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Ryan Alyson-Yao Tiu

Tanya K. Meyer

Ross M. Mayerhoff
Henry Ford Health, rmayerh1@hfhs.org

Joel C. Ray

Patricia A. Kritek

See next page for additional authors

Authors
Ryan Alyson-Yao Tiu, Tanya K. Meyer, Ross M. Mayerhoff, Joel C. Ray, Patricia A. Kritek, Albert L. Merati, and Maya G. Sardesai

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ORIGINAL RESEARCH

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Tracheotomy care simulation training program for inpatient providers

Ryan Alyson-Yao Tiu BA[1] | Tanya Kim Meyer MD[1] | Ross M. Mayerhoff MD[2] | Joel C. Ray RRT[3] | Patricia A. Kritek MD, EdM[4] | Albert Lincoln Merati MD[1] | Maya Guirish Sardesai MD, MEd[1]

[1]Department of Otolaryngology – Head and Neck Surgery, University of Washington, Seattle, Washington, USA

[2]Department of Otolaryngology – Head and Neck Surgery, Henry Ford Health System, Detroit, Michigan, USA

[3]Manager of Ancillary Services, UW-Valley Medical Center, Renton, Washington, USA

[4]Division of Pulmonary, Critical Care and Sleep Medicine, University of Washington, Seattle, Washington, USA

Correspondence
Ryan Alyson-Yao Tiu, BA, Department of Otolaryngology – Head and Neck Surgery, University of Washington, 1959 NE Pacific Street, Seattle, WA 98195, USA.
Email: ryantiu312@gmail.com

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Abstract

Objectives: Tracheotomy complications can be life-threatening. Many of these complications may be avoided with proper education of health care providers. Unfortunately, access to high-quality tracheotomy care curricula is limited. We developed a program to address this gap in tracheotomy care education for inpatient providers. This study aimed to assess the efficacy of this training program in improving trainee knowledge and comfort with tracheotomy care.

Methods: The curriculum includes asynchronous online modules coupled with a self-directed hands-on simulation activity using a low-cost tracheotomy care task trainer. The program was offered to inpatient providers including medical students, residents, medical assistants, nurses, and respiratory therapists. Efficacy of the training was assessed using pre-training and post-training surveys of learner comfort, knowledge, and qualitative feedback.

Results: Data was collected on 41 participants. After completing the program, participants exhibited significantly improved comfort in performing tracheotomy care activities and 15% improvement in knowledge scores, with large effect sizes respectively and greater gains among those with little prior tracheotomy care experience.

Conclusion: This study has demonstrated that completion of this integrated online and hands-on tracheotomy simulation curriculum training increases comfort and knowledge, especially for less-experienced learners. This training addresses an important gap in tracheotomy care education among health care professionals with low levels of tracheotomy care experience and ultimately aims to improve patient safety and quality of care. This curriculum is easily transferrable as it requires only access to the online modules and low-cost simulation materials and could be used in other hospitals, long-term care facilities, outpatient clinics, and home settings.

Level of evidence: 4.

KEYWORDS
mannequin-based simulation, medical education, otolaryngology, tracheotomy, training program

1 | INTRODUCTION

Tracheotomy complications are well described and can be life-threatening, with an estimated 1000 catastrophic tracheotomy-related events and 500 tracheotomy-related deaths in the U.S. annually.[1–3] Many of these serious complications occur beyond the immediate post-operative period and may be avoidable.[1] At the national level, 66% of tracheotomy-associated injuries involve loss of airway or bleeding, with 34% involving accidental or planned removal of a tracheotomy tube with inability to reinsert the appliance to establish an airway.[1] An additional 14% of tracheotomy-associated injuries involve occlusion or plugging of a tracheotomy tube with mucus and secretions, which are believed to be preventable with improved tracheotomy care.[1] It is essential that providers caring for patients with tracheotomies have a sound understanding of routine and emergency tracheotomy management to minimize preventable adverse events. As such, there are many areas that may be targeted for improvement, including core tracheotomy care education for various health care providers, such as physicians, nurses, advanced practice providers, respiratory therapists, and their respective trainees.

