

Original Research

Assessment of a Low Cost Cricothyrotomy Model for Simulation and Education

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Objectives

Emergent Cricothyrotomy is a life-saving procedure that should only be used as a last resort to obtain a means for oxygenation and ventilation in a critical patient when all other options have been exhausted. This study seeks to address the resource and time inefficiencies of conventional simulation techniques by assessing noninferiority of one example of a novel, cost-effective cricothyroidotomy simulation technique that uses an open-sourced, 3D printed trachea model for simulated practice among resident physicians, paramedics, and critical care flight nurses compared to the current training techniques using conventional simulation models.

Methods

Participants were randomized into two groups, a group utilizing the 3D printed model and a group using the traditional mannequin simulator. Both groups underwent a standardized educational session consisting of a PowerPoint presentation on the cricothyrotomy procedure. The initial training session consisted of an explanation of a bougie-assisted cricothyrotomy using a scalpel and endotracheal tube. The components of the educational session were consistent with a standardized, validated procedure checklist for an emergent cricothyrotomy. Participants were then randomized during the hands-on component to either the 3D-printed model or the traditional mannequin simulator. A washout period of a minimum of two weeks (but no more than three weeks) followed the initial training. After the washout period, participants were asked to perform a bougie-assisted cricothyrotomy using a scalpel and endotracheal tube on the traditional mannequin to assess the efficacy of the training.

Results

A total of 47 participants, including 14 residents, 23 critical care flight nurses and paramedics, and 10 fire-based paramedics, participated in the study. 25 (53%) participants were randomized to the 3D-printed model, and 22 (47%) participants used the standard mannequin model. Pre-training, participants in the 3D-printed model ranked their comfortability with performing a cricothyrotomy 2.7/5, whereas post-training reported 3.9/5 ($P < 0.05$). Participants who trained with the mannequin ranked their comfortability 2.8/5 before training and 3.9/5 after training ($P < 0.05$). After the washout period, all participants (100%) were able to complete all steps of a successful cricothyrotomy. The average time from the start of the procedure to first bag-valve mask was 63 seconds, 57 seconds for those who trained using the 3D model, and 71 seconds for those who trained using the mannequin ($P < 0.05$). Participants rated the realistic experience of the 3D printed model 4.1/5, compared to the mannequin 3.8/5 ($P = 0.13$). Participants agreed with the statement that the cricothyrotomy simulator used was more realistic than other models used in the past 3.7/5 in the 3D printed model group and 3.1/5 in the mannequin model.

Conclusion

This study demonstrates that the use of a low-cost, 3D-printed cricothyrotomy model is a viable and non-inferior alternative to traditional high-fidelity mannequins for training medical professionals in this high-acuity, low-opportunity procedure. While there are

limitations related to the lack of anatomical context and the potential bias introduced by familiarity with the mannequin model, the results highlight the potential for 3D-printed models to provide a cost-effective and accessible means for improving cricothyrotomy training.

Emergent Cricothyrotomy is a life-saving procedure that should only be used as a last resort to obtain a means for oxygenation and ventilation in a critical patient when all other options have been exhausted.¹ Given the dire nature of the cases that require cricothyroidotomy, medical providers must be prepared to identify the anatomical landmarks, accurately incise, and efficiently establish a definitive airway within a highly vascular body region in an intensely stressful scenario.² The low frequency and high stress/acuity nature of this procedure creates a reliance on simulation training to offer adequate educational and procedural opportunities to medical professionals to master and maintain the skills associated with this procedure.

