AMERICAN ACADEMY OF OTOLARYNGOLOGY–HEAD AND NECK SURGERY FOUNDATION

OTO Open
2023, Vol. 7(4):e93
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DOI: 10.1002/oto2.93
http://oto-open.org
WILEY

Teaching Tracheostomy Tube Changes: Comparison of Operant Learning Versus Traditional Demonstration

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Abstract

Objective. Tracheostomy tube change is a multistep skill that must be performed rapidly and precisely. Despite the critical importance of this skill, there is wide variation in teaching protocols.

Methods. An innovative operant conditioning teaching methodology was employed and compared to traditional educational techniques. Medical student volunteers at a tertiary care academic institution (Albert Einstein College of Medicine) were recruited and randomly distributed into 2 groups: operant vs traditional (control). Following the educational session, each group was provided with practice time and then asked to perform 10 tracheostomy tube changes. Performance was recorded and scored by blinded raters using deidentified video recordings.

Results. The operant learning group (OLG) demonstrated greater accuracy in performing a tracheostomy tube change than the traditional demonstration group. Twelve of 13 operant learners performed the skill accurately each time compared to 3 of 13 in the traditional group ($P = 0.002$). The median lesson time was longer for the OLG (535 seconds) than for the traditional group, (200 seconds $P < 0.001$). The average time per tracheostomy change was not significantly different between the 2 groups (operant learners mean 7.1 seconds, traditional learners mean 7.5 seconds, $P = 0.427$).

Discussion. Although the operant conditioning methodology necessarily requires a greater time to teach, the results support this methodology over traditional learning modalities as it enhances accuracy in the acquired skill. Operant learning methodology is under consideration for other skills and education sessions in our program. Future steps include the application and adaptation of this education model to students and residents in other settings and fields.

Implications for Practice. Operant learning is effective for teaching multistep skills such as tracheostomy tube changes with decreased error rates.

Keywords

medical education, PSQI, tracheostomy, tracheotomy

Received February 18, 2023; accepted October 20, 2023.

Tracheostomy tube change (the removal and insertion of one tube for another) is a multistep skill that must be performed rapidly and precisely during both routine and emergency exchanges.[1-3] Performing a tracheostomy tube change is an essential skill not only for physicians, nurses, and respiratory therapists but also for family members and caretakers of patients with tracheostomies. Improper tracheostomy care, including failure to recognize and change an occluded or dislodged tracheostomy tube, has been reported to have complication incidences of 40% to 50% and mortality rates as high as 5.9%.[3-5] Despite the critical importance of this skill, there is wide variation in performance and teaching protocols.[6-9] A tracheostomy care education program accessible to the caregivers of patients with

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This article was accepted as an oral presentation at the Triological Society Annual Meeting at COSM; originally scheduled for April 24-26, 2020 (canceled due to the COVID pandemic).

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tracheostomies (with varying levels of medical knowledge, clinical experience, and language fluency) is critical for the safety of these vulnerable patients.

Current teaching methods employ demonstration, emulation, and self-teaching of skills (the traditional "see one, do one, teach one"). However, skills learned in this manner can deteriorate over time and may devolve into reinforced incorrect behaviors which can slow the learning progress and hinder the learner-teacher relationship.[10-12]

Operant learning is an alternative teaching method that has shown promise for procedural skill acquisition in multiple athletic settings including golf, tennis, dance, and football.[13-15] It has also been shown to be effective for teaching surgical skills such as knot tying and drilling in orthopedic surgery.[11,16] This educational model involves the reinforcement of correctly performed skill components by marking correctly executed behaviors with a sound from a handheld acoustic marker (clicker). An example of an operant learning approach is used by TAGteach® (TAGteach International; Indian Trail), which deconstructs multistep procedural skills into simple behaviors that are each reinforced and then strung back together into the desired skill.[17] Deliberate practice and repetition of the multistep procedural skill then allows the learner to perform the skill in any environment with the confidence of achieving success.[18-20]

The goal of this study was to determine if there was a difference in the accuracy and speed of performance, and time to acquire the skill between novice learners taught using operant learning methods and those taught by traditional demonstration methods. We hypothesized that learners taught tracheostomy tube change using an operant learning methodology would perform the skill more accurately and with greater speed than the traditional learning group (taught by demonstration alone).

