



An effective multi-modality model for single-session cricothyroidotomy training for trainees



Charity C. Glass, Charles S. Parsons, Nakul P. Raykar, Ammara A. Watkins, Sayuri P. Jinadasa, Aaron Fleishman, Alok Gupta*

Beth Israel Deaconess Medical Center, Boston, MA, USA

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ABSTRACT

Background: We piloted a curriculum combining a flipped classroom with two-stage narration, role-play, and partial task trainer simulation to teach this critical skill to trainees.

Methods: This “flipped classroom” module (2012–2018) for open and percutaneous cricothyroidotomy (OC and PC) required participants to watch two 4 min training videos for OC and PC. The simulation session consisted of a 45-min hands-on simulation of OC and PC in which participants rotated between the roles of operator, narrator, and critiquer. Median performance scores were calculated.

Results: 103 trainees were evaluated. The median performance score was 14 out of maximum 14 (range: 9–14) across all trainees for OC. The median performance score was 13 out of maximum 13 (range: 3–13) across all trainees for PC.

Conclusion: A multi-modality approach including the flipped classroom, role-play, and partial task trainer simulation is an efficient and effective method for teaching trainees proficiency in short, single operator procedures.

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Introduction

As work hours decline, but the skills surgical and critical care trainees must master before practicing independently do not, there has been an emphasis on the role of simulation for knowledge and skill acquisition.¹ Learning to perform cricothyroidotomy during routine clinical training is not always feasible, due to the infrequent need for an emergent surgical airway. Salvino et al. reviewed the emergent surgical airways over 8000 trauma admissions during a 36 month period and noted a cricothyroidotomy incidence of only 0.36% during the study period at this level 1 trauma center.²

Prior studies have explored trainee confidence and performance of cricothyroidotomy relying on resource-heavy cadaver and swine models.³ Other studies that utilized fewer resources have failed to show that trainees obtained proficiency after training or evaluated fewer trainees.^{4–7} To our knowledge, this is the largest study to

evaluate trainee performance of cricothyroidotomy and the first to report efficacy using the flipped classroom model. This study aims to describe the development and implementation of a novel curriculum to teach cricothyroidotomy to trainees combining a flipped classroom with two-stage narration, role-play, and task trainer simulation to teach this low frequency, high acuity skill to students, residents and fellows in surgery and anesthesiology in an efficient and cost-effective manner.

Materials and methods

Curriculum design

To ensure functional task alignment, seven experts (acute care and trauma surgeons) underwent four rounds of review to determine the essentials components of open and percutaneous cricothyroidotomy performance. These criteria were then divided into major and minor criteria for each procedure. Major criteria were defined as basic steps critical to successful performance of cricothyroidotomy, such as correct identification of landmarks and proper incision (Table 1). Minor criteria were defined as those steps that are advised, but not critical to the successful performance of cricothyroidotomy such as prepping the site (Table 2).

* Corresponding author.

E-mail addresses: cglass1@bidmc.harvard.edu (C.C. Glass), cparsons@bidmc.harvard.edu (C.S. Parsons), nraykar@bidmc.harvard.edu (N.P. Raykar), aawatkin@bidmc.harvard.edu (A.A. Watkins), sjinadas@bidmc.harvard.edu (S.P. Jinadasa), afleishm@bidmc.harvard.edu (A. Fleishman), agupta4@bidmc.harvard.edu (A. Gupta).

Table 1
The major criteria for open and percutaneous cricothyroidotomy.

| Open Cricothyroidotomy | Percutaneous Cricothyroidotomy |
|-----------------------------------|---|
| Preoxygenate | Preoxygenate |
| Identify of landmarks | Identify of landmarks |
| Vertical midline incision | Insert needle/angiocath |
| Blunt dissection | Seldinger technique to remove needle, insert wire and remove angiocath |
| Incision in cricothyroid membrane | Vertical midline incision |
| Dilation of cricothyroid membrane | Seldinger technique to insert tracheostomy apparatus and remove dilator |
| Insert tube | Inflate cuff |
| Inflate cuff | Attach ventilator tubing |
| Attach ventilator tubing | Secure tube |
| Secure tube | |

Table 2
The minor criteria for open and percutaneous cricothyroidotomy.

| Open Cricothyroidotomy | Percutaneous Cricothyroidotomy |
|--------------------------------------|--------------------------------------|
| Prep Site | Prep Site |
| Demonstrate organization & foresight | Demonstrate organization & foresight |
| Stabilize trachea | Stabilize trachea |
| Order chest x-ray | Order chest x-ray |

An attending trauma surgeon was then videotaped performing both the open and percutaneous cricothyroidotomy while narrating the technical steps of the procedure using the Limbs and Things TruCric model for demonstration. Each video is approximately 4 minutes in length.