Implementation and maintenance of cricothyrotomy training through conventional simulation techniques involve specialized and expensive models and materials in addition to planning and coordinating locations for simulation events for participants. Most popular high-fidelity cricothyrotomy simulators cost between \$400 to \$1500 and often have single-use aspects, making the repetition required for mastery difficult.³ Performing simulation training is time and resource-intensive. Considering the low frequency of this procedure and the unequal access to requisite simulation resources amidst the medical providers in need of simulation opportunities, current methods are poorly positioned to meet recent guidelines by the Difficult Airway Society which emphasize that regular, frequent simulation opportunities be performed due to the infrequent incident of cases requiring emergent cricothyrotomy. With the advancement of other airway management skills and devices, the requirement for cricothyrotomy has decreased, meaning that simulation is often a provider's only experience with this important procedure for an extended period, and thus even more crucial to master and maintain the skill.⁴

Given the critical importance of this life-saving procedure, the resource and time requirements associated with conventional simulation techniques, and the recent guidelines by the Difficult Airway Society, the development and implementation of a simulation training technique(s) that provides medical professionals with increased access to simulation opportunities that are non-inferior to conventional training standards would provide the opportunity to optimize simulation training of emergent cricothyrotomy for medical professionals.

This study seeks to address the resource and time inefficiencies of conventional simulation techniques by assessing noninferiority of one example of a novel, cost-effective cricothyroidotomy simulation technique that uses an open-sourced, 3D printed trachea model⁵ for simulated practice among resident physicians, paramedics, and critical care flight nurses compared to the current training techniques using conventional simulation models.



Figure 1. Equipment needed, including open source, 3D printed trachea, tape and sauce packet

METHODS

This is a non-inferiority study designed to assess the use of our proposed, novel cricothyroidotomy training technique on cricothyrotomy simulation training. We assessed our 3D-printed cricothyrotomy model against a standard mannequin training model currently being used at an academic emergency department.

CRICOTHYROTOMY MODEL: “THE PACKET METHOD?”

The 3D-printed cricothyrotomy model consists of an open-source 3D-printed trachea, white tape to create the cricothyrotomy membrane, a sauce-packet with appropriate color and viscosity to mimic blood, assembled with white tape to simulate skin. See Figures [1](#), [2](#), [3](#).

PARTICIPANTS AND TRAINING

This project was submitted and reviewed by the Orlando Health Institutional Review board and was considered exempt. Participants including residents at an academic Emergency Medicine program, fire-based paramedics, and critical care flight nurses and paramedics participated in the study on a volunteer basis. The inclusion criteria were medical professionals with cricothyrotomy within their scope of practice, who volunteered to undergo cricothyrotomy training. Exclusion criteria were those unable to



Figure 2. 3D printed trachea and sauce packet



Figure 3. Final 3D printed cricothyrotomy model

provide consent, participants who had prior experience or exposure to our novel technique, and those who did not complete the washout period and follow up testing or surveys.

Participants were randomized into two groups, a group utilizing the 3D printed model and a group using the traditional mannequin simulator. Both groups underwent a standardized educational session consisting of a PowerPoint presentation on the cricothyrotomy procedure. The

initial training session consisted of an explanation of a bougie-assisted cricothyrotomy using a scalpel and endotracheal tube. Indications, contraindications, equipment, and demonstration of the procedure were all covered in the lecture component for both groups. The components of the educational session were consistent with a standardized, validated procedure checklist for an emergent cricothyrotomy.⁶ Participants were then randomized during the hands-on component to either the 3D-printed model or the traditional mannequin simulator. A washout period of a minimum of two weeks (but no more than three weeks) followed the initial training. After the washout period, participants were asked to perform a bougie-assisted cricothyrotomy using a scalpel and endotracheal tube on the traditional mannequin to assess the efficacy of the training.

DATA COLLECTION

An anonymous survey was completed by every participant before the initial training. After the washout period, participants were asked to perform a cricothyrotomy on a traditional mannequin. The participants were evaluated and timed by emergency medicine (EM) attendings who were blinded to the initial intervention groups. To ensure blinding, the EM attending physicians leading the education training groups did not serve as evaluators. No additional education information was given, and no assistance was provided by the EM attending evaluator. The evaluators assessed performance using the standardized, validated procedure checklist used during the initial educational session. Participants were then asked to complete a follow-up survey regarding the efficacy of the training.