Approaches to care and education for tracheotomy patients and their caregivers vary at our institution and many others.[4,5] Much of the current practical education is institution- and provider-dependent and generally more experience-based than evidence-based. To address this variation, a multidisciplinary, multi-institutional, and nationwide panel of experts was developed to generate a clinical tracheotomy care consensus statement.[5] The panel strongly agreed caregiver education would improve patient outcomes and decrease tracheotomy-related complications, and that caregivers should be educated around appropriate actions to take in emergency situations.

Tracheotomy care curricula that incorporate both written materials and scheduled lectures have demonstrated improved knowledge, confidence, and comfort among trainees.[6–8] However, lecture-style learning and review of written material in isolation can carry the limitation of reduced learner engagement and retention.[9–11] Better results have been demonstrated with instructor-guided simulation, including programs on tracheotomy care education.[12–18] However, because instructor-led simulation is time intensive and incorporating high-fidelity mannequins can be costly, generalized use of these modalities is limited. This, coupled with the relative infrequency of airway complications, may contribute to the fact that knowledge, competence, and confidence with urgent and emergent airway and tracheotomy scenarios among non-otolaryngology providers remains poor.[19]

Optimal curricula would enable flexible training schedules with delivery of information paced to a trainee's personal learning preference and ability. Compared to structured and scheduled in-person training, online modules enable more accessible, convenient, and low-cost learning at a trainee's preferred pace, with opportunities for review.[20,21] Online modules also permit easy low-cost renewal, refreshing of knowledge, and just-in-time reference for situations where tracheotomy-related issues are not emergent, but time sensitive (e.g., gradual fouling of cannula or build-up of crusting around tracheotomy appliance leading to complete occlusion with mucus plug). Coupling this method of content delivery with hands-on simulator training can augment skills learning and retention.[12,22–24]

This type of integrated safety educational program for tracheotomy care with self-paced online modules and self-directed provider-centered hands-on simulation has not previously been described. Based on national consensus guidelines and institutional needs assessments, we developed a multimodality training program with these features. This study aimed to determine the utility of the training program, specifically whether participants possessed greater comfort with tracheotomy care activities and whether they demonstrated improved tracheotomy care knowledge after completing the training.

2 | MATERIALS AND METHODS

This study was reviewed by the University of Washington Human Subjects Division institutional review board and deemed to be exempt. The tracheotomy care educational program covered routine and emergent tracheotomy care and included asynchronous online modules and self-directed hands-on mannequin simulation activities. Content included, but was not limited to, anticipated changes in patient function, side effects, and complications after a tracheotomy; the parts and functions of a tracheotomy appliance; managing mucus plugs and bleeding within a tracheotomy; changing tracheotomy ties; cleaning the tracheotomy site and inner canula; accidental decannulation; managing the tracheotomy when showering; water and environmental safety precautions; the tracheotomy change procedure; finger capping; and button capping. The University of Washington Department of Otolaryngology offered this program to inpatient providers and trainees including medical students, residents, medical assistants, nurses, and respiratory therapists. Learners participated voluntarily and were recruited using flyers and e-mail invitation from inpatient units, surgical areas, and outpatient clinics. Participants gave informed consent before taking part in the study. The program's virtual component (testing and viewing the online modules) was performed at the location of the learner's choosing, and the hands-on simulation component was performed in the hospital setting. Necessary equipment included an electronic communication device, tracheotomy simulator, and trach tube with ties and suction catheter (Figure 1). The tracheotomy simulator can be a higher fidelity mannequin (Figure 1A) or a low-cost Styrofoam "Wig head" with an incision to mimic a tracheotomy site (Figure 1B). The training required no prerequisite knowledge about tracheotomy but did require an understanding of the English language. Learners were evaluated using pre-training and post-training surveys that included a multiple-choice knowledge test and self-perceived comfort level ratings, which are evaluation methods consistent with other tracheotomy education programs in the literature.[6,12–14,18]

Immediately before watching the online module, trainees completed a pre-training survey (Appendix S1), in which participants rated their comfort with 9 tracheotomy care activities and were tested on