In the flipped classroom model, the learner is assigned content to review before the teaching session; class time is used for application of knowledge and hands on training. In our module, prior to attending the in-person session, learners reviewed a document (the “walkthrough”) detailing the indications and technique for open and percutaneous cricothyroidotomy. They then watched the videos for both procedures. The videos demonstrated the surgical technique, first with no accompanying narration. The learner reviewed the steps of the walkthrough as they watched the muted video. The second part of the video showed the same technique, but with each step being described by a narrator. They then reviewed the walkthrough document once more before the classroom session. Additionally, learners were asked to read “The Steel Windpipe,” a short story by Mikhail Bulgakov that addresses a practitioner’s harrowing first time performing a cricothyroidotomy. The pre-session preparation took approximately 60 minutes to complete.

The in-person session began with a brief, 30-minute discussion of the assigned humanities piece. Immediately following this discussion, students rotated between three roles – (1) narrating the performance of the operator, (2) playing the role of the critiquer under faculty supervision and (3) performance of the open and percutaneous technique on the partial task trainer. By the end of the training module, learners have reviewed the procedure (reading, watching, narrating, and performing) at least seven times (Fig. 1). The in-person session took approximately 75 minutes.

Study cohort

Our study cohort consisted of fourth-year medical students matched into general surgery and surgical subspecialties participating in a pre-internship surgical bootcamp; surgical residents (PGY1 and PGY2); anesthesia critical care fellows (PGY-5); and surgery critical care fellows (PGY-6); from 2012 to 2018.

Methods: Curriculum

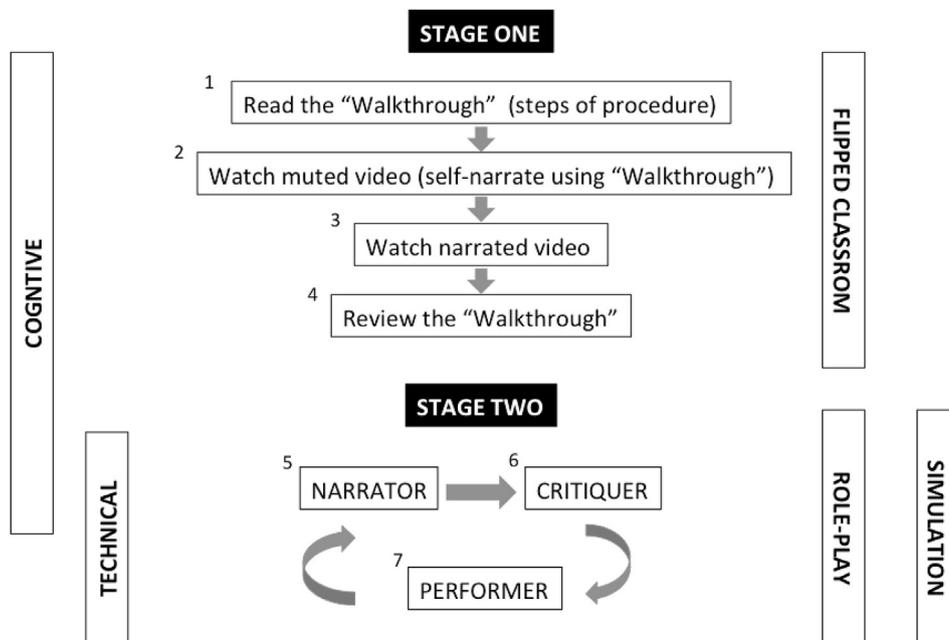


Fig. 1. This diagram illustrates the cricothyroidotomy curriculum.

Outcomes/statistical analysis

For both OC and OP median scores for overall, major and minor criteria were calculated. We calculated the percent of trainees who achieved mastery (perfect score) for each procedure as well as which criteria were most likely to be missed. Additionally, we used the Kruskal-Wallis rank sum test to determine if there was any difference in overall performance scores between the medical students, residents and fellows.