RESULTS

A total of 47 participants, including 14 residents, 23 critical care flight nurses and paramedics, and 10 fire-based paramedics, participated in the study. 25 (53%) participants were randomized to the 3D-printed model, and 22 (47%) participants used the standard mannequin model. The breakdown of participants is listed in [Table 1](#).

Pre-training, participants in the 3D-printed model ranked their comfortability with performing a cricothyrotomy 2.7/5, whereas post-training reported 3.9/5 ($P < 0.05$). Participants who trained with the mannequin ranked their comfortability 2.8/5 before training and 3.9/5 after training ($P < 0.05$). After the washout period, all participants (100%) were able to complete all steps of a successful cricothyrotomy. The average time from the start of the procedure to first bag-valve mask was 63 seconds, 57 seconds for those who trained using the 3D model, and 71 seconds for those who trained using the mannequin ($P < 0.05$). Participants rated the realistic experience of the 3D printed model 4.1/5, compared to the mannequin 3.8/5 ($P = 0.13$). Participants agreed with the statement that the cricothyrotomy simulator used was more realistic than other models used in the past 3.7/5 in the 3D printed model group and 3.1/5 in the mannequin model.

Table 1. Participant Demographics

	3D Printed Model	Simulated
Residents	6	8
Critical Care Flight Paramedics	12	11
Fire-Based Paramedics	7	3
Total	25 (53%)	22 (47%)

Table 2. Results from pre-training and post-training survey and following up testing

	3D Printed Model	Mannequin Model	P Value
Comfortability with Cricothyrotomy Pre-Training Post-Training	2.7/5 3.9/5 P value <0.05	2.8/5 3.9/5 P value <0.05	
Cricothyrotomy Success Rate on Follow up Testing	100%	100%	
Time from Start of Procedure to first Breath	57 seconds	71 seconds	P<0.05
Was the cricothyrotomy simulator used today effective in creating a realistic experience for performing a cricothyrotomy?	4.1/5	3.8/5	P = 0.13
Was the cricothyrotomy simulator used today more realistic than other cricothyrotomy models you have used in the past?	3.7/5	3.1/5	P<0.05

DISCUSSION

The results of this study indicate that our novel technique utilizing an open-source 3D-printed cricothyrotomy model is a promising alternative to the traditional, high-fidelity, simulation mannequins for cricothyrotomy training. Simulation-based training has long been recognized as a crucial method for training medical professionals, particularly for high-stakes, low-frequency procedures such as cricothyrotomy.⁵ The ability to practice and refine these skills in a controlled, non-urgent environment before applying them in real-world situations can significantly enhance both the competence and confidence of trainees.⁷ However, high-fidelity simulation mannequins often come with prohibitive costs, making them inaccessible for widespread use, particularly in resource-limited settings.⁸ Our study addresses this issue by demonstrating that a 3D-printed model, which costs less than \$2.00 to produce, can offer a viable, low-cost alternative without compromising training efficacy. This finding is particularly important in the context of resource-constrained environments, where access to advanced simulators is limited. By offering a low-cost alternative that is non-inferior to more expensive options, this 3D-printed model has the potential to make cricothyrotomy training more accessible to a larger group of healthcare providers. Moreover, the reusability of 3D-printed models could further reduce the overall cost of training, allowing for frequent practice sessions that are essential for mastering such a critical procedure.

