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Megha Chandna

Sana Siddiqui

Dylan Bertoni

Marah Sakkal

Sara Belko

See next page for additional authors

Authors
Megha Chandna, Sana Siddiqui, Dylan Bertoni, Marah Sakkal, Sara Belko, Maurits Boon, and Joseph Spiegel

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ORIGINAL RESEARCH

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Comparing cadaveric and 3D-printed laryngeal models in transcutaneous injection laryngoplasty

Megha Chandna BS[1] | Sana Siddiqui MD[1] | Dylan Bertoni MD[1] | Marah Sakkal BA[2] | Sara Belko MS, BSE[3] | Maurits Boon MD[1] | Joseph Spiegel MD[1]

[1]Department of Otolaryngology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania, USA

[2]Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, USA

[3]Thomas Jefferson University Health Design Lab, Philadelphia, Pennsylvania, USA

Correspondence
Megha Chandna, 925 Chestnut St, Floor 6, Philadelphia, PA 19107, USA.
Email: mchandna@tamu.edu

Abstract

Background: There is increasing focus on the development of high-quality simulation models for medical education. Cadaveric models, although considered more realistic, may be difficult to obtain and costly. The advent of three-dimensional (3D) printing has offered a low-cost, reliable, and reproducible alternative. This study sought to compare the utility of 3D-printed to cadaveric models for training in transcutaneous injection laryngoplasty (TIL).

Methods: A simulation course with a cross-over design was employed. Video laryngoscopes were utilized for both the 3D and cadaveric models to assess the accuracy of injection into the vocal fold. Pre-procedure and post-procedure surveys were administered to evaluate understanding and comfort level on a Likert scale of 1–10. Each model was also rated on a 1–5 Likert scale for self-efficacy, fidelity, and educational value.

Results: Pre- and post-survey data were completed by 15 otolaryngology residents and medical students. Mean pre-seminar understanding and comfort level were 3.7 and 2.2, respectively, compared to 6.9 and 5.9 ($p < .05$) following use of the 3D model and 6.4 and 4.7 ($p < .05$) following use of the cadaver model. When comparing 3D and cadaveric models, no significant differences were observed regarding self-efficacy, fidelity, and educational value.

Conclusion: There was a similar mean increase in understanding and comfort following use of the 3D and cadaveric models. 3D-printing can provide an excellent adjunct to, and eventually a potential replacement for hands-on cadaveric training in medical education, particularly for TIL.

Level of Evidence: Level III.

KEYWORDS

laryngology, medical education < comprehensive otolaryngology, resident education < comprehensive otolaryngology, vocal fold paralysis/paresis/motion impairment < laryngology

This study was presented as a poster at the American Laryngology Association Combined Otolaryngology Spring Meetings in May 2023 in Boston, MA, USA.

1 | INTRODUCTION

Procedures in otolaryngology require a significant amount of practice, dexterity, and confidence to master. Residents may not be exposed to some procedures, such as transcutaneous injection laryngoplasty (TIL), until late in their training. Simulator models are a burgeoning tool for surgical trainees with which they can study anatomy and hone their technical skills for such procedures. In this study, we are evaluating a high-fidelity three-dimensional (3D)-printed laryngeal simulator for TIL.

TIL is a mainstay surgical management option for unilateral vocal fold paralysis and vocal fold atrophy, among other conditions.[1] Historically, this procedure was performed under general anesthesia. More recently, it has evolved into a common office procedure with local anesthesia, given the risk and costs of general anesthesia. In the past, numerous materials were used for this procedure, including Teflon and bovine collagen, with some inducing hypersensitivity, while others were resorbed into the body and reversed vocal cord alignment.[2] Now, biocompatible gels such as Prolaryn or Restylane are the mainstay of treatment. Flexible video laryngoscopy via a transoral route allowed for the procedure to transition to an office setting but runs into physical limitations if the patient had a strong gag reflex or a large tongue.[3] Transcutaneous techniques use flexible video laryngoscopy for visual guidance, especially for those who cannot tolerate a transoral procedure.[2] The approach can be conducted through the thyroid cartilage, thyrohyoid, or cricothyroid membrane, but these require adequate training and detailed knowledge of anatomic relationships to master. When the procedure is performed in the office, the patient is awake, adding another barrier to effective training.[4] Furthermore, injection laryngoplasty is difficult to learn through observation since it requires a combination of both tactile and visual cues.[5] Overall, experience with this procedure is relatively uncommon for residents early on in their training—a paucity that needs to be addressed.