Statistical analysis was performed using R version 3.4.3 (R Foundation for Statistical Computing).

Results

Cohort description

The performance of 103 trainees was evaluated. Fourth year medical students who have matched into surgery or a surgical subspecialty, anesthesia and surgical residents, and critical care fellows represented 65% (67), 25% (26), and 10% (10) of the total study population, respectively.

Open cricothyroidotomy

The median performance score was 14 out of maximum 14 (range: 9–14) across all trainees for OC. The median score was 10 (of 10) (range: 7–10) for the major criteria. The median score was 4 (of 4) (range: 1–4) for the minor criteria (Table 3). Seventy-five percent of trainees had a perfect performance score on OC. Trainees tended to perform slightly better in the major criteria than the minor criteria in the OC. The major criterion most often missed was securing the tube, missed by 9% of the trainees. The minor criteria step most often missed was ordering the chest xray to confirm correct placement, missed by 11% of trainees (Fig. 2). There was no difference in performance between medical students, residents and fellows ($p = 0.45$).

Percutaneous cricothyroidotomy

The median performance score was 13 out of maximum 13 (range: 3–13) across all trainees for PC. The median score was 9 (of 9) (range: 3–9) for the major criteria. The median score was 4 (of 4) (range: 0–4) for the minor criteria (Table 4). Fifty-nine per cent of trainees had a perfect performance score on PC. Similarly to the

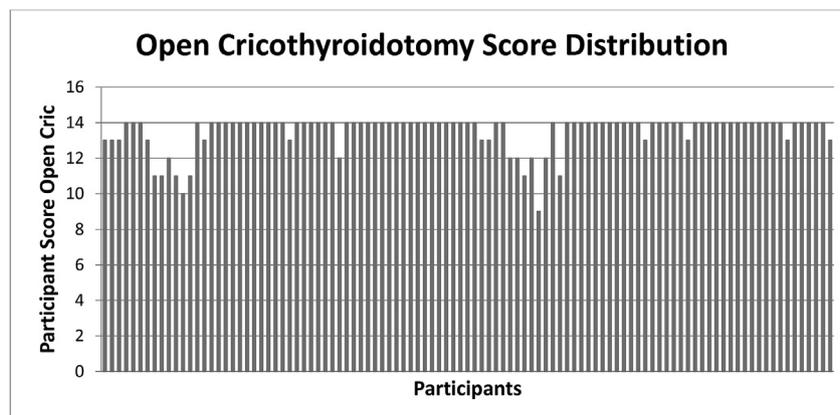
open procedure, while doing the percutaneous cricothyroidotomy, trainees tended to perform slightly better in the major criteria than the minor criteria. Again securing the tube and ordering the chest xray were the major and minor criteria missed most often at 12% and 19%, respectively (Fig. 3). There was no difference in performance between medical students, residents and fellows ($p = 0.73$).

Discussion

This study noted that incorporating the “flipped classroom” is an effective model for teaching trainees how to perform open and percutaneous cricothyroidotomy. A majority of participants (75% open, 59% percutaneous) achieved mastery, with an even greater percentage (85% open, 75% percutaneous) adequately performing every major criteria. Securing the tube and ordering a post-procedure chest x-ray were the steps most likely to be missed or performed incorrectly and greater emphasis on them could be considered in the future. Learners performed better during the open simulation. The authors suspect this may be because the open procedure has fewer steps to learn. We noted no difference in performance between students, residents and fellows. This is likely due to a multitude of reasons. First, the entire group of trainees were novices to this uncommon procedure, perhaps leveling the playing field among trainees. We suspect a difference may be seen between experienced and inexperienced technicians if the trainees were evaluated on haptics, tissue handling, time to completion, or other definitive measures of technical skill; these were outside the scope and purpose of our study. Also, we did not have the power to determine a difference between fellows and the rest of the group unless it was quite large since only 10% of the entire cohort was composed of fellows. Finally, everyone performed relatively well, making differences less evident. This may be attributed to the degree of repetition of steps in the course, especially in the pre-course preparation, suggesting that learners at every level benefit from sheer repetition.