Laryngoscope Investigative Otolaryngology

FIGURE 1 (A) High-fidelity tracheotomy task trainer (AED Superstore—LF01083U, $605). (B) Low-cost Styrofoam task trainer fashioned from an online-ordered "Wig head." ($8–$15). Both trainers provide comparable simulation experience for tracheotomy care activities: changing trach ties, cleaning a trach site, suctioning through the trach tube, changing an inner cannula, changing the entire trach appliance, placing and removing a heat-moisture exchanger, and inflating a cuffed tracheotomy tube. (C) Supplies for completing the hands-on simulation: trach tie, cuffed and cuffless tracheotomy outer cannula, inner cannula, introducer, and suction catheter

facts relevant to tracheotomy care through 10 questions written by the authors.

After taking the pre-training survey, participants viewed 11 videos in the online module[25] at their own pace and convenience. The videos were easily accessible via YouTube and available for repeated viewing at variable speed. The module's total viewing time was 61 min and 9 s, though some participants anecdotally reported viewing the videos on accelerated speed.

Participants then individually scheduled a time for the mannequin simulation, in which they performed self-guided simulated tracheotomy care activities on a task-trainer at their own pace and were instructed to complete a checklist of tasks including changing trach ties, cleaning a trach site, suctioning through the trach tube, changing an inner cannula, changing the entire trach appliance, placing and removing a heat-moisture exchanger, and inflating a cuffed trach tube. There was no time limit for the self-guided practice.

Following this time for deliberate practice, participants completed a post-training survey (Appendix S2) with the same comfort and knowledge questions included in the pre-training survey. Participants also provided their demographic information, previous experience with patients with tracheotomies, and qualitative comments and feedback. Surveys were anonymous and untimed. Comfort level and knowledge around tracheotomy care were compared between paired pre-training and post-training surveys.

3 | STATISTICAL ANALYSIS

Data from participants who completed both the pre-training and post-training surveys was analyzed. Demographic characteristics were summarized using frequencies and percentages (Table 1). Trainees designated comfort on a 1–4 scale, with 1 correlating with "not comfortable," 2 with "somewhat comfortable," 3 with "usually comfortable," and 4 with "very comfortable." Trainees also had the option to choose "not applicable," which, if chosen, was not included in data analysis. Knowledge tests were scored out of 10 total points. Two-tailed, paired t tests were conducted to compare pre-training and post-training knowledge and comfort level, respectively (Table 2). The association between experience and changes in knowledge and comfort level was determined using one-way analysis of variance

TABLE 1 Demographic characteristics of participants that completed pre-training and post-training questionnaires ($n = 41$)

Demographic value	Frequency	Percentage
Total	41	100
Gender		
Male	16	39
Female	25	61
Age group		
18–35	30	73.2
36–65	9	21.9
Over 65	2	4.9
Occupation		
Medical assistant	6	14.6
Nurse	9	22
Respiratory therapist	7	17.1
Medical student	8	19.5
Resident/fellow	11	26.8
Tracheotomy care experience		
None: no experience	11	26.8
Novice: <1 year	15	36.6
Intermediate: 1–5 years	9	22
Experienced: >5 years	6	14.6

(ANOVA). Post hoc Tukey–Kramer tests were used to make multiple comparisons between experience level groups' mean knowledge and comfort levels, respectively. Effect size for knowledge and comfort level changes was calculated with Hedge's g with Hedge's correction, and effect size for one-way ANOVA was calculated with partial eta-squared. Because comfort data for "integrated" activities requiring integration of module knowledge and skills learned from the simulation was not normally distributed, Kruskal–Wallis tests (nonparametric equivalent of one-way ANOVA) with Dunn post hoc tests assessed the association between experience level and comfort performing simulated and integrated tracheotomy care activities, with pairwise comparison significance values adjusted by the Bonferroni correction for multiple tests (Appendix S3). Effect size for Kruskal–Wallis tests was calculated with epsilon-squared. p-Values < .05 were considered statistically significant. Statistical analysis was conducted using IBM SPSS Statistics Version 28.

