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Simulation of Adult Surgical Cricothyrotomy for Anesthesiology and Emergency Medicine Residents: Adapted for COVID-19

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Abstract

Introduction: In a CICO (cannot intubate, cannot oxygenate) situation, anesthesiologists and acute care physicians must be able to perform an emergency surgical cricothyrotomy (front-of-neck airway procedure). CICOs are high-acuity situations with rare opportunities for safe practice. In COVID-19 airway management guidelines, bougie-assisted surgical cricothyrotomy is the recommended emergency strategy for CICO situations. **Methods:** We designed a 4-hour procedural simulation workshop on surgical cricothyrotomy to train 16 medical residents. We provided prerequisite readings, a lecture, and a videotaped demonstration. Two clinical scenarios introduced deliberate practice on partial-task neck simulators and fresh human cadavers. We segmented an evidence-based procedure and asked participants to verbalize the five steps of the procedure on multiple occasions. **Results:** Thirty-two residents who participated in the workshops were surveyed, with a 97% response rate (16 of 16 from anesthesiology, 15 of 16 from emergency medicine). Participants commented positively on the workshop's authenticity, its structure, the quality of the feedback provided, and its perceived impact on improving skills in surgical cricothyrotomy. We analyzed narrative comments related to three domains: preparation for the procedure, performing the procedure, and maintaining the skills. Participants highlighted the importance of performing the procedure many times and mentioned the representativeness of fresh cadavers. **Discussion:** We developed a surgical cricothyrotomy simulation workshop for anesthesiology and emergency medicine residents. Residents in the two specialities uniformly appreciated its format and content. We identified common pitfalls when executing the procedure and provided practical tips and material to facilitate implementation, in particular to face the COVID-19 pandemic.

Keywords

Airway, Surgical Cricothyrotomy, Cricothyroidotomy, Front-of-Neck Airway Procedure, Anesthesiology, Simulation, Emergency Medicine, COVID-19, Virtual Learning

Educational Objectives

By the end of this activity, learners will be able to:

1. Identify a CICO (cannot intubate, cannot oxygenate) situation and the indications for emergent bougie-assisted surgical cricothyrotomy.
2. Justify, based on current scientific evidence, the choice between a bougie-assisted surgical cricothyrotomy and a needle-guided cricothyrotomy in CICO situations.
3. Select the necessary equipment for a surgical cricothyrotomy.
4. Correctly perform a bougie-assisted surgical cricothyrotomy in less than 60 seconds, reestablishing proper ventilation in an adult patient.
5. Apply objectives 3 and 4 in COVID-19 simulated adult cases (or similar pathogens with airborne transmission).

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Introduction

The daily practice of anesthesiology and acute care allows the acquisition and maintenance of the basic skills required for airway management (mask ventilation, supraglottic devices, intubation).[1] When these methods fail, a CICO (cannot intubate, cannot oxygenate) situation occurs.[2] The patient's life now depends on the physician's ability to provide oxygen quickly, often through an emergency cricothyrotomy, also called cricothyroidotomy

(front-of-neck access). The procedure recommended by the Difficult Airway Society is an open, bougie-assisted, surgical cricothyrotomy that includes the use of the scalpel.[3] Accordingly, in 2016, we developed a surgical cricothyrotomy simulation workshop for anesthesiology and emergency medicine residents.

Most anesthesiologists will use this procedure only once during their career because the risk of a CICO is one out of 50,000 general anesthetics.[4,5] Therefore, competence for the procedure cannot be learned in a clinical setting. It should instead be developed by using dedicated simulation activities and maintained through scheduled retraining.[6]

Multiple studies can be found on the use of simulation for cricothyrotomy training. The vast majority focus on needle-guided (nonsurgical) cricothyrotomy.[7-10] An example of a needle cricothyrotomy scenario can be found in *MedEdPORTAL*.[11] Studies with physicians in practice, however, have revealed the need for dedicated training of surgical cricothyrotomy. A recent survey on the methods preferred by anesthesiologists showed a clear preference for a needle-guided cricothyrotomy of 67%, far ahead of a surgical cricothyrotomy, preferred by 33% of respondents.[2] Two-thirds of respondents would delegate surgical cricothyrotomy to a surgeon. Only 10% of respondents would do it themselves.