Our study is consistent with prior studies that note cricothyroidotomy can be effectively taught using simulation. Jayaraman et al. studied 19 residents and reported improved mean time and efficacy compared to pre- and post-test with the addition of a simulation to their standard lecture and video module.⁵ Hubert et al. investigated the performance of 27 3rd year anesthesiology residents after participating in a two-day airway management seminar and demonstrated improved performance of cricothyroidotomy after this intervention.⁶ Petrosniak et al. reported that

Table 3
Distribution of open cricothyroidotomy total scores among participants.



Open Cricothyroidotomy Performance by Criteria

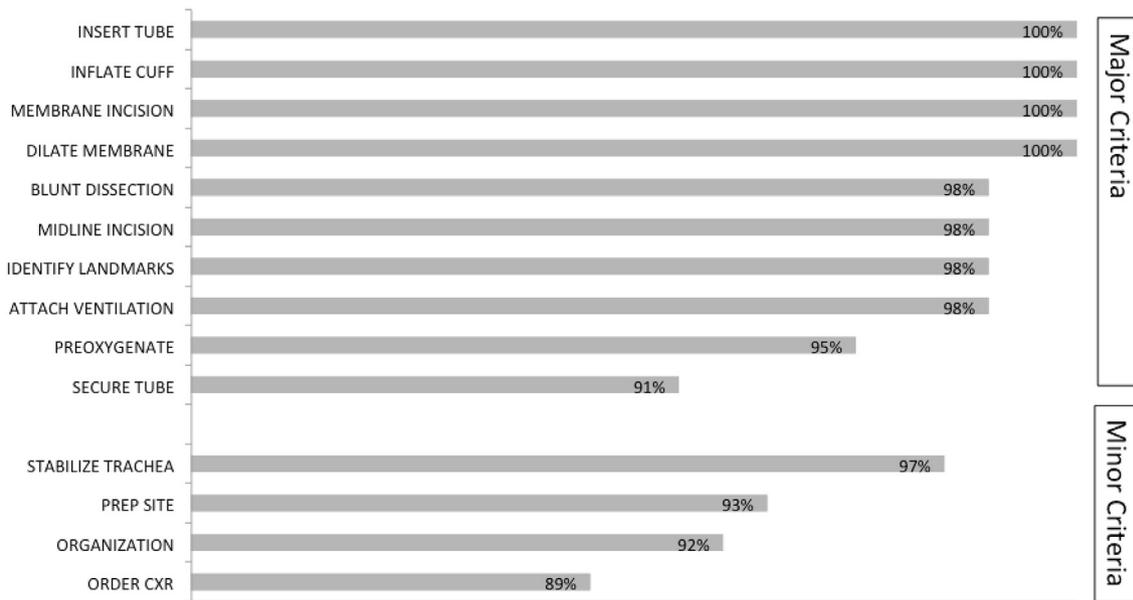
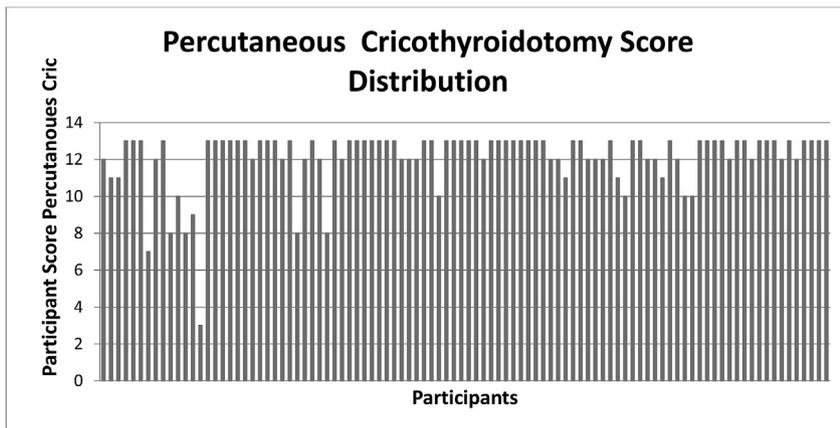


Fig. 2. This graph illustrates learner's performance on the open cricothyroidotomy by criteria.

Table 4
Distribution of percutaneous cricothyroidotomy total scores among participants.