Despite these positive results, several limitations should be considered when interpreting the findings. First, the final skills evaluation used the traditional high-fidelity mannequin, which introduces a potential bias. Participants had prior exposure to this mannequin during the initial training session, which may have influenced their performance during the final assessment. The familiarity with the mannequin model could have given participants an advantage, which makes it challenging to attribute the observed performance solely to the 3D-printed model. Additionally, while the 3D-printed model effectively replicated the cricothyroidotomy procedure, it lacks the anatomical context of a full mannequin with head and chest. This absence of surrounding anatomy may have simplified the procedure for participants, potentially limiting the realism of the simulation. In real-life scenarios, finding the correct anatomical landmarks can be more challenging due to factors such as patient body type, tissue resistance, and the need for precise spatial awareness. Therefore, the 3D-printed model may not fully replicate the complexities encountered during actual patient care. Future studies should explore how these simplified models perform in more complex training settings, including how they may be adapted to better simulate the complete anatomy and offer a more realistic representation of the procedure. Furthermore, the generalizability of the findings to real-life cricothyrotomy procedures is still uncertain. The final assessment on the high-fidelity mannequin does not directly reflect the performance of participants during an actual emergency. While the 3D-printed model may have helped trainees build

technical skills, it is crucial to evaluate how these skills translate to a high-pressure, real-world situation. Follow-up studies should assess the long-term retention of skills and the performance of trainees under more realistic conditions, such as simulated emergency scenarios or in vivo training settings, to determine how well these low-cost models support skill transfer.

In conclusion, this study demonstrates that the use of a low-cost, 3D-printed cricothyrotomy model is a viable and non-inferior alternative to traditional high-fidelity mannequins for training medical professionals in this high-acuity, low-opportunity procedure. While there are limitations related to the lack of anatomical context and the potential

bias introduced by familiarity with the mannequin model, the results highlight the potential for 3D-printed models to provide a cost-effective and accessible means for improving cricothyrotomy training. Future research should further explore the practical application of these models, including how they may be adapted to more closely mimic real-life anatomical variations and how they contribute to clinical performance under high-pressure conditions.

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REFERENCES

1. Schober P, Hegemann MC, Schwarte LA, Loer SA, Noetges P. Emergency cricothyrotomy - A comparative study of different techniques in human cadavers. *Resuscitation*. 2009;80:204-209. doi:[10.1016/j.resuscitation.2008.10.023](https://doi.org/10.1016/j.resuscitation.2008.10.023)
2. Schaumann N, Lorenz V, Schellongowski P, et al. Evaluation of Seldinger technique emergency cricothyroidotomy versus standard surgical cricothyroidotomy in 200 cadavers. *Anesthesiology*. 2005;102:7-11. doi:[10.1097/0000542-200501000-00005](https://doi.org/10.1097/0000542-200501000-00005)
3. Anatomywarehouse.com. <https://www.anatomywarehouse.com>
4. Makowski AL. A survey of graduating emergency medicine residents' experience with cricothyrotomy. *West J Emerg Med*. 2013;14(6):654-661. doi:[10.5811/westjem.2013.7.18183](https://doi.org/10.5811/westjem.2013.7.18183)
5. Duggan LV, Lockhart SL, Romano KR, Weingart SD, Levitan RM, Brindley PG. Front-of-neck airway meets front-of-neck simulation: improving cricothyroidotomy skills using a novel open-access three-dimensional model and the Airway App. *Can J Anesth*. 2017;64:1079-1081. doi:[10.1007/s12630-017-0926-9](https://doi.org/10.1007/s12630-017-0926-9)
6. Dharamsi A, Gray S, Hicks C, Sherbino J, McGowan M, Petrosoniak A. Bougie-assisted cricothyroidotomy: Delphi-derived essential steps for the novice learner. *CJEM*. 2019;21(2):283-290. doi:[10.1017/cem.2018.386](https://doi.org/10.1017/cem.2018.386)
7. Hall AB. Randomized objective comparison of live tissue training versus simulators for emergency procedures. *Am Surg*. 2011;77(5):561-565. doi:[10.1177/000313481107700514](https://doi.org/10.1177/000313481107700514)
8. So HY, Chen PP, Wong GKC, Chan TTN. Simulation in medical education. *JR Coll Physicians Edinb*. 2019;49(1):52-57. doi:[10.4997/jrcpe.2019.112](https://doi.org/10.4997/jrcpe.2019.112)