In COVID-19 airway management guidelines, bougie-assisted surgical cricothyrotomy is the recommended emergency procedure for CICO situations.[12,13] It is recommended that physicians acting as airway operators be able to rapidly and autonomously perform a surgical cricothyrotomy.[12,13] Delays can occur if waiting for experts.[13]

We focused this workshop on airway management in CICO situations on bougie-assisted surgical cricothyrotomy that included the use of the scalpel. The limited number of steps, the high success rate, and the ubiquity of the equipment required supported our decision.[3] CICOs are high-acuity situations with rare opportunities for safe practice; hence, the use of a procedural simulation workshop was preferred.[6,14] We provided prerequisite readings, a lecture, and a videotaped demonstration. Two clinical scenarios introduced deliberate practice on partial-task neck simulators and fresh human cadavers.

Methods

Development

We designed 4-hour procedural simulation workshops for 16 residents. Workshop structure is presented in the Figure. We planned the workshops to occur twice over the course of the 5-year residency training in anesthesiology (i.e., second and fourth years, R2 and R4) and emergency medicine (R3 and R5). Participation in the workshop and in the quality assurance process (surveys) was mandatory in anesthesiology and optional in emergency medicine.

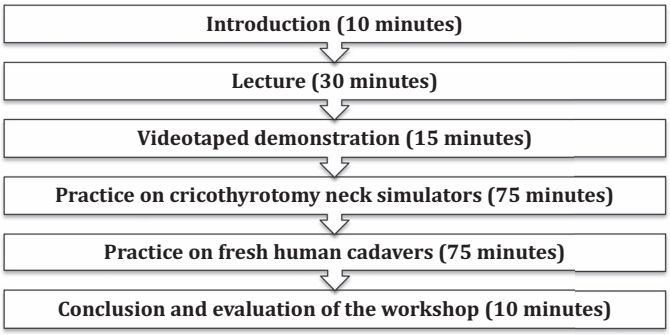

Figure. Flow diagram of the structure of the procedural simulation workshop on surgical cricothyrotomy.

The workshop was conducted in 2018 for 16 anesthesiology residents: eight R2s and eight R4s (i.e., all residents of those cohorts). Using the same format and material, the workshop was conducted in 2019 for 16 emergency medicine residents: nine R3s and seven R5s (i.e., all residents of those cohorts). In both programs, previous procedural training did not cover surgical cricothyrotomy.

Equipment/Environment

Procedural simulation took place in the Centre Apprentiss, the health sciences simulation center at Université Laval (Quebec City, Quebec, Canada). All the materials presented in this publication, including surveys and appendices, were translated from French and reviewed by bilingual authors with expertise in anesthesiology, simulation, and medical education.

As presented in Appendix A, we used four cricothyrotomy neck simulators with a double-layered human-like skin (Crico-Trainer Adelaide, VBM Medizintechnik). To limit costs, we used models allowing displacement of the just-made incision laterally after each attempt. Hence, our participants made new incisions on the same skin 10-20 times.

The workshop ended by practicing on four fresh human cadavers to familiarize students with the anatomy of the human neck and authentic tactile sensations. By shifting the skin 1 cm laterally and closing it with staples, it was possible to make on average five incisions per cadaver. The cricothyroid membrane was pierced only once.

Personnel

We designed this workshop for a maximum of 16 residents working in subgroups of four participants. We used one simulator for four participants rotating between different roles (one operator, one assistant, and two observers). Four qualified instructors supervised participants on the simulators. Instructors were anesthesiologists with advanced training in airway management in CICO situations. Two technical assistants set up all the equipment (average time of 1.5 hours) and were available during the simulation. The schedule is presented in Appendix B.

