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Authors
Shay, Sophie G
Chrin, Jonathan D
Wang, Marilene B
et al.

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Initial and Long-term Retention of Robotic Technical Skills in an Otolaryngology Residency Program

Sophie G. Shay, MD; Jonathan D. Chrin, BA; Marilene B. Wang, MD, FACS;
Abie H. Mendelsohn, MD, FACS

Objectives/Hypothesis: To objectively assess the initial and long-term retention of robotic surgical skills of otolaryngology residents.

Study Design: This study was performed in an academic otolaryngology residency training program. Between October 2015 and November 2016, residents were invited to complete a prospective, multiphase robotic surgical skills training course: 1) online da Vinci Surgical System Assessment and didactic, 2) faculty-supervised robotic simulator training, 3) robotic docking and draping training, 4) robotic dry-lab exercises. To optimize surgical skill retention, the training laboratory was repeated 2 weeks after the initial training session.

Methods: Twenty otolaryngology residents were included. Primary outcome was measured as robotic skill assessment scores on three tasks: camera targeting, peg board, and needle targeting. Skill assessments were completed prior to training, between the two training sessions, and at 1 month and 6 months after training. Residents were also asked to complete a self-assessment questionnaire.

Results: Camera targeting scores were improved at midtraining ($P < .001$) and 1-month posttraining ($P = .010$). Peg board scores were improved at 1 month training ($P = .043$). Needle targeting scores were improved at midtraining ($P = .002$), 1 month ($P = .002$), and 6 months posttraining ($P < .001$). Resident self-assessment scores demonstrating comfort with using the robotic console ($P < .01$) and docking/draping ($P < .01$) improved significantly following the training.

Conclusions: Following a multiphase robotic training program, otolaryngology residents demonstrated significant, objective skill acquisition and retention at 1 month and 6 months follow-up. Although the proposed training strategy may be considered an important step in otolaryngology residency training, additional innovations are being designed toward a formal robotic training curriculum.

Key Words: Da Vinci, transoral robotic surgery, medical education, residency training.

Level of Evidence: NA

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INTRODUCTION

Since transoral robotic surgery (TORS) was approved by the United States Food and Drug Administration for treatment of oropharyngeal and laryngeal tumors, otolaryngologic applications of the da Vinci Surgical System (dVSS) (Intuitive Surgical, Inc., Sunnyvale, CA) have skyrocketed.[1] TORS has since been proven as a safe and effective oncologic approach, with outcomes demonstrating decreased morbidity compared to primary chemoradiation for malignancies of the head and neck, as well as faster recovery time and improved cosmesis postoperatively.[2–5] Additionally, the expansion of TORS toward nonneoplastic conditions such as obstructive sleep apnea, thyroid nodules, and dysphonia/phonosurgical procedures has made the role of the surgical robotic system within otolaryngology undeniable.[2,6–8]

Rising integration of TORS as a standard surgical approach within otolaryngology is paralleled by a rising demand for unified training. The structured time period of residency training offers an ideal time for systematic acquisition of robotic surgical skills. Compared with the published resident training experience for gynecology, urology, and general surgery, there is a relative void in the literature guiding the training of otolaryngology residents. Although there have been selected reports describing potential curriculum designs, no standardized curriculum exists among otolaryngology residency robotic training programs, nor has skill retention following any of the previously proposed curricula been demonstrated.[9–17] In the current study, we look to demonstrate both short-term resident robotic surgical skill acquisition and long-term skill

From the Division of Pediatric Otolaryngology–Head and Neck Surgery (S.G.S.), Ann and Robert Lurie Children's Hospital, Northwestern University Feinberg School of Medicine, Chicago, Illinois; Center for Advanced Surgical and Interventional Technology (J.D.C., A.H.M.), David Geffen School of Medicine, Ronald Reagan Medical Center, University of California Los Angeles, Los Angeles, California; Department of Head and Neck Surgery (M.B.W., A.H.M.), David Geffen School of Medicine, University of California Los Angeles, Los Angeles, California.