4 | RESULTS

In all, 44 learners enrolled in the study. A complete data set was obtained for 41 learners, which was analyzed in this study. Table 1 shows the participants' demographic information, including gender, age, and occupation. Participants' tracheotomy care experience ranged from none (no experience), <1 year (novice), 1–5 years (intermediate), to >5 years (experienced).

Impact of the training was assessed by comparing answers between the pre-training and post-training surveys in three domains: self-reported comfort in performing 9 tracheotomy care activities, performance on a 10-question knowledge test, and post-training solicited written comments. Paired t tests showed that overall mean comfort improved significantly from 18.1 before the training to 28.2 after the training ($p < .001$) (Table 2). Participants were stratified by level of previous tracheotomy care experience into four cohorts: no experience, novice, intermediate, and experienced. Effect size was large for all participants (Hedge's $g = 1.33$) and larger for less-experienced participants (Table 2). Less-experienced learners reported lower comfort before the training and demonstrated the largest gains in comfort afterward (Figure 2A).

One-way ANOVA was then performed to compare mean changes in comfort between cohorts. A statistically significant difference between groups was found ($F[3,37] = 3.341$, $p = .029$, partial eta-squared = 0.21 [95% CI 0.2–0.61]) with a large effect size such that 21% of the variance in comfort level change was attributable to experience level. Post hoc Tukey–Kramer tests indicated a significant difference between participants with no experience and experienced participants ($p = .031$ [mean difference 95% CI 0.7–19.4]).

Each tracheotomy care activity question assessing comfort level was analyzed according to learner experience (Appendix S3, Figure 2). Care activities were labeled as "simulated" for activities simulated on the mannequin (Figure 2A), or "integrated" for higher complexity care activities requiring the incorporation of knowledge from the modules and skills learned from the hands-on simulation (Figure 2B). For simulated activities, less-experienced learners endorsed the least comfort before the training and demonstrated the greatest gain in comfort after the training. For more experienced groups, comfort levels increased after the training, but to a lesser degree. The intermediately experienced cohort reported the highest pre-training and post-training comfort levels for integrated activities. For simulated activities, Kruskal–Wallis and Dunn post hoc tests found statistically significant mean rank differences in pre-training and changes in comfort level most frequently between learners with no experience and experienced learners, with no statistically significant differences between groups for post-training comfort levels (Appendix S3, Figure 2A). For integrated activities, there were statistically significant mean rank differences in pre-training and post-training comfort levels between learners with no experience and intermediate learners, with no significant difference between groups for changes in comfort level (Appendix S3, Figure 2B).

Factual knowledge was assessed by 10 multiple choice and true/false questions (Table 2). The same test was given at each time point. Across all trainees, mean knowledge test scores improved significantly from 74.9% to 89.5% ($p < .001$). Parsing performance by experience level, less-experienced participants showed greater test score improvement than groups with more experience. Effect size was large for all participants (Hedge's $g = 0.77$) and larger for participants with less experience (Table 2).

Using one-way ANOVA and post hoc Tukey–Kramer tests, significant differences in knowledge changes were found between learners with no experience and each of the other groups ($F[3,37] = 5.722$, $p = .003$, partial eta-squared = 0.32 [95% CI 0.05–0.48]) (compared

Laryngoscope Investigative Otolaryngology

TABLE 2 Comfort level and knowledge test outcome measures and paired *t* test results for all participants and by experience level