Implementation

Part one—prerequisite readings: The preliminary readings enabled the participants to identify CICO situations, make an evidenced-based decision between a surgical cricothyrotomy and a needle-guided procedure, and consolidate the steps of the procedure. The following selection was sent to participants 8 weeks before the workshop to allow sufficient time to integrate these new notions:

- Copy of Appendix C, created by the authors.
- Difficult Airway Society guidelines[3]: p. 828 (their figure 1), p. 833 (their figure 2), and pp. 835-838 ("Plan D: Emergency Front-of-Neck Access").
- Canadian Airway Focus Group recommendations[1]: p. 1095 (their figure 1), pp. 1100-1101 ("Failed Oxygenation During Attempted Tracheal Intubation: The Emergency Strategy"), and pp. 1106-1107 ("Emergency Surgical Airway" from "Summary of Recommendations").
- American Society of Anesthesiologists guidelines[15]: p. 257 (algorithm).
- We suggest adding the COVID-19 guidelines from the Difficult Airway Society.[12]
- Three studies selected for their practical impact.[5,16,17]
- Steps of the surgical airway checklist (Appendix D), developed by the authors based on the literature.
- Silent video demonstration (Appendix E), created by the authors.

Part two—lecture: A 30-minute lecture summarized the theoretical and practical aspects of bougie-assisted surgical cricothyrotomy (Appendices F and G):

- Indications.
- Airway management during the COVID-19 pandemic (added in 2020).
- Neck anatomy.
- Review of airway guidelines, recommendations, and supporting literature for choosing a surgical approach.
- Necessary equipment and the five steps of bougie-assisted surgical cricothyrotomy.
- What to expect when performing the procedure (visually, to the touch).
- Recommendations on the use of neuromuscular blockers and ultrasound in CICO situations.
- Human factors in CICO situations.

Part three—videotaped demonstration: We played the silent video demonstration of a surgical cricothyrotomy executed by a competent instructor performing the steps in the correct order and with the expected speed (Appendix E, video created by the authors). The video also provided a standard for self-assessment. We presented the video twice; the second time, an instructor interrupted the video to pinpoint important steps and pitfalls.

Part four—deliberate practice on neck simulators: We introduced the learners' practice on simulators and cadavers with two scenarios (Appendix H). For this publication, the second scenario has been adapted to the COVID-19 pandemic. Participants used cricothyrotomy neck simulators to practice the psychomotor skills needed for autonomous practice. To facilitate recall, the steps of the procedure were continuously displayed on screen, with a printed version of Appendix D placed on the workbench. When performing procedural simulation on neck simulators, participants followed three steps. First, the participant verbalized each step of the procedure, and the instructor then performed it. Second, the participant verbalized once more each step of the technical skill, but this time, on approval of the instructor, the participant performed it. Lastly, pairs of participants performed a cricothyrotomy, each taking turns assuming the roles of operator then assistant. Meanwhile, an instructor immediately corrected major errors, while limiting verbal interventions. Instructors debriefed in more detail at the end of each attempt.

Part five—deliberate practice on fresh human cadavers: During the first attempt and after the skin incision, digital dissection, and identification of the cricothyroid membrane, the operator stopped so that all other residents could palpate the cricothyroid membrane, thyroid and cricoid cartilages, and trachea. The operator then completed the procedure. The assistant next assumed the role of operator, and a new assistant was chosen from among the other residents. This rotation of roles was repeated until all residents had assumed both roles and for as long as the anatomic structures remained adequately preserved.

Assessment

Instructors assessed the number of procedures done by each participant (as the operator) on simulators and cadavers. A

countdown timer of 60 seconds was used to monitor each procedure.