Methods

Approval was obtained from the institutional review board at Einstein-Montefiore and consent was obtained from all subjects before beginning the study.

First- and second-year medical student volunteers from the Albert Einstein College of Medicine were recruited in August 2019. Medical students with no prior experience with tracheostomy tube change were selected for this study to demonstrate the value of operant teaching methods in true novices without prior exposure. Prior to the study, a power analysis with a perceived difference of 70% was used to determine enrollment. Volunteers' experience with operant conditioning and tracheostomy tube change were self-reported. Volunteers with previous experience with tracheostomy tubes were excluded. The volunteers were randomly distributed into a test "Operant Learning Group (OLG)" and control "Traditional Demonstration Group (TDG)." Participants in both groups were not informed of the teaching style they would receive during the lesson time. They were not reimbursed for their participation.

Both groups were taught the "tracheostomy tube change skill" using the same 6 component steps of tracheostomy tube changes (**Figure 1A-F**): (1) insertion of the obturator into the new tracheostomy tube, (2) grasping of the new tracheostomy tube with the dominant hand, (3) instructing the assistant to remove the existing tracheostomy tube, (4) insertion of the new tracheostomy tube into the airway, (5) stabilization of the new tracheostomy tube, and (6) removal of the obturator with the nondominant hand. These steps were chosen based on TAG teaching methodology: the individual component behavior you want (1-6), that is only 1 behavior, is observable, and can be described in 5 words

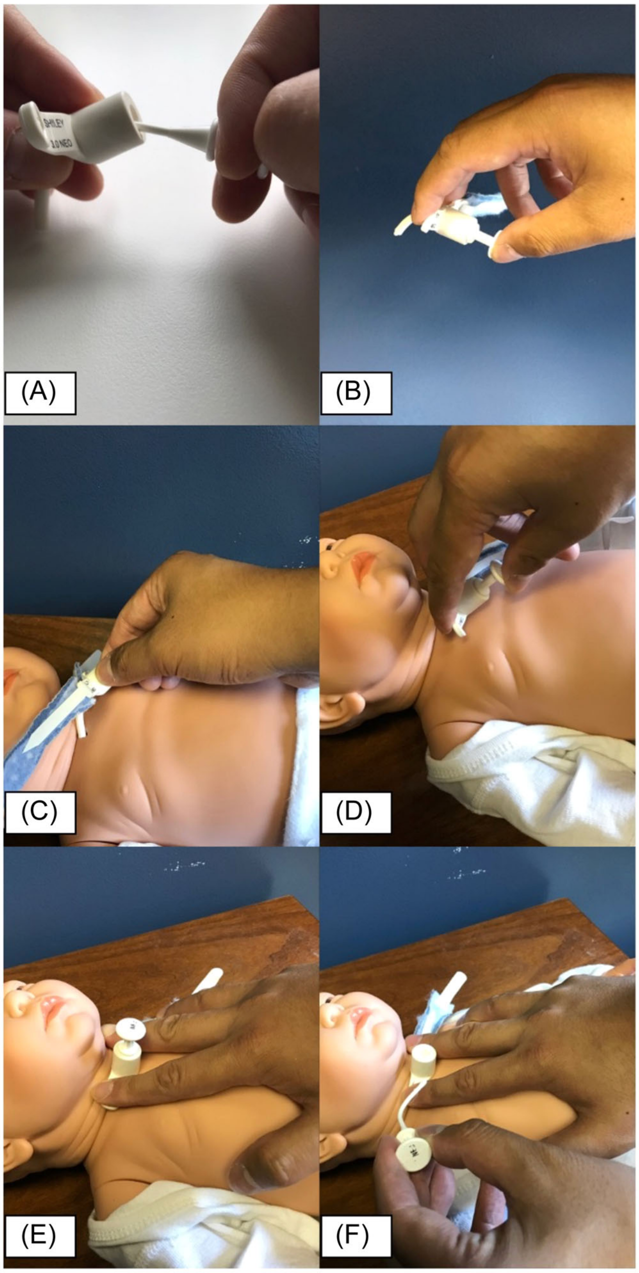

Figure 1. (A-F) Photos utilized for tracheostomy tube change skill expanded diagram (for traditional demonstration group).