	Comfort level					Knowledge test (% correct)				
Group	Pre-training mean (SD)	Post-training mean (SD)	Change[a] mean (SD) [95% CI]	*p*-Value[b]	Hedge's *g* effect size[c] [95% CI]	Pre-training mean (SD)	Post-training mean (SD)	Change[a] mean (SD) [95% CI]	*p*-Value[b]	Hedge's *g* effect size[c] [95% CI]
All participants	18.1 (8.9)	28.2 (6.1)	10.1 (7.4) [7.7, 12.4]	<.001	1.33 [0.91, 1.74]	74.9 (18.5)	89.5 (9.7)	14.6 (18.7) [8.7, 20.5]	<.001	0.77 [0.42, 1.11]
Experience level subgroup										
No experience	10.5 (3.4)	24.3 (7.7)	13.7 (6.3) [9.5, 18]	<.001	2 [0.96, 3]	57.3 (14.9)	87.3 (9)	30 (21) [15.9, 44.1]	<.001	1.32 [0.52, 2.09]
Novice	16.3 (6.4)	27.7 (4.7)	11.4 (6.9) [7.6, 15.2]	<.001	1.57 [0.81, 2.3]	77.3 (13.3)	90 (10.7)	12.7 (14.4) [4.7, 20.6]	.004	0.83 [0.26, 1.39]
Intermediate	24.8 (9.6)	32.4 (4.2)	7.7 (8.1) [1.4, 13.9]	.022	0.85 [0.12, 1.55]	80 (18.7)	90 (11.2)	10 (15.8) [−2.2, 22.2]	.094	0.57 [−0.09, 1.21]
Experienced	26.7 (6.3)	30.3 (4.2)	3.7 (5.5) [−2.1, 9.4]	.161	0.56 [−0.21, 1.3]	93.3 (8.2)	91.7 (7.5)	−1.7 (7.5) [−9.6, 6.2]	.611	−0.19 [−0.86, 0.51]

[a]Change = post-training minus pre-training. Positive denotes improvement after treatment for all measures.
[b]Paired *t* tests were used to compare pre-training and post-training comfort level and knowledge, respectively.
[c]Hedge's *g* with Hedge's correction was calculated to measure effect size for knowledge and comfort level changes, respectively, with 0.2 or smaller indicating a small effect size, 0.5 indicating a medium effect size, and 0.8 or larger indicating a large effect size. A positive effect size indicated an improved outcome; a negative effect size indicated a worse outcome.

with: the novice group, $p = .047$ [mean difference 95% CI 0.16–34.51]; the intermediate group, $p = .042$ [mean difference 95% CI 0.55–39.45]; and the experienced group, $p = .002$ [mean difference 95% CI 9.7–53.63]). Effect size was large: 32% of the variance in knowledge changes was attributable to experience level.

5 | DISCUSSION

We developed a multimodal education program consisting of online modules and self-directed simulation with the goal of improving comfort and knowledge in tracheotomy care. Learners demonstrated statistically significant higher comfort scores after completing the study curriculum. The increase in comfort was most notable for simulated care activities among subjects with the least experience. For simulated activities, groups with different experience endorsed significantly different pre-training comfort, yet all learners achieved similarly high post-training comfort levels (Appendix S3). These results highlight the efficacy of this training for routine tracheotomy care education but also indicate a ceiling effect that occurs as providers gain experience with routine tracheotomy care. A different pattern was noted for integrated activities such as managing bleeding and assistance with showering. Comfort level for intermediately experienced participants was unexpectedly higher than that for experienced participants (Figure 2B), with statistically significant differences in pre-training and post-training comfort between inexperienced and intermediately experienced cohorts, but not between inexperienced and experienced cohorts (Appendix S3). In contrast, for simulated activities, the difference in comfort was most pronounced between learners with no experience and those with the most experience. This may reflect that experienced participants were more likely to have had exposure to live clinical situations that humbled them or tempered their confidence, a phenomenon that has been seen in other surgical simulations.[26] Additionally, the ceiling effect was not seen in post-training comfort ratings, reflecting that the training provides insight into the gravity of these critical scenarios. This speaks to the benefit of ancillary education, including complex task instruction, virtual reality medical simulation, or high-fidelity simulation scenarios, to enhance comfort and skill with complex tracheotomy care.

Participants also demonstrated higher knowledge scores after training, especially learners with less experience; but, as expected, differences were of smaller magnitude in participants with more prior experience, again likely reflecting a ceiling effect.

Subjective feedback around the value of the program was collected through post-training comments. Feedback was uniformly positive, reflecting appreciation for, and educational benefit from the curriculum and emphasizing the curriculum's value for novices in providing basic tracheotomy care knowledge, though it is worth noting that participants may not have included concerns about the program in their comments. Representative comments include:

- "I thought the modules were very thorough and explained well for everyone."