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Send correspondence to Abie H. Mendelsohn, MD, Director of Robotic Head and Neck Surgery Program, Department of Head and Neck Surgery, David Geffen School of Medicine at UCLA, 200 Medical Plaza, Suite 550, Los Angeles, CA 90095. E-mail: amendelsohn@mednet.ucla.edu

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retention following an intensive, structured dry lab designed specifically for otolaryngology residents.

MATERIALS AND METHODS

This study was exempt from internal review board approval as the residents completed the training program as a component of their structured surgical educational program.

Twenty otolaryngology–head and neck surgery residents (postgraduate year [PGY]2–PGY5) from an Accreditation Council for Graduate Medical Education–accredited academic residency program underwent our novel, robotic surgical skills training curriculum. Residents performed an online dVSS didactic followed by an online assessment of knowledge regarding the surgical system (www.intuitivesurgical.com). Residents then completed a 2-hour, faculty-supervised skills lab with multiple training stations. As described below, the skills lab consisted of rotation between the following training stations: 1) dVSS docking and draping station, 2) dry lab using inanimate objects on the dVSS, 3) robotic simulators. The residents were then requested to repeat the 2-hour skills lab 2 weeks after the first skills lab. As this training was a voluntary portion of residency education and training, partial participation was observed for the long-term assessments. During the training course, the residents did have access to the simulator between evaluation sessions to use at their own leisure on a voluntary basis. Some residents were also exposed to robotic surgical cases as assistants prior to, and during, the course of the training, but none were operative surgeons on the robotic console.

Docking and Draping Module

Residents were oriented to the dVSS by one of the senior authors, shown how to appropriately dock and drape the robot, and presented correct transoral instrument positioning. Residents were asked to demonstrate appropriate docking and draping of the dVSS. Successful completion of the docking station was a required component of the training curriculum.

Robotic Dry-Lab Exercises

Using the dVSS, residents completed three dry-lab exercises using inanimate objects. These exercises included passing a plastic ring around a metal apparatus, moving plastic beads on and off a peg board, and suturing. Residents were asked to complete each of the exercises at least one time, but were allowed at their own discretion to repeat the exercises. Of note, timing of the physical exercises allowed for increased resident engagement and friendly skills competition.

Robotic Simulator Exercises

The skills lab utilized both the da Vinci simulator (Intuitive Surgical, Inc, Sunnyvale, CA) as well as the Mimic dV-Trainer developed specifically for training learners on the dVSS (Mimic Technologies, Inc., Seattle, WA). Residents had access to both simulator systems during proctored lab sessions as well as during their own private study time. During the proctored lab sessions, residents were asked to utilize both simulator systems and spend approximately 1 hour using the simulators.

Outcome Measures

The Mimic dV-Trainer is equipped with a testing module in which three exercises are completed, and labeled by the Mimic dV-trainer by stage of training: pretraining, midtraining, and posttraining. These exercises included the following: camera targeting (the user moves and zooms the camera toward various targets), peg board (the user moves rings from one peg to another as instructed during the exercise), and needle targeting (the user threads a needle through several rings, as seen in Figure 1). Additional information regarding the exercise activities can be found at the developer website: http://mimicsimulation.com/dv-trainer. The Mimic dV-Trainer testing system allows for an objective performance report that is generated following completion of the exercises with scaled scores reflecting performance in a number of categories. The primary outcome measure was the overall score, representing a composite score of the participant's performance on the activity. Additionally, subset metrics were analyzed on various aspects of exercise performance: economy of motion, time to complete exercise, excessive instrument force, instrument collisions, and instrument out of view, all scored on a scale of 0 to 200 points (200 reflecting a perfect score).