Simulator models allow trainees to practice challenging surgical procedures, like TIL, in low-risk environments.[6] These models bridge the gap in educational opportunities, especially in hospitals that have lower volumes of cases.[7] Simulations also provide the advantage of repetition in performing the procedure to refine skills and residents can receive immediate feedback to adjust their technique.[6] Animal or cadaveric airway models are frequently utilized for training, but 3D-printed airway models have been shown to be an advantageous alternative. 3D-printed models are lower in cost than porcine or human cadaver models, do not decompose, do not need to be refrigerated, and can be tailored to specific surgical scenarios.[7]

Past studies have utilized simulator tools, ranging from cadaver to 3D printed models, to train residents in laryngoplasty techniques. Cabrera-Muffly et al. created a lo-fi, low-cost model using materials like toilet paper tubes, cardboard, zip ties, and muslin cloth that taught residents the fundamentals of office vocal fold injection.[8] They found that the model increased resident confidence in performing the procedure as well as learning from the model.[8] Kavanagh et al. studied 3D-printed pediatric laryngeal simulators for pediatric airway emergencies.[9] They pointed out the importance of practicing on simulators for these rare emergencies, which they otherwise do not routinely experience.[9] Falls et al. compared the use of 3D printed and porcine models,[7] while Ainsworth et al. was the first study to describe a multimaterial model to teach transcervical laryngeal injections.[10] Over and over, resident confidence has significantly increased in these studies, which would ideally translate to greater skill level.

The purpose of our study was to determine the utility of a 3D-printed model in a simulation of TIL. This was compared to cadaver models, a more costly alternative. We believe simulation on a 3D-printed model will provide residents and medical students with a better understanding of the anatomy and procedure that is comparable to cadaver models.

2 | MATERIALS AND METHODS

This study has been approved by the Thomas Jefferson University Institutional Review Board #22E.894.

2.1 | Participants

Simulated TILs were completed by 15 otolaryngology residents and 6 fourth-year medical students on the cadaveric and 3D-laryngeal models. Resident trainees ranged from PGY 1 to PGY 5 levels, with three residents at each level of training participating in the simulation course. Two faculty participants within the Division of Laryngology completed each model to evaluate anatomic realism, palpability of landmarks, pierceability with a needle, and ability to evaluate surgical performance.[5] Residents and medical students were randomly distributed between completing the 3D-printed model as their first station ($n = 7$) or the cadaveric laryngeal model as their first station ($n = 7$). Per station, survey attrition was high, with a response rate of 14 out of 21 participants.

2.2 | Simulator course and surveys

All participants started the course with the same pre-course survey detailing their previous experience with transcutaneous vocal fold injections; understanding of anatomical landmarks and key steps of the procedure on a 1–10 Likert scale; and comfort level with the procedure on a 1–10 Likert scale. Half of the participants began the course with the cadaveric laryngeal model and half of the participants started with the 3D-printed model. After the first round, participants filled out a post-procedure survey specific to the simulator used (Figure 1A,B) detailing their level of understanding of laryngeal anatomy on a 1–10 Likert scale; comfort level with TIL on a 1–10 Likert scale; and educational value, fidelity, and self-efficacy of the simulator used on a 1–5 Likert scale. The Michigan Standard Simulation Experience Scale was used as a framework for the post-simulator surveys, as this provides information on face validity (whether or not the model tests what it is intended to), content validity (adequacy of

Laryngoscope Investigative Otolaryngology

(A) **3D MODEL – Post-Survey**

Training Year (please circle): M1 2 3 4 PGY 1 2 3 4 5 6 7 Fellow Attending

After engaging with the simulator, please take a moment to complete the rating below.

Please mark your level of understanding when it comes to the landmarks and key features of transcutaneous injection laryngoplasty (1 = no understanding, 10 = complete understanding of the procedure).