or less. The 6 component behaviors selected, when strung together form the complex behavior that results in tracheostomy change (a complex behavior that is performed when the airway is most vulnerable). All learners were taught individually by a single senior otolaryngology physician who was assisted by a research team member.[17] The instructor (C.J.Y.) is an expert in pediatric otolaryngology and simulation who underwent instruction in operant learning techniques directly from co-author I.M.L., who is an international expert in operant learning, TAGteach® instructor, and orthopedic surgeon, using TAG teaching level 1 certification resources.

The OLG members were taught using principles derived from behavioral science and trained with TAGteach® methods using a standard script (**Table 1**). The overall goal, "changing a tracheostomy tube," was identified, the purpose of the activity was described, and the tracheostomy tube change was demonstrated. The component skill (behavior) was first identified by the physician teacher. Instructions for performing the skill were then provided by the teacher, followed by a demonstration. The specific learning goal was then named with a tag point in 5 words or less: for example, "Chicken Foot" (**Figure 2**). The OLG learners were then asked to perform the component skill. The instructor produced an auditory mark with a clicker when the skill was completed satisfactorily and the tag point was achieved. The learner was asked to reproduce the behavior 5 times and was marked each time the skill was successfully performed. As each new component behavior was learned, it was linked to previously learned behaviors forming a behavior chain. This process was continued until all 6 steps of "changing a tracheostomy tube" were learned in sequence. The learner was then allotted 2 minutes of practice time on an infant manikin during which no feedback or correction was provided about the learner's technique. After the practice sessions, the OLG was asked to perform 10 tracheostomy tube changes on an infant manikin.

Each TDG learner observed 2 demonstrations with verbal instructions of all 6 component steps on how to perform a tracheostomy tube change. The learner was allotted 2 minutes of practice time to learn the skill on an infant manikin with full access to the expanded diagram of all steps needed to perform the skill (**Figure 1**). No feedback or correction was provided about the learner's technique. The TDG learners were then asked to perform 10 tracheostomy tube changes on the infant manikin.

All participants were video recorded. Deidentified videos were reviewed and scored in random order by 2 raters, who were blinded to the study arm and were not involved in providing instruction or feedback during the educational sessions. The raters, who were trained by senior author C.J.Y. to recognize key components of a successful tracheostomy tube change, completed a scoring sheet to document the percentage of successful tracheostomy tube changes, the total time to perform each tracheostomy tube change, and the number of errors of each of the component steps (**Figure 3**). A tracheostomy tube change was considered accurate and correct only if all 6 component steps were performed exactly as demonstrated.

After an independent review of the videos, the 2 blinded raters met to discuss their observations and achieve consensus for each data point. Percentage correct, time for performance for each tracheostomy tube change, and lesson times of both groups were compared using a Wilcoxon rank-sum test. Statistical analyses were performed on Microsoft Excel Version 16.76.

Results

Twenty-seven medical students volunteered to participate in the study. One volunteer with prior experience with tracheostomy tubes was excluded from participating. Each group was composed of 13 medical students (**Table 2**). Five participants (2 in the OLG and 3 in the TDG) had prior exposure to operant learning.

The OLG was more accurate in performing a tracheostomy tube change compared to the TDG. Twelve of 13 OLG learners performed the skill correctly each time compared to only 3 of 13 in the TDG. The median percentage of all tracheostomy tube changes performed correctly in the OLG was 100% (range, 70%-100%). One operant learner lost the skill after the seventh repetition. The median percentage of all tracheostomy changes performed correctly in the TDG was 10% (range, 0%-100%). Using the Wilcoxon rank-sum test for median comparison, the operant group was determined to be more accurate ($P = 0.002$) (**Table 2**).

In the OLG, the median of the average time per tracheostomy tube change was 7.1 seconds (range 5.3-8.6 seconds) compared to 7.5 seconds (range 5.0-10.4 seconds) in the TDG. Using the Wilcoxon rank-sum test for median comparison, no statistically significant difference was observed ($P = 0.427$).

