9 hours per week	4 (40)	2 (20)
>9 hours per week	0 (0)	3 (30)
Unknown	0 (0)	3 (30)
Past Music		
No history of participation	5 (50)	4 (40)
1 – 9 hours per week	3 (30)	1 (10)
>9 hours per week	2 (20)	2 (20)
Unknown	0 (0)	3 (30)

Table 2A

Association between pre-curriculum task trainer GRS score and pre-curriculum ESS GRS score.

Predictor	Univariate Model Slope (95% CI) ^a	P	Multivariate Model Slope (95% CI) ^b	P
<i>Pre-curriculum task trainer GRS score</i>	0.31 (−0.05, 0.68)	0.086	0.045 (−0.31, 0.40)	0.79
<i>Training Level</i>	0.98 (0.40, 1.57)	0.0026	0.013 (−1.68, 1.71)	0.99
<i>Pre-test score</i>	0.023 (0.011, 0.035)	0.0009	0.022 (−0.016, 0.060)	0.24

^aUnivariate regression model evaluating association between predictor and GRS score

^bMultivariate regression model adjusting for training level and pre-test score.

Table 2B

Association between pre-curriculum task trainer GRS score and pre-curriculum ESS checklist score.

Predictor	Univariate Model Slope (95% CI) ^a	P	Multivariate Model Slope (95% CI) ^b	P
<i>Pre-curriculum task trainer GRS score</i>	0.30 (−0.056, 0.65)	0.12	0.022 (−0.31, 0.35)	0.89
<i>Training Level</i>	0.91 (0.32, 1.49)	0.0049	−0.53 (−2.10, 1.03)	0.48
<i>Pre-test score</i>	0.023 (0.011, 0.034)	0.0006	0.033 (−0.0021, 0.068)	0.064

^aUnivariate regression model evaluating association between predictor and GRS score

^bMultivariate regression model adjusting for training level and pre-test score.

Table 3

Pre- vs post-curriculum average GRS and endoscopic checklist scores for residents and medical students.

	Pre-curriculum Mean (SD)	Post-curriculum Mean (SD)	p-value
Residents			
<i>GRS</i>	2.31 (0.74)	2.93 (0.54)	0.051
<i>Checklist</i>	2.09 (0.78)	2.88 (0.54)	0.023
Medical Students			
<i>GRS</i>	1.33 (0.34)	2.46 (0.68)	0.0045
<i>Checklist</i>	1.18 (0.25)	2.58 (0.57)	0.0002

Table 4

Pre- vs post-curriculum average GRS and endoscopic checklist subdomain scores for residents and medical students.

	Pre-curriculum Mean (SD)	Post-curriculum Mean (SD)	Difference	p-value	Adjusted p-value
Residents					
GRS^a					
<i>Endoscope</i>	2.87 (0.59)	3.17 (0.59)	0.30	0.30	0.32
<i>Instrument</i>	2.54 (0.75)	3.04 (0.72)	0.50	0.24	0.28
<i>Tissue</i>	2.38 (0.67)	2.96 (0.78)	0.58	0.076	0.10
<i>Time</i>	2.00 (0.86)	2.62 (0.57)	0.62	0.044	0.089^c
<i>Flow</i>	2.00 (0.94)	2.92 (0.50)	0.92	0.019	0.065
<i>Overall</i>	2.08 (1.04)	2.87 (0.53)	0.79	0.077	0.10
Endoscopic Checklist^b					
<i>Uncinate^c A</i>	2.33 (0.71)	3.00 (0.50)	0.67	0.077	0.10
<i>Uncinate B</i>	1.96 (0.79)	3.08 (0.59)	1.12	0.0098	0.065
<i>Uncinate C</i>	1.88 (0.59)	2.83 (0.47)	0.95	0.0095	0.065
<i>Max^d A</i>	2.04 (0.80)	2.42 (0.77)	0.38	0.36	0.36
<i>Max B</i>	2.08 (0.79)	2.96 (0.70)	0.87	0.027	0.076
<i>Ant^e A</i>	2.33 (0.98)	3.21 (0.56)	0.88	0.017	0.065
<i>Ant B</i>	2.17 (1.08)	2.88 (0.69)	0.71	0.038	0.089
<i>Ant C</i>	1.83 (0.82)	2.46 (0.67)	0.63	0.079	0.10
Medical Students					
GRS					
<i>Endoscope</i>	1.74 (0.76)	3.00 (0.65)	1.21	0.011	0.012
<i>Instrument</i>	1.56 (0.44)	2.63 (0.81)	1.13	0.0073	0.0095
<i>Tissue</i>	1.37 (0.59)	2.52 (0.78)	1.04	0.032	0.032
<i>Time</i>	1.15 (0.24)	2.04 (0.59)	0.88	0.0074	0.0095
<i>Flow</i>	1.11 (0.24)	2.26 (0.79)	1.17	0.0033	0.0051
<i>Overall</i>	1.04 (0.11)	2.33 (0.74)	1.33	0.0013	0.0024
Endoscopic Checklist					
<i>Uncinate A</i>	1.30 (0.31)	2.78 (0.67)	1.46	0.00068	0.0021

	Pre-curriculum Mean (SD)	Post-curriculum Mean (SD)	Difference	p-value	Adjusted p-value
<i>Uncinate B</i>	1.15 (0.44)	2.85 (0.67)	1.67	0.000048	0.00068
<i>Uncinate C</i>	1.11 (0.33)	2.58 (0.82)	1.44	0.0011	0.0021
<i>Max A</i>	1.04 (0.11)	2.30 (0.79)	1.38	0.0011	0.0021
<i>Max B</i>	1.30 (0.48)	2.30 (0.84)	0.92	0.026	0.028
<i>Ant A</i>	1.37 (0.51)	3.00 (0.44)	1.63	0.00031	0.0021
<i>Ant B</i>	1.18 (0.24)	2.59 (0.66)	1.46	0.00054	0.0021
<i>Ant C</i>	1.04 (0.11)	2.26 (0.64)	1.25	0.0011	0.0021

^aGRS subdomains described in **Methods and Materials**.

^bEndoscopic checklist subdomains described in **Methods and Materials**.

^cBolded values represent statistically significant differences.