1 2 3 4 5 6 7 8 9 10

Please mark your comfort level with performing transcutaneous vocal fold injection (1 = no comfort, 10 = very comfortable).

1 2 3 4 5 6 7 8 9 10

Model Features

	Strongly disagree (1)	Somewhat disagree (2)	Neutral (3)	Somewhat agree (4)	Strongly agree (5)
SELF-EFFICACY					
The 3D laryngeal model helped improve my **confidence** at performing transcutaneous vocal fold injections					
The 3D laryngeal model helped improve my ability to perform transcutaneous vocal fold injections **independently**					
FIDELITY					
The 3D laryngeal model used has adequately **realistic** landmark structures					
The resistance when passing a 25-gauge needle through the model is adequately similar to real human cartilage/tissue					

PLEASE CONTINUE ON THE NEXT PAGE →

	Strongly disagree (1)	Somewhat disagree (2)	Neutral (3)	Somewhat agree (4)	Strongly agree (5)
EDUCATIONAL VALUE					
The 3D laryngeal model is a good training tool for **developing skills** in laryngeal injections					
The 3D laryngeal model helps develop dexterity, accuracy and precision with instruments					
The 3D laryngeal model is useful for teaching the **needle insertion technique** for injection laryngoplasty.					
The 3D laryngeal model is useful for teaching **the target site** for injection.					
The 3D laryngeal model will **increase resident competency** when used prior to their 1st laryngeal injection					
OVERALL RATING					
	Not at all useful	Neutral	Somewh at useful	Useful	Very useful
Overall, this simulation experience as a training tool was					

(B) **CADAVER**

Training Year (please circle): M1 2 3 4 PGY 1 2 3 4 5 6 7 Fellow Attending

After engaging with the simulator, please take a moment to complete the rating below.

Please mark your level of understanding when it comes to the landmarks and key features of transcutaneous injection laryngoplasty (1 = no understanding, 10 = complete understanding of the procedure).

1 2 3 4 5 6 7 8 9 10

Please mark your comfort level with performing transcutaneous vocal fold injection (1 = no comfort, 10 = very comfortable).

1 2 3 4 5 6 7 8 9 10

Model Features

	Strongly disagree (1)	Somewhat disagree (2)	Neutral (3)	Somewhat agree (4)	Strongly agree (5)
SELF-EFFICACY					
The cadaver model helped improve my **confidence** at performing transcutaneous vocal fold injections					
The cadaver model helped improve my ability to perform transcutaneous vocal fold injections **independently**					
FIDELITY					
The cadaver model used has adequately **realistic** landmark structures					
The resistance when passing a 25-gauge needle through the model is adequately similar to real human cartilage/tissue					

PLEASE CONTINUE ON THE NEXT PAGE →

	Strongly disagree (1)	Somewhat disagree (2)	Neutral (3)	Somewhat agree (4)	Strongly agree (5)
EDUCATIONAL VALUE					
The cadaver model is a good training tool for **developing skills** in laryngeal injections					
The cadaver model helps develop dexterity, accuracy and precision with instruments					
The cadaver model is useful for teaching the **needle insertion technique** for injection laryngoplasty.					
The cadaver model is useful for teaching **the target site** for injection.					
The cadaver model will **increase resident competency** when used prior to their 1st laryngeal injection					
OVERALL RATING					
	Not at all useful	Neutral	Somewh at useful	Useful	Very useful
Overall, this simulation experience as a training tool was					

FIGURE 1 (A) Participants who started the transcutaneous injection laryngoplasty (TIL) simulation course with the 3D model were asked to complete this survey after using the 3D model. (B) Participants who started the TIL simulation course with the cadaver were asked to complete this survey after using the cadaver.

individual components of the model), and self-efficacy (an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments).[5,11] After completing both simulators, residents filled out a short post-course survey once again detailing their level of understanding of laryngeal anatomy on a 1–10 Likert scale; comfort level with TIL on a 1–10 Likert scale; and evaluating the 3D model as a useful adjunct to cadaver models for TIL on a 1–10 Likert scale, along with an open-ended question regarding the strengths and weaknesses of each model.

Two faculty participants in the Division of Laryngology independently evaluated the 3D model and cadaver using the same surveys. Their responses are listed in the discussion section below.