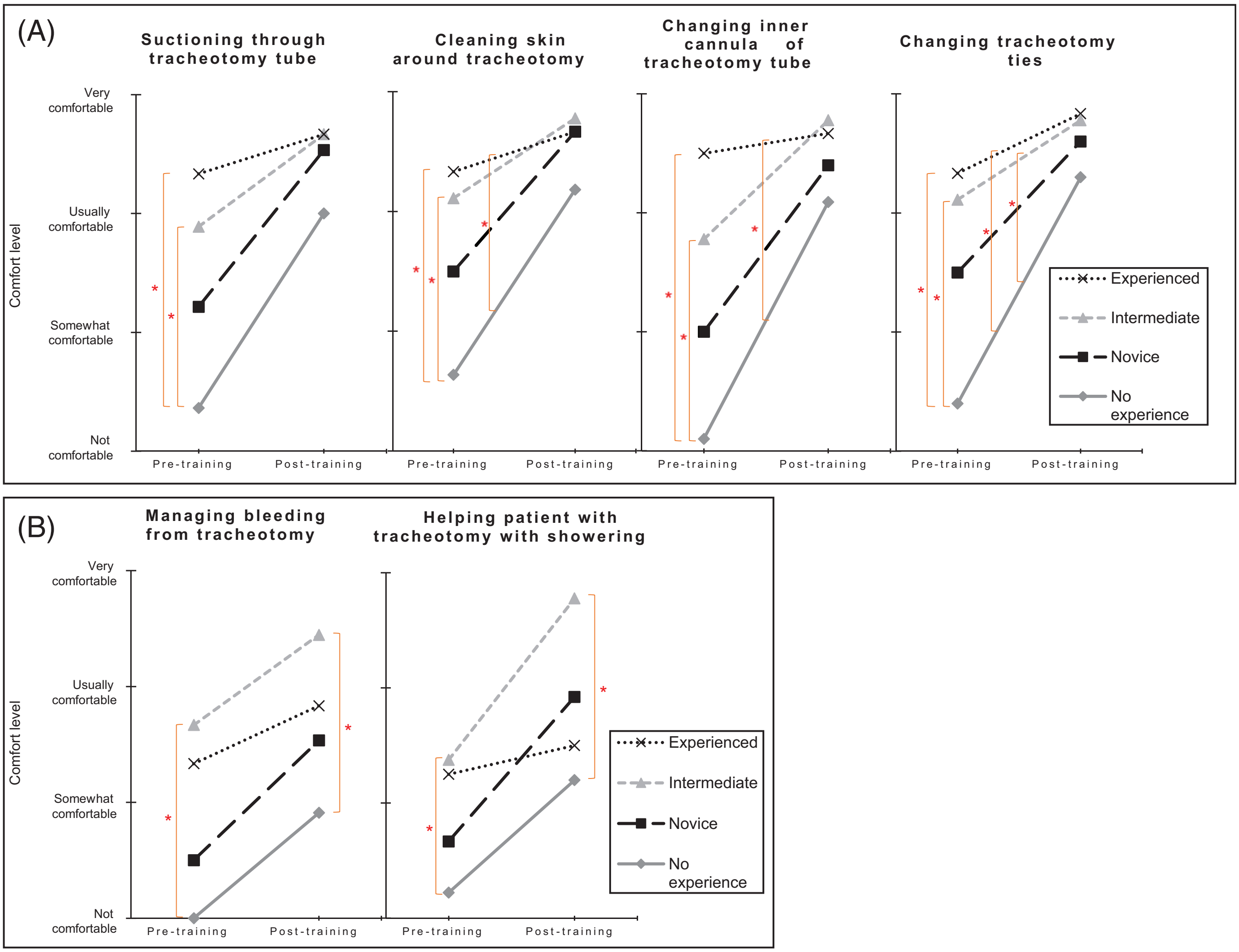

FIGURE 2 Differences in pre-training and post-training comfort level based on trainees' tracheotomy care experience for simulated care activities (A) and integrated care activities (B). Kruskal–Wallis tests and Dunn post hoc tests were performed to evaluate the effect of experience level on pre-training, post-training, and changes in comfort level. Four simulated and two integrated tasks are shown to highlight the most common important tasks and the most complex tasks and illustrate key findings. Left brackets (*[) on the left side of graphs indicate statistically significant ($p < .05$) mean rank differences between groups in pre-training comfort level, while left brackets midway between pre-training and post-training indicate statistically significant mean rank differences between groups in changes in comfort level. Right brackets (]*) on the right side of graphs indicate statistically significant mean rank differences between groups in post-training comfort level. See Appendix S3 for Kruskal–Wallis and Dunn post hoc test results and Epsilon-squared effect sizes for all surveyed tasks