The median lesson time for the OLG was 535 seconds (range, 409-655). The median lesson time for the TDG was 200 seconds (range, 141-227). Using the Wilcoxon rank-sum test for median comparison, the lesson times between the 2 groups were found to be significantly different ($P < 0.001$).

Within both the test (OLG) and control (TDG) groups, there were no significant differences between the performance (ie, percentage of tracheostomy tube changes performed correctly, average time per tracheostomy tube change) or lesson times of male and female participants. Similarly, within each group, there were no significant differences in performance or lesson times between first-year medical students and second-year medical students.

The cumulative number of mistakes for the TDG was 143, compared to 3 mistakes in the OLG (**Figure 4**). Steps 2 (grasp the tracheostomy tube with the dominant hand), 5 (stabilize the tracheostomy tube), and 6 (remove the

Table 1. The Script for Performing a Tracheostomy Tube Change

Background: Goal	Today we are going to learn how to perform a tracheostomy tube change. My assistant has already been trained; he will assist me and then assist you also.
Background: Importance	Tracheostomy tube changes are important to maintain a stable airway for breathing. The procedure is the same for routine changes and for emergencies.
Demonstrate	
Behavior 1	
Describe the behavior	The goal is to insert the obturator into the tracheostomy tube.
Instruct	The instructions are to place the tube in the nondominant hand and insert the obturator with the dominant hand.
Demonstrate	See **Figure 1A**.
Repeat demonstration with instruction	"Insert Obturator."
Identify the tag point	The tag point is "Insert Obturator."
Practice	Practice to fluency with a peer marking the behavior 5× with a clicker.
Behavior 2	
Describe the behavior	The goal is to grasp the trach tube with the dominant hand.
Instruct	The instructions are thumb on obturator, fingers over phalanges for the chicken foot.
Demonstrate	See **Figure 1B**.
Repeat demonstration with instruction	Insert obturator, then "Chicken Foot."
Identify the tag point	The tag point is "Chicken Foot."
Practice	Practice to fluency with a peer marking the behavior 5× with a clicker.
Behavior 3	
Describe the behavior	The goal is to instruct the assistant to remove the existing trach at the correct moment.
Instruct	"1-2-3 OUT."
Demonstrate	See **Figure 1C**.
Repeat demonstration with instruction	Insert obturator, chicken foot, then "1-2-3 OUT."
Identify the tag point	The tag point is "1-2-3 OUT."
Practice	Practice to fluency with a peer marking the behavior 5× with a clicker.
Behavior 4	
Describe the behavior	The goal is to insert the trach tube into the airway.
Instruct	Insert by following the curve
Demonstrate	See **Figure 1D**.
Repeat demonstration with instruction	Insert obturator, chicken foot, "1-2-3 OUT," then "Follow the Curve."
Identify the tag point	The tag point is "Follow the Curve."
Practice	Practice to fluency with a peer marking the behavior 5× with a clicker.
Behavior 5	
Describe the behavior	The goal is to stabilize the trach. Drop wrist, fingers to a V position, away from the face, and hold.
Instruct	Drop to V.
Demonstrate	See **Figure 1E**.
Repeat demonstration with instruction	Insert obturator, chicken foot, "1-2-3 OUT," follow the curve, then "drop to V."
Identify the tag point	The tag point is "drop to V."
Practice	Practice fluency with a peer marking the behavior 5× with a clicker.
Behavior 6	
Describe the behavior	The goal, while still holding the V, is to remove the obturator with a nondominant hand.
Instruct	Pull obturator.
Demonstrate	See **Figure 1F**.
Repeat demonstration with instruction	Insert obturator, chicken foot, "1-2-3 OUT," follow the curve, drop to V, then "Pull Obturator."
Identify the tag point	The tag point is "Pull Obturator."

(*continued*)

Table 1. (continued)

Practice	Practice to fluency with a peer marking the behavior 5× with a clicker.
Practice	You now have 2 min of practice.
Performance cue	Perform a tracheostomy tube change 10 times (leave the tube in after each change).