Basic descriptive statistics were calculated for quantitative survey measures and qualitative responses were analyzed. The data collected was nonparametric in distribution; therefore, Mann–Whitney *U* tests were used for comparisons between group medians.

2.3 | Injection laryngoplasty simulation

Cadaveric laryngeal models were provided by the Thomas Jefferson University Department of Pathology, Anatomy, and Cell Biology.

An open-source laryngeal cartilaginous model created by a team at the University of Dundee and BodyParts3D served as the basis for our simulator's laryngeal framework.[5] An open-source laryngeal soft-tissue model created by a team at Weill–Cornell served as the basis for our simulator's endolaryngeal structures.[5] No modifications were made to the existing models. Previously, the endolaryngeal structures were created by 3D printing the negative mold in hard ABS (Acrylonitrile Butadiene Styrene) filament and pouring silicone to form the internal structures. We elected to resin print the internal endolaryngeal structures directly using an elastic material as described below.

The open-sourced 3D files (surface tessellation language, STL) were prepared for 3D printing using Formlabs' Preform print preparation software (version 3.25.1). Both models were oriented so the posterior anatomical structures faced the build plate to allow for no supports to attach to the anterior anatomical structure since this was our area of interest. Density of supports was set to 1.0, touchpoint size was set to 0.40 mm, internal supports were left on, and layer thickness was set to 100 μm. The final cartilaginous model was printed in Flexible 80A and the final soft-tissue model was printed in Elastic 50A, both were printed on a FormLabs 3B printer (www.formlabs.com). Post-printing, the models were then processed in isopropyl alcohol, cured, and finished according to the instructions for use published by the material manufacturer. 3D-printed support structures were removed manually. One model made in our lab is estimated to cost $14.93, with a three-station workshop costing $44.79.

Our modifications to the simulator were reviewed by a laryngologist on various occasions, including during the design process to recommend areas for improvement and a formal assessment at the completion of the design. All modifications and printing of materials was performed by the Thomas Jefferson University Health Design Lab. A photograph of the 3D-printed larynx and endolaryngeal structures is provided in Figure 2. The simulator was draped in silicone "tattoo skin" to emulate real skin, and accuracy of injection location within both the 3D and cadaveric models was assessed by video laryngoscopes, provided by Ambu (Ballerup, Denmark) (Figure 3A,B).

FIGURE 2 Anterior and posterior views of the 3D-printed, open-source, larynx model and endolarynx structures.

3 | RESULTS

A total of 15 otolaryngology residents and six medical students participated in the simulation course. Survey responses were collected and analyzed. These were anonymous and only identified by training level.