The residents were asked to complete pretraining exercises within the week prior to the first skills lab. They were asked to complete the midtraining exercises in the 2 weeks between the two skills labs. Finally, they were asked to complete the posttraining exercises 1 month and 6 months following completion of the final proctored skills lab. Additionally, residents were asked to complete a follow-up survey within 1 month of lab completion regarding their perception of skill acquisition and comfort with the dVSS.

Statistical Analysis

All data were imported into SAS version 9.4 (SAS Inc., Cary. NC) for analyses. Changes from pretraining compared to midtraining, 1 month posttraining, and 6 months posttraining for each subject were computed for overall scores as well as each subset metric. Nonparametric analyses were used given participant dropout, which prevented normalization of data and use of parametric models. A series of Wilcoxon sign rank tests were used to compare the pretraining to midtraining/posttraining scores at each time interval and to calculate *P* values. The survey responses were also evaluated using the Wilcoxon sign rank test. All *P* values for comparisons to pretraining were computed using the nonparametric Wilcoxon sign rank test for paired (repeated measures) data. Survey responses were also analyzed using the nonparametric Wilcoxon sign rank test.

For a given measure, nonparametric median and interquartile range are reported. Statistical significance was set at $P = .05$.

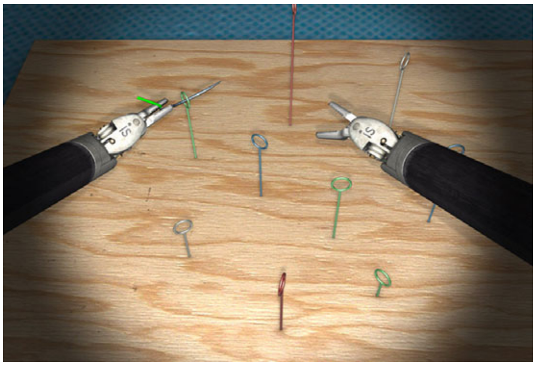

Fig. 1. Needle targeting exercise screen image demonstrates the training environment within the simulator training system. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

RESULTS

Twenty residents completed the exercises at pretraining, 16 at midtraining, and 12 at posttraining. All 20 residents completed the survey. There were no statistically significant differences based on PGY level ($P > .05$) on any of the objective skill exercise scores throughout all of the assessment time points.

Camera Targeting

There was significant improvement in residents' overall scores on camera targeting at midtraining ($P < .001$) and 1 month posttraining ($P = .010$). These improvements in overall score did not maintain statistical significance at 6 months posttraining ($P = .110$) compared to pretraining overall scores. On economy of motion, residents' scores were significantly higher at midtraining ($P = .013$) and 1 month posttraining ($P = .002$), but not at 6 months posttraining ($P = .1294$). Time to complete exercise scores improved at midtraining ($P < .001$), 1 month posttraining ($P = .002$), and 6 months posttraining ($P = .021$). Scores related to excessive instrument force, instrument collision, and instruments out of view did not show statistically significant improvements compared to pretraining scores ($P > .05$). Figure 2 depicts the overall scores over time for the camera targeting exercise.

Peg Board

For peg board training, the residents' overall scores were improved at 1 month posttraining ($P = .043$), but did not have any significant changes at midtraining or 6 months posttraining compared to pretraining ($P = .051$ and $.064$, respectively). On economy of motion, the residents did show improvements at midtraining ($P = .016$) and 6 months posttraining ($P = .043$). Time to complete exercise scores were significantly improved compared to pretraining at midtraining ($P = .006$), 1 month posttraining ($P = .004$), and 6 months posttraining ($P = .009$).