Figure 2. Visual comparison of tracheostomy apparatus (left) with chicken foot (right).

Scoring Sheet for Tracheostomy Tube Changes

Participant ID: ___________________________

Tracheostomy change attempt number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Time for each tracheotomy change (seconds)										
Error in step 1: insertion of the obturator into the new tracheostomy tube (yes/no)										
Error in step 2: grasping of the new tracheostomy tube with the dominant hand (yes/no)										
Error in step 3: instructing the assistant to remove the existing tracheostomy tube (yes/no)										
Error in step 4: insertion of the new tracheostomy tube into the airway (yes/no)										
Error in step 5: stabilization of the new tracheostomy tube (yes/no)										
Error in step 6: removal of the obturator with the non-dominant hand (yes/no)										

Figure 3. Scoring sheet for tracheostomy tube changes.

obturator with the nondominant hand) were associated with the majority of mistakes.

Discussion

To our knowledge, this is the first application of operant learning techniques to tracheostomy tube changes. As a complex, multistep procedure, it is well suited to operant learning methodologies through the reinforcement and chaining of component skills.

While international groups, including the Global Tracheostomy Collaborative, work to share educational resources and strategies for teaching tracheostomy tube

Table 2. Demographic Information and Time Comparisons Between Test and Control Groups

	Operant learning (n = 13)	Classical demonstration (n = 13)	*P* value
Gender			
Female	7	8	0.69
Class year			
MS1	6	6	1.0
MS2	7	7	1.0
Previous operant learning experience	2	3	1.0
Total lesson time,[a] s, median (range)	535 (409-655)	200 (141-227)	<0.001
Average time per trach change, s, median (range)	7.10 (5.3-8.6)	7.50 (5.0-10.4)	0.427
Percentage of trach changes performed correctly,[b] median (range)	100% (70%-100%)	10% (0%-100%)	0.002

[a]Defined as time for teaching and practice prior to testing.
[b]Defined as completion of all component steps, in the correct order, without mistakes.

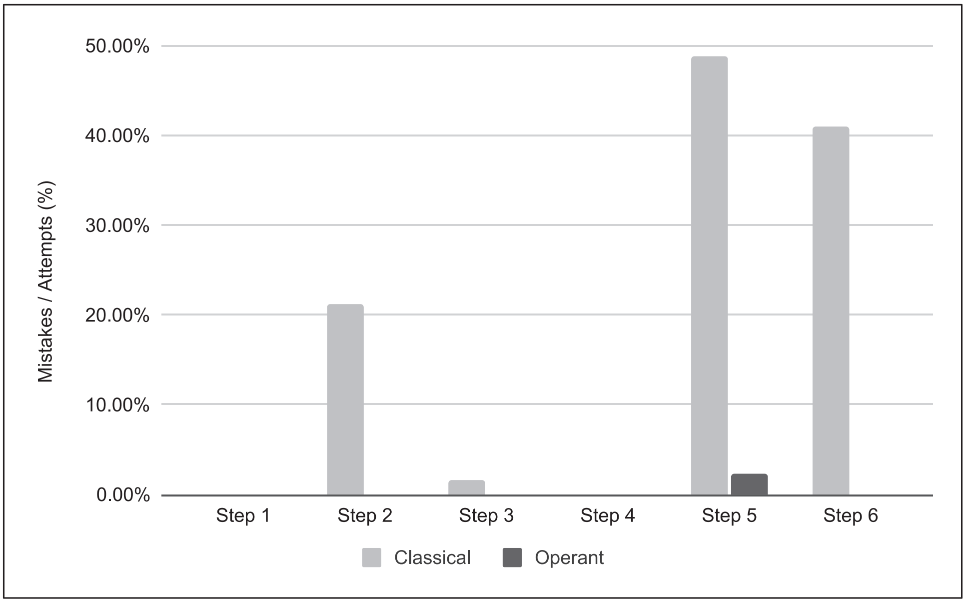

Figure 4. Mistakes divided by attempts of individual component steps among learners.

care, our work highlights the importance of educational methodology.[21] In comparison to the TDG, the OLG (intervention) demonstrated greatly improved accuracy, with twelve of thirteen learners able to perform each tracheostomy tube change successfully compared to just 2 out of 13 traditional learners. There was no significant difference in performance time between the 2 groups during testing. There was a significant difference between the 2 lesson times; however, after considering that those who made mistakes would require further instruction before achieving mastery, the increase in lesson time with operant learning methods (535 vs 200 seconds) far outweighs the perceived advantage of shorter teaching times with traditional demonstration methods.