For quality assurance, participants answered a web-based survey created with LimeSurvey. Surveys were sent via email immediately after the workshop and were all answered within 1 week. Formulated by a focus group of educators with expertise in simulation, questions were used for all procedural simulation workshops. An example of the postworkshop survey is provided in Appendix I.

The participants commented that the scale from −5 (*completely disagree*) to 5 (*completely agree*) used in 2018 was complex. In 2019, we changed it to a 4-point agreement scale (1 = *totally disagree,* 2 = *partly disagree*, 3 = *partly agree*, 4 = *totally agree*). We also simplified the wording of the questions. Open questions at the end of the survey asked for narrative comments on "What was, or was not, useful in this workshop" to prepare for the procedure, perform the procedure, and maintain the skills.

Follow-up assessments will begin in 2021, when the workshops are repeated, and every 2 years thereafter. This will allow us to synchronize the training of R2s and R3s and the assessment/retraining of R4s and R5s. Meanwhile, we emphasize the need to watch the video demonstration of the procedure and review the steps at least twice a year.

Results

In 2018, all 16 residents in anesthesiology (100% response rate) answered the quality assurance questionnaire. Results are presented in Table 1. In 2019, 15 residents in emergency medicine answered the new version of the questionnaire (94% response rate). Results are presented in Table 2.

Table 1. 2018 Postworkshop Survey Results for Anesthesiology Residents (*N* = 16)

Statement	*M* (*SD*)
The workshop made it possible to faithfully reproduce the actions necessary for performing the procedure in a real patient.[a]	4.7 (0.6)
The environment (physical places, material, equipment) was conducive to learning.[a]	4.7 (0.6)
The instructors actively ensured that I understood the concepts covered during the training activities.[a]	4.8 (0.5)
The organization and overall structure of this training session were adequate.[a]	4.7 (0.6)
My general opinion on this workshop is...[b]	4.7 (0.6)
My skills to perform a surgical cricothyrotomy before the workshop were...[b]	−1.1 (3.5)
My skills to perform a surgical cricothyrotomy after the workshop are...[b]	2.9 (1.4)

[a]Rated on an 11-point Likert-type scale (−5 = *completely disagree,* 5 = *completely agree*).
[b]Rated on an 11-point Likert-type scale (−5 = *very bad*, 5 = *excellent*).

Table 2. 2019 Postworkshop Survey Results for Emergency Medicine Residents (*N* = 15)

Statement[a]	*M* (*SD*)
The task and material were representative of authentic acute care practice.	3.8 (0.4)
The instructors provided timely and formative feedback.	3.9 (0.3)
The overall schedule of this training session was adequate.	3.9 (0.4)
Sufficient time was allocated for practice on the simulator.	3.7 (0.6)
The workshop improved my technical skills.	4.0 (0.0)

[a]Rated on a 4-point Likert-type scale (1 = *totally disagree*, 4 = *totally agree*).

We analyzed the narrative comments from 29 residents—15 in anesthesiology (2018) and 14 in emergency medicine (2019)—related to three domains: preparing for the procedure, performing the procedure, and maintaining the skills. Some participants suggested that the theory should be brief, focusing on the clinical (indications, advantages) and technical (anatomy, material, steps) aspects, using well-selected images. They mentioned that study results should be simplified and that the lecture should last no more than 30 minutes. They also highlighted the importance of performing the procedure many times and mentioned the representativeness of fresh cadavers. Responses related to the five-step approach were worded as "Easy to understand step-by-step instructions." Some participants mentioned the importance of having clinical scenarios to contextualize their practice. Participants stated that brief simulations should take place annually and the complete workshop twice in their residency to maintain their skills.