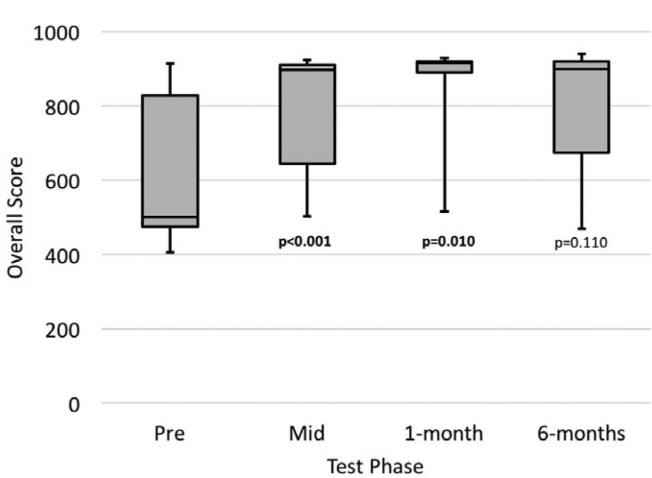

Fig. 2. Box and whisker plot depicting camera targeting overall scores across pretraining, midtraining, 1 month posttraining, and 6 months posttraining test phases. Corresponding *P* values comparing overall scores to pretraining scores are displayed.

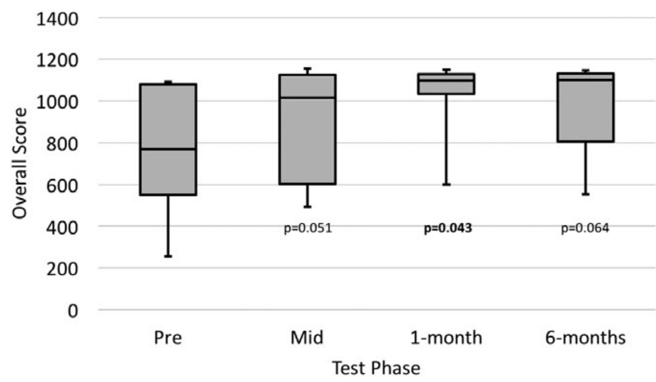

Fig. 3. Box and whisker plot depicting peg board overall scores across pretraining, midtraining, 1 month posttraining, and 6 months posttraining test phases. Corresponding *P* values comparing overall scores to pretraining scores are displayed.

Resident scores did not improve on measures of excessive instrument force, instrument collision, and instruments out of view. Figure 3 shows the median overall scores over time for the peg board exercise.

Needle Targeting

For needle targeting, resident overall scores were significantly improved at midtraining ($P = .002$), 1 month posttraining ($P = .002$), and 6 months posttraining ($P < .001$) compared to pretraining. Economy of motion scores for this exercise were statistically improved at 1 month posttraining ($P = .005$), and 6 months posttraining ($P = .001$), but not at midtraining ($P = .389$). Time to complete exercise scores were significantly increased at midtraining ($P = .042$), 1 month posttraining ($P < .001$), and 6 months posttraining ($P = .003$). Excessive instrument force was significantly improved at 1 month posttraining ($P = .008$) but not at midtraining or 6 months posttraining. Instrument collision scores were significantly improved at midtraining ($P = .049$) and 6 months posttraining ($P = .041$) but not at 1 month posttraining ($P = .110$). Instrument out of view scores were significantly improved at 6 months posttraining ($P = .008$) but not at midtraining ($P = .079$) or 1 month posttraining ($P = .190$). Figure 4 shows the overall scores for this exercise over time.

Survey Scores

Residents reported a significant improvement in self-rated comfort with docking and draping of the dVSS ($P < .001$). The residents also reported a significant improvement in self-rated comfort with using the dVSS surgical console ($P < .001$).