An important distinction between demonstrations using operant learning methods and those using traditional methods is the presence of reinforcement in operant learning. Without reinforcement of correct behaviors, learned component steps may deteriorate during the learning period, and thereafter. This is especially important when learners are not retrained and reassessed periodically. A total of 143 mistakes in component steps during testing were accumulated by the TDG. These learners did not experience reinforcement of correct behaviors, and likely self-reinforced incorrect behaviors during and after learning, which resulted in poor performance of the procedural skill, particularly steps 2, 5, and 6.

Operant learning requires more time and discipline on the part of the teacher to learn and execute its methodologies and novel terminology.[17] However, once the operant learning strategies are learned, the methodology can be applied to many different skills. We believe the training time and effort are worth the desired outcome of accurate and precise skill acquisition among learners.

In addition, operant learning methods have been associated with correct behaviors that persist months after teaching. The longer durability of the skill and lower decay (fewer errors) when taught using an operant learning method further support its use when compared to traditional learning methods, particularly for skills that are infrequently practiced by many clinicians who only sporadically care for patients with tracheostomies and thus have inconsistent opportunities to reinforce this skill in the clinical setting.

Our study has some limitations. First, prior tracheostomy experience was only determined by self-reporting. Further, we relied on medical student learners for our educational protocols. While medical students may differ from other (professional and volunteer) caregivers in age, dexterity, clinical experience, prior training, and motivation for participating in training (whether mandatory or voluntary), we believe that the teaching models are suitable for graduate medical education as well. Additionally, while our study comprised 1-on-1 lessons with medical student learners for scientific rigor and convenience, operant conditioning has been shown to be effective in groups (such as ballet or gymnastics lessons).[14,22]

Implications for Practice

Although tracheostomy tube changes seem simple and rapid, the skill is complex. By learning to perform tracheostomy tube changes accurately and precisely through operant learning methods, medical personnel and caretakers with varying medical literacy can acquire the confidence to perform this skill, ensure patient safety, and prevent adverse outcomes. It is reasonable to conclude that teaching skills using operant learning methodologies may be an effective educational tool for teaching procedural skills in other areas of medicine.

Future directions include studying the use of operant learning for tracheostomy skill group teaching (eg, "skills fair"), skill retention over time, and additional clinical learner groups. At our institution, we have started to apply operant learning to tracheostomy skill training for nurses, respiratory therapists, residents, and fellows in pediatrics, surgery, anesthesia, and critical care.

Acknowledgments

The authors would like to thank Yungtai Lo, PhD, Associate Professor, Department of Epidemiology and Population Health, Albert Einstein College of Medicine. Dr. Yang was a Clinical Research Training Program Scholar supported by the Clinical and Translational Science Award from the National Institutes of Health National Center for Advancing Translational Sciences through the Harold and Muriel Block Institute for Clinical and Translational Research, a partnership between the Albert Einstein College of Medicine and Montefiore Medical Center from 2021 to 2023.

Author Contributions

Elliot Schiff, analysis, drafting, review and approval of manuscript; **Anthony Ma**, study design, analysis, drafting, review, and approval of manuscript; **Tracy Cheung**, analysis, drafting, review and approval of manuscript; **Marc-Mina Tawfik**, analysis, drafting, review and approval of manuscript; **Ryan S. Ference**, study design, analysis, drafting, review and approval of manuscript; **Michael S. Weinstock**, study design, analysis, drafting, review and approval of manuscript; **I. Martin Levy**, study design, analysis, drafting, review and approval of manuscript; **Christina J. Yang**, study design, analysis, drafting, review, and approval of manuscript.

Disclosures

Competing interests: None.

Funding source: None.

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