20 emergency medicine residents improved mean time of performance after a two-part curriculum consisting of a didactic session followed by a simulation session using a task trainer.⁷ To our knowledge, our study is the most contemporary and largest to evaluate trainee performance of cricothyroidotomy. It is the first to report efficacy using the flipped classroom model and role-play for this task using an efficient, cost-effective model. Additionally, this study spans different trainee levels and shows effectiveness at each learner level.

In the flipped classroom model, the learner is assigned content before attending a classroom session. The teaching session is then used for application of knowledge and hands on practice. As Morgan et al. explains, "The flipped classroom model has been described as particularly well suited for medical education, as the pre-class assignment can create a framework of core knowledge, and the active learning exercise can embed the knowledge in an interactive, compelling and engaging format."⁸ In our intervention,

the pre-class is used to build the cognitive components while the class session is used to build the technical skill. This separation of cognitive and technical allows for both mastery of the cognitive aspects such as error-detection, decision making and forward planning, as well as the technical maneuvers required to perform a procedure.⁹ (Fig. 1) We believe this model is particularly well suited to teaching a short, single-operator technical skill. Studies have shown improved performance and satisfaction with the flipped classroom approach as compared to the traditional didactic approach. Belfi et al. studied 101 radiology clerkship students and demonstrated that students who participated in the flipped classroom showed the greatest pretest to posttest improvement compared to traditional didactics as well as having the highest satisfaction scores.¹⁰ Lew implemented the flipped classroom model for emergency medicine clerkship students and reported that students found high value in this model and preferred it to lecturing, citing interactivity, discussion and "high level of

Percutaneous Cricothyroidotomy Performance by Criteria



Fig. 3. This graph illustrates learner's performance on the percutaneous cricothyroidotomy by criteria.

involvement” as the main reasons.¹¹ This model is perhaps especially effective for skills acquisition when the goal is to maximize the learner's time with a procedural expert actually practicing a skill, particularly one rarely performed over the course of residency. In this setting, the content or procedural expert's time is better used interacting with the trainee in a hands-on scenario as opposed to delivering content that could be mastered at home on the trainees own time, allowing the in classroom session to focus on higher order cognitive and procedural skills as opposed to lower level cognitive skills.

More studies are needed to evaluate the effectiveness of low fidelity models to maximize outcomes while limiting resources (both time and financial). Current studies describe no difference in trainee performance when initial training occurred on high fidelity models (animals) and low fidelity models (mannequins). In a 2015 study, Iverson et al. found that there was no difference in success rate, time to completion or accuracy of cricothyroidotomy when learners are trained on a swine model versus a mannequin.¹² Low fidelity models have the potential to decrease the cost of training without compromising skills acquisition. As the prevalence of fourth year pre-internship preparatory courses increase, course directors could potentially incorporate this model into 4th year electives. This model should also be considered for other short, single-operator skills encountered during medical training such as central line insertion and tube thoracostomy. Its greatest value may be for training in rare, but emergently needed procedures. In a 2011 study by Boet et al of 38 attending anesthesiologists, the authors reported that after a single simulation training session, cricothyroidotomy skills improvements were retained for at least a year.¹³ Future studies of this module should investigate cricothyroidotomy skills retention to determine optimal timing for a skills refresher course.

The results of this study must be considered in the context of its limitations. While there is no assessment of trainee performance prior to the intervention for comparison, the majority of the trainees evaluated were medical students or junior general surgery residents. We have no reason to think this population would have

considerable prior knowledge about performing these relatively infrequent procedures. This study also doesn't evaluate time it takes trainees to perform the procedure, which is important to success in an emergent surgical airway. Finally, the study does not compare this intervention to an alternative training methodology, so additional studies are needed to determine whether this teaching modality is more effective than other alternatives.

Conclusion

A multi-modality approach including the flipped classroom, role-play, and partial task trainer simulation is an efficient and effective method for teaching trainees proficiency in short, single operator low frequency, high acuity procedures such as open and percutaneous cricothyroidotomy. Future studies should evaluate whether trainees taught using this model are able to perform the procedures in a timely manner, as the success in a real patient encounter depends upon expeditious performance. Future studies should also evaluate for knowledge retention at different intervals (potentially 1, 3 and 5 years) to determine the ideal time for a refresher course, especially for those physicians practicing in remote locations with little or no backup in emergent “can't intubate, can't ventilate” situations.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.amjsurg.2018.12.059>.

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