DISCUSSION

With increasing applications of TORS, the need for earlier initiation of standardized training is becoming more evident. The joint American Academy of Otolaryngology–Head and Neck Surgery and American Head and Neck Society Committee on Transoral Robotic

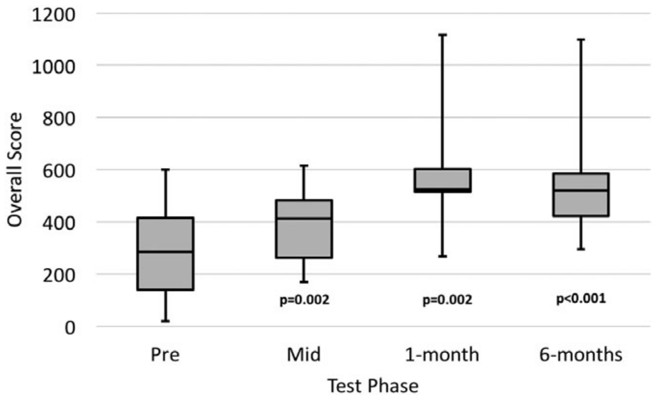

Fig. 4. Box and whisker plot depicting needle targeting overall scores across pretraining, midtraining, 1 month posttraining, and 6 months posttraining test phases. Corresponding *P* values comparing overall scores to pretraining scores are displayed.

Surgery Training and Certification published the recommendations that training curricula should include a preclinical component consisting of a didactic session, dry lab exercises, and cadaver/simulator exercises, as well as a clinical component with gradually increasing surgical responsibility.[18] Furthermore, it has been shown that clinical outcomes are highly correlated with objectively assessed surgical skills.[19] Thus, objective assessments of surgical training curricula and trainee skill retention are crucial toward improving clinical outcomes and reducing surgical complications and must be integrated into otolaryngology training opportunities.

A select number of investigations have focused on training otolaryngology residents on the dVSS[9,20–22]; however, no training curriculum has yet been adopted as a standard for TORS training. Moles et al. demonstrated a preliminary training program using inanimate laboratory tasks on the dVSS.[21] Sobel et al. recently expanded on a previously described curriculum by Curry et al. by presenting a step-wise, competency-based curriculum utilizing didactic, TORS simulator modules, and porcine-model dissection.[20,22] The residents included in the study demonstrated improvement on porcine-model base of tongue resections after undergoing the curriculum on objective structured assessments of technical skills. Sperry et al. also described a multistage curriculum utilized at their institution including assigned readings, didactic sessions, skills lab (including robotic simulation, inanimate tasks, and cadaver laboratory), and progressive intraoperative responsibility.[9] However, when critically evaluating these prior studies, severe limitations exist with the requirement for animal- or cadaver-based robotic skills training, both in financial costs as well as logistical constraints. Additionally, many surgical faculty still grapple with how to safely provide progressive surgical responsibility through offering instrument control to a novice robotic surgeon with questionable proficiency.

We sought out objective assessment of robotic technical skills with initial robotic training, and in turn, the efficacy of robotic technical skill acquisition and maintenance. Notably, the current study utilized a method that relied upon resources expected of an active academic robotic surgical lab. Based on the current study, it appears that otolaryngology residents who completed the described training curriculum had significant increases in objective measures of skills. The largest improvements were seen with efficient use of the dVSS (time to complete tasks, economy of motion), suggesting that these skills are more easily attainable in the early stages of training. The skills that did not show significant improvements over the course of the study were related to fine-tuned instrument use (instruments out of view, instrument collisions, excessive instrument force), and reflect skills that would likely maintain with more consistent practice of robotic technique. Additionally, the use of a twice-repeated skills labs demonstrated technical skill retention over a 6-month follow-up period, which suggests that integration of regularly scheduled robotic skills labs could translate into continued skill refinement, particularly for the more advanced skills of the peg board and needle targeting exercises.

Our residents overall had reported very low level of comfort using the dVSS prior to undergoing the training curriculum; the rapid acquisition of basic robotic technical skills along with the self-reported confidence in utilizing the robotic system with the lab suggest that the acquisition of basic initial robotic manipulation skills is readily achievable for novice surgeons. It is also worth mentioning that regardless of PGY level, our residents were all considered novice surgeons, as pretraining scores and relative improvement across training phases were not correlated with PGY level. Furthermore, this reflects the observation that increased skills in open surgical training are not directly translated to robotic surgical skills.