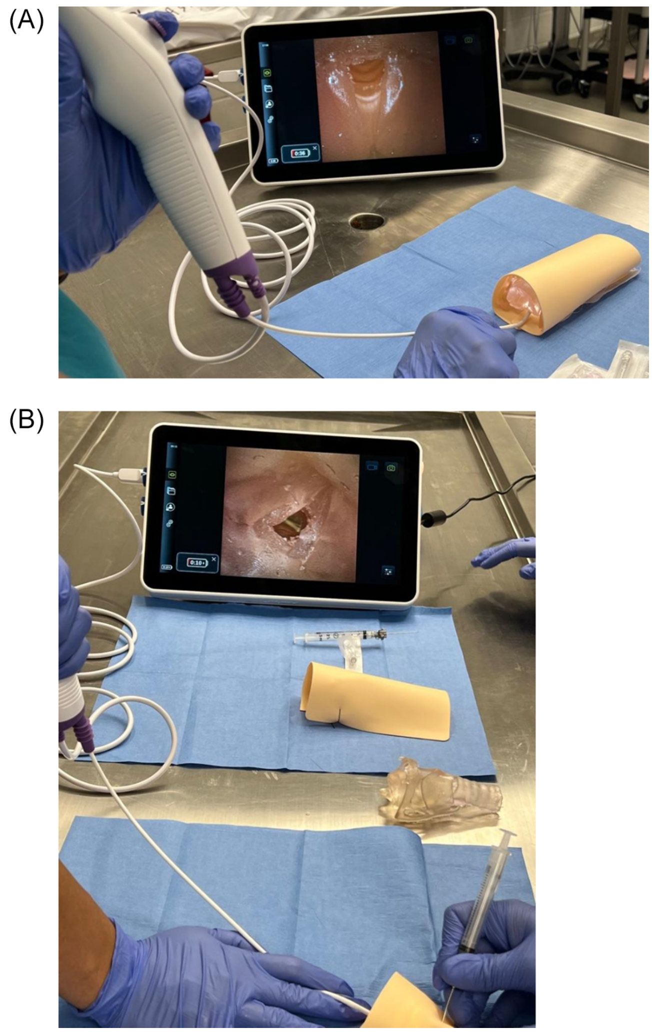

FIGURE 3 (A) View of endolaryngeal structures within the 3D model using a video laryngoscope. (B) Video laryngoscope view of a needle puncturing the inferior border of the thyroid cartilage into the left vocal fold of the 3D model.

Of the participants who completed the pre-survey, 66.7% reported participating in 0 transcutaneous vocal fold injections during their training, while 28.6% reported participating in 1–5 TVFIs and 4.8% participated in 5–10 TVFIs.

On a Likert scale of 1–10, participants rated their pre-seminar and post-seminar understanding of anatomy and confidence levels with performing transcutaneous vocal fold injections, which was significantly different in both categories ($W = 24.5$, $p < .001$) and ($W = 29$, $p < .001$), respectively (Table 1). When comparing pre-seminar to post-simulation surveys, level of understanding of landmarks in TIL and comfort with performing TIL significantly differed after the cadaver simulation ($W = 27.5$, $p = .014$) and ($W = 22$, $p = .005$), respectively, as well as after the 3D model simulation ($W = 20.5$, $p = .005$) and ($W = 11.5$, $p < .001$), respectively.

Participants also rated their understanding of anatomy and comfort level with transcutaneous vocal fold injections after each simulator: median pre-seminar understanding and comfort level were 3.7 and 2.2, respectively, compared to 6.9 and 5.9 ($p < .05$) following use of the 3D model and 6.4 and 4.7 ($p < .05$) following use of the cadaver model. When comparing 3D and cadaveric models, no significant differences were observed regarding the self-efficacy, fidelity, and educational value of each model (Table 2). Scores regarding the level of understanding of landmarks and key features of TIL, along with comfort level in performing TIL, did not significantly differ after completing each model ($p = .60$ and $p = .363$, respectively). When asked about improved confidence and independence in performing TIL, scores were not significantly different between models ($p = .72$ and $p = .79$, respectively). Scores regarding the realism of landmarks and resistance when passing a 25-gauge needle through each model also did not significantly differ between models ($p = .79$ and $p = .18$, respectively). When asked about each model's educational characteristics—development of skills, dexterity, accuracy, precision, needle insertion technique, and target site identification—the models did not significantly differ from one another (Table 2).

4 | DISCUSSION

Laryngeal injection is usually performed as an outpatient, awake procedure, making it more difficult to teach and for residents to receive regular practice. Although simulators do not replace clinical training, they have been shown to improve residents' patient outcomes and increase confidence.[7] This is the first published study, to the authors' knowledge, to directly compare a 3D-printed laryngeal model to a cadaver model for resident education in TIL. Participants had similar increases in understanding of laryngeal anatomy and comfort with TIL after performing either simulation in this study ($p < .05$). Additionally, there was no significant difference found when comparing the self-efficacy, fidelity, and educational value of the 3D model compared to the cadaver model (Table 2). Our findings are consistent with similar studies previously discussed regarding the use of simulators in resident education for other procedures. Simulation is a valuable tool in medical education to increase understanding, comfort, and self-efficacy for TIL. 3D-printed models can be as reliable, if not more useful, than costly cadaver models for this purpose.

This study measured the self-efficacy, fidelity, and educational value of each model in order to better establish validity. When measuring fidelity of each model, the following questions posed to participants: "the laryngeal model used has adequately realistic landmark structures" and "the resistance when passing a 25-gauge needle through the model is adequately similar to real human cartilage/tissue" resulted in similar median values for both the cadaver and 3D models (4 [0.82] and 4 [0.90]) and (3 [0.98] and 4 [1.03]), respectively. When comparing ratings between the 3D-printed model and cadaver model groups, the 3D model exhibited overall higher ratings regarding self-efficacy and fidelity, whereas the cadaver model exhibited higher ratings regarding educational value, though the differences were not significantly different (Table 2).