- "Very helpful and detailed modules that are easy to understand for the basic knowledge of trachs."
- "Very educational! I learned a few things. Well done, and I think that anyone who has not had a lot to do with trachs will benefit."

Taken as a whole, the improved comfort levels, improved knowledge, and positive comments support the value of this integrated learning curriculum.

The goal of the training described in this study was to provide medical trainees with flexible, easily accessible education with just-in-time reference to enhance knowledge and comfort around performing tracheotomy care. This training can easily be implemented in a variety of settings by having access to the internet and low-cost mannequin simulation materials. For example, the program can be implemented by making the task trainer available in a hospital's respiratory care department, nursing station, or outpatient clinic, and trainees can watch the modules at home before engaging independently with the task trainer, thus enabling them to learn and practice at their own pace. This hybrid, self-directed trainee-driven model has been successful for cardiopulmonary resuscitation training.[27]

There was little cost to the program as participants did not require time away from clinical work or incur the travel and accommodation costs associated with attending in-person classes in a remote location. In addition, the model is affordable for health systems and requires minimal storage and maintenance. Considering the recent COVID-19 pandemic's travel restrictions and financial impacts, the flexibility of this training is particularly valuable.

This study has several limitations. The small sample size impacts the reliability of the findings. The voluntary nature of the survey and challenges ensuring follow-up while enabling self-paced completion of modules and anonymity in survey responses likely affected completion rate. The evaluation was also limited by methods of assessment of comfort level and knowledge. Learners self-reported their comfort levels, which should not be considered a substitute for assessing learner skills. Long-term retention was not assessed after the training. The ceiling effect seen in knowledge may reflect the relative ease of the knowledge test questions that were written by the study investigators, not professional test question writers, and the fact that they had not undergone robust psychometric testing. The content was designed primarily to facilitate a baseline level of understanding across a wide range of health care professionals, not further enhance knowledge among subject matter experts. This, along with the small sample size for experienced learners, may contribute to why the more experienced groups did not exhibit increased knowledge scores. For this type of training, a method that focuses on application of knowledge (case-based) and technical skills (objective clinical skills evaluation) may better assess learner skills and understanding. A future direction may include creation or use of a superior assessment tool to measure learner ability and application of knowledge.

This study demonstrates that learners benefit from structured tracheotomy care curricula, and less-experienced learners derive the most gains in knowledge and comfort. Further study could enhance materials for this less-experienced cohort and examine longer-term retention. Controlling for factors such as variability of interim clinical experience, and identifying optimal timing for spaced review of materials could further enhance the program. For more-experienced learners, developing complex high-fidelity simulations would further enhance their knowledge and abilities for complex or urgent scenarios. Finally, a standardized process for updating content and ensuring accessibility for all learners, including those with disabilities, will be of critical importance.

6 | CONCLUSION

In summary, we successfully developed an easily implementable tracheotomy care education program of self-paced, widely accessible online modules coupled with deliberate practice on low-cost task trainers for simulated tracheotomy care tasks. This study has demonstrated that completion of this program increases comfort and knowledge, especially for less-experienced learners. Given the lack of accessible, low-cost tracheotomy care training available to providers and the high acuity of tracheotomy-related complications, this curriculum serves as a useful resource to bridge an important gap in tracheotomy care education across a wide range of health care professionals and ultimately improve patient safety and quality of care.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ORCID

Ryan Alyson-Yao Tiu https://orcid.org/0000-0003-1189-2836
Tanya Kim Meyer https://orcid.org/0000-0002-1112-2674
Ross M. Mayerhoff https://orcid.org/0000-0002-3262-4737
Maya Guirish Sardesai https://orcid.org/0000-0001-9670-4931

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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