One of the main challenges of resident robotic skills training highlighted by the published literature is the high cost of dVSS instrumentation and curriculum infrastructure. Although the simulators used by our curriculum also represent a costly resource, they represent a fixed-cost and therefore are more cost-effective than devising laboratories with single-use cadaver or animal models for robotic skill acquisitions. The validity of simulators in robotic training and the use of simulators for objective assessment are well supported, particularly within the urology literature.[23–27] These robotic simulators, when costs are shared among the several robotic surgical specialties, can become a financially justifiable purchase. Based on our described experience, we advocate for the increased use of surgical simulator technology as a critical component of preclinical otolaryngology robotic surgical skills training. Robotic simulators continue to represent a vastly underutilized resource among surgical residency training programs despite evidence that they are effective teaching tools.[28] As a shared resource that can be utilized repeatedly, the cost of purchasing the surgical simulator is balanced with the large number of surgical trainees across an institution that can benefit from such an important resource.

Otolaryngology residents need to have a clinical training component in the operating room, graduating from clinical observer to bedside surgical assistant, and finally proctored console surgeon[9,18]; however, the era of "practicing" surgeries on patients is rapidly coming to a close. With the intrinsic temporal pressures of residency, training opportunities outside of the operating room to achieve surgical skill proficiency must be increasingly integrated into our training curricula. The long-term retention of preclinical robotic technical skills demonstrated by the current study is promising for the future of otolaryngology robotic training. The use of dry lab and simulator exercises may prove an important and efficacious stage in allowing trainees to demonstrate basic robotic technical skills and instrument manipulation, which serve as the foundation of surgical competency. Certainly, these skills would require further development in the clinical setting with time spent on the dual console and in supervised time as console surgeon.

Our training study must also be interpreted with caution as it is weakened by methodological concerns. A main consideration is the partial resident completion of the long-term skills assessments. As this study was taken on as part of resident education, additional resident clinical responsibility and unavailability at times prevented uniform completion of the curriculum. Although the authors initially devised methods of resident incentivizing for training participation, local institutional policy prevents additional resident remuneration. However, as the use of robotic technology becomes more widespread, the need for mandatory participation in preclinical, robotic surgical skills training is likely to become more apparent. Although the incomplete long-term data limit the statistical calculations, it does reflect real-life challenges with resident training requiring self-motivated learning. Our preclinical skills lab also suffered from a lack of skill assessment on the physical model exercises. Outsourcing video review of robotic instrument manipulation was unfortunately beyond the available resources, and current institutional infrastructure does not offer local surgical video review. However, recent literature on crowdsourcing review of surgical techniques is promising for inexpensive, decentralized feedback, and further study on the applications of crowdsourcing on robotic surgical skills would be intriguing.[29] The lack of correlation between simulator skills assessment and video review of physical dry lab robotic exercises was unavoidable. However, it was felt that the vast majority of otolaryngology training programs are similarly without these resources, and so their absence did not prevent the applicability of the curriculum.

Residency is an ideal time to begin the long and resource-intensive process of robotic surgical skills training. Residency training offers a natural period of time in which trainees are supervised and proctored during surgical cases, and have protected didactic and educational time. Given the rapid rise of TORS within otolaryngology, a parallel increase in the number of trainees able to perform TORS would serve to increase standardization of these surgical procedures nationally, as well as create a population of surgeons able to further improve the application of the TORS to our surgical specialty.

CONCLUSION

With the increasing applications of TORS, it is becoming increasingly important that otolaryngology residents are adequately trained on and familiar with robotic technology. The use of twice-repeated skills labs demonstrated acquisition and long-term retention of robotic surgical skills. Additionally, based on both objective skill assessments and subjective trainee surveys, overall comfort and familiarity with the robotic surgical system improved following the curriculum. Additional cost-effective curriculum development specific to TORS is needed.

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