Two attending physicians in the Division of Laryngology evaluated both the 3D and cadaver models using each of our three survey tools. Both physicians had performed over 10 TVFIs; expressed complete understanding of the landmarks and key features of TIL; and rated their comfort level with the procedure as a 10/10. When asked

TABLE 1 Median survey scores regarding resident experience before and after using both models and feedback for each model. This also includes significance levels for differences in survey responses throughout the simulation.

	Median (StDev) Pre-survey ($n = 21$)	Median (StDev) Post-survey ($n = 15$)	Median (StDev) Cadaver ($n = 7$)	Median (StDev) 3D model ($n = 7$)	Mann–Whitney *U*/ Wilcoxon rank-sum test (*W* [*p* value]) Pre-survey versus Cadaver	Mann–Whitney *U*/ Wilcoxon rank-sum test (*W* [*p* value]) Pre-survey versus 3D model	Mann–Whitney *U*/ Wilcoxon rank-sum test (*W* [*p* value]) Pre-survey versus post-survey
Level of understanding of surface landmarks in TIL	4 (1.93)	7 (1.54)	7 (2.37)	8 (2.12)	27.5 ($p = .014$)	20.5 ($p = 0.005$)	24.5 ($p < .001$)
Comfort with performing TIL	2 (1.21)	6 (2.39)	5 (2.14)	6 (2.34)	22 ($p = .005$)	11.5 ($p < .001$)	29 ($p < .001$)

Abbreviation: TIL, transcutaneous injection laryngoplasty.

TABLE 2 Median survey scores regarding resident feedback for each model, and corresponding significance levels for differences between the two models.

	Median (StDev) Cadaver	Median (StDev) 3D-model	*W* value Mann–Whitney *U*/ Wilcoxon rank-sum test	*p* Value Mann–Whitney *U*/ Wilcoxon rank-sum test
Level of understanding of landmarks and key features of TIL	7 (2.37)	8 (2.12)	20	.60
Comfort level with performing TIL	5 (2.14)	6 (2.34)	17	.36
Self-efficacy				
The cadaver model helped improve my confidence at performing TIL	4 (0.53)	5 (1.57)	21.5	.72
The cadaver model helped improve my ability to perform TIL independently	3 (1.13)	5 (1.70)	22	.79
Fidelity				
The cadaver model used has adequately realistic landmark structures	4 (0.82)	4 (0.90)	22	.79
The resistance when passing a 25-gauge needle through the model is adequately similar to real human cartilage/tissue	3 (0.98)	4 (1.03)	22	.18
Educational value				
The 3D or cadaver model is a good training tool for developing skills in laryngeal injections	5 (0.53)	5 (1.67)	22	.93
The 3D or cadaver model helps develop dexterity, accuracy and precision with instruments	5 (0.79)	4 (1.63)	27.5	.32
The 3D or cadaver model is useful for teaching the needle insertion technique for injection laryngoplasty.	5 (0.79)	4.5 (1.60)	26.5	.41
The 3D or cadaver model is useful for teaching the target site for injection.	5 (0.53)	5 (1.60)	20.5	1
The 3D or cadaver model will increase resident competency when used prior to their 1st laryngeal injection	5 (0.53)	4.5 (1.55)	24	.69
Overall, this simulation experience as a training tool was	5 (0.53)	5 (0.41)	15.5	.37

Abbreviation: TIL, transcutaneous injection laryngoplasty.

about the self-efficacy of the 3D and cadaver models, both physicians responded neutrally or somewhat agreeing, as they have extensive prior experience with TVFIs. Regarding fidelity, both physicians strongly agreed that the 3D model has realistic structures. One physician somewhat agreed the resistance when passing a 25-gauge needle through the 3D model was similar to real human cartilage/tissue, while the other was neutral. This was a contrast to "somewhat agree" and "somewhat disagree," respectively, for the previous questions regarding the cadaver model. One attending strongly agreed that both models encompassed high educational value while the other somewhat agreed the 3D model had high educational value and strongly agreed the cadaver model had high educational value. Both attendings agreed both simulation tools were useful simulation experiences. Although face validity and educational value are often determined from experts evaluating the intervention, we found it unique to query a trainee perspective on these variables, while still having our attending physicians attest to these characteristics in their formal survey.

3D-printed models introduce many benefits to medical education. They have a great framework for basic anatomy and can be customized to fit various scenarios. 3D models can be stored and used multiple times. It also was noted by participants that the cadaver models often had desiccated material within the pharynx and larynx and significant atrophy of the vocal folds making visualization of successful injection difficult. 3D-printed models thus may be more easily accessible and efficient, with equal, if not greater, educational value, for the purpose of TIL training. Additionally, these models lack ethical concerns, unlike their animal and human counterparts.[7] Although there are many benefits to 3D-printed simulators, the realism of the material is usually an area of issue; such models lack surrounding soft tissue and skin.

For simulations involving multi-step procedures, the human cadaver model may be the only viable option when compared to a 3D model for this type of experience. In addition, anatomical dimensions may range on human cadaver models, which is more realistic in terms of what participants will face in their training or clinical practice. Vessels and nerves are also present on cadaver models and are not usually an option with 3D simulators. However, human cadavers are known to encompass many disadvantages, including unpleasant odors, stiff muscles, cost, and storage.[12] Porcine larynges have classically been used as human-cadaver alternatives, but also include similar disadvantages, such as storage and mess. Even well-preserved biologic larynges have natural degradation and drying of tissues, such that

Reinke's space and the epithelial layers are not accurate representations of the in vivo situation. Most important, biological larynges rarely have pathology to excise, so many surgical situations cannot be simulated. Ultimately, the anatomical accuracy of the human or animal larynx did not justify these drawbacks or the expense.

5 | LIMITATIONS

This was a single-institution study with a small sample of participants, of which only a subset participated in each simulation group. Our study included six medical students who participated in the simulation and answered any of the three surveys. We understand medical students and residents have varying procedural experiences; however, our sample size does not warrant a separate analysis for the two groups. Future studies could examine residents alone or in two different groups, including medical students in the latter. Additionally, a large query of laryngologists could have been recruited to provide formal evaluations of each model to be reported. Holliday et al. designed synthetic laryngeal trainers to establish face and content validity in surgical education. Unlike our study, they only queried expert evaluation and feedback, with subjects consisting of attending laryngologists.[13] Future studies could explore multi-institutional options, involving residents, laryngology fellows, and attendings. In terms of resident understanding, predictive validity was low as results cannot confirm use of the simulator led to resident mastery. This was not a true randomized-controlled trial to test each simulation. Future studies may benefit from more objective measures to test the true efficacy of each model. Finally, the statistical analysis included multiple pairwise comparisons between groups. Although this may typically require corrections for multiple comparisons, the authors determined that the risk of false positives was low in this situation and these corrections were not necessary.

6 | CONCLUSION

Our study is the first of its kind to compare an open-source 3D-printed laryngeal model to human cadavers as training simulators for TIL. To be successful training tools, 3D models should be reasonably priced, have high anatomical quality and tactile accuracy, and be reproducible. This study pushes previous studies beyond the exploration of 3D printing as a tool, revealing its comparability and superiority in many ways to cadaver models. While each simulator has its advantages, it is important to continue exploring this topic with the investigation of both options in medical education, particularly as we aim to increase the availability and access of simulation for surgical training. Following this study, our institution will now include these models in our yearly laryngeal medialization course.

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Ambu (Ballerup, Denmark) provided video laryngoscopes. Stryker (Kalamazoo, MI, USA) provided the Sonopet iQ® Ultrasounic Aspirator system. Thomas Jefferson University Department of Pathology, Anatomy, and Cell Biology (Philadelphia, PA, USA) provided the cadavers for use of simulation. Thomas Jefferson University Health Design Lab provided the 3D-printed models.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ORCID

Megha Chandna https://orcid.org/0009-0002-4677-7010
Dylan Bertoni https://orcid.org/0000-0002-8306-8937

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