In 2018 and 2019, each participant (*n* = 32) performed five to 10 procedures on the neck simulator, depending on the participant's efficacy and the length of debriefings. In their last attempt on the simulator, all participants completed the procedure in less than 60 seconds. Participants performed, in the operator role, one or two procedures on the human cadaver. In their last attempt on the cadaver, all participants completed the procedure in less than 60 seconds. A supervisor was available for an extra 30 minutes on simulator if a participant needed more time to gain efficiency. None of the 2018-2019 participants needed extra time.

Discussion

We developed a simulation workshop on bougie-assisted surgical cricothyrotomy for 16 anesthesiology or emergency medicine residents. The literature on procedural skills simulation underpinned our choice of deliberate practice (i.e., practice that is purposeful and systematic) on partial-task neck simulators and cadavers.[6,14,18] Realistic scenarios provided clinical context. Residents in the two specialities provided positive comments on the workshop regarding its authenticity, its structure, and the

quality of the feedback provided. Participants perceived that this first workshop moderately improved their skills in surgical cricothyrotomy.

We chose a video demonstration to ensure optimal visualization for all, as opposed to an onsite demonstration with participants gathered around the instructor. We followed Mayer's[19] advice to reduce extraneous material and redundancy (i.e., adding text to narration). We filmed a silent video demonstration in a clean simulation setting and did not add on-screen text. An instructor added live verbal comments.

To rapidly execute an infrequently performed procedure, participants must instantly remember its basic steps and pitfalls. We used a didactic read-aloud checklist to reduce the number of omitted steps.[1,3,8] To facilitate processing in the working memory, the procedure was segmented into five steps.[19] Other checklists or global rating scales could be used.[20,21] Instructors corrected major errors immediately while deferring other comments for debriefing. Our goal was to focus feedback on process rather than exclusively on outcome.[14,18]

We identified common pitfalls (marked with an asterisk in Appendix D) on which instructors could focus their feedback. Participants should begin the procedure away from the simulator to practice the counterintuitive habit of standing on the left-hand side of the patient. Using double-layered skins, instructors can recognize that the cut is too deep if the second layer (usually red) is cut through. After cutting through the first layer (beige), participants should use digital dissection to locate the cricothyroid membrane. Holding the scalpel with the nondominant hand in a vertical position while pulling on it is essential to avoid blocking the opening when introducing the bougie.

Based on our experience and previous studies, we estimated that this lifesaving procedure should be completed within 60 seconds.[20] Time needed to achieve a patent airway in cricothyrotomy was measured as being between 38 and 123 seconds, with a failure limit around 300 seconds.[7,20,22] Using percutaneous cricothyrotomy simulators, Wong and colleagues[10] showed that after five attempts, 96% of participants were able to successfully perform a cricothyrotomy in 40 seconds or less. Likewise, all our participants were able to reach a target of 60 seconds after five to 10 attempts. Practicing the procedure on a fresh human cadaver further allowed learners to appreciate the effect of their actions on human-like tissues, especially the cricothyroid membrane.[17,23,24] To replace cadavers, other institutions could use porcine models.[25]

Limitations

Our results were based on self-reported comments of a limited number of participants as part of a nonvalidated quality assurance questionnaire. We did not assess participants' performance in the short or long term. Nevertheless, many studies using cricothyrotomy simulators have demonstrated the value of this educational method on success rates, length of procedure, or confidence.[7,8,10] Although well supported by theory, the superiority of deliberate practice for surgical cricothyrotomy is the focus of ongoing research.[26]

Our maximal number of 16 participants was based on the number of simulators and instructors available. We began at R2 in anesthesiology and at R3 in emergency medicine because we believed that the workshop was more useful if residents were proficient in basic airway management. However, in a study by Heymans and colleagues,[27] medical students simulated surgical cricothyrotomy with a 95% success rate.

Considering that CICO situations are rare, stressful events, training should be complemented by immersive simulation with proper debriefing on crisis resource management principles, as detailed in a previous *MedEdPORTAL* publication.[9] Siu and colleagues[20] proved that both age and years from residency graduation independently affected the ability to perform a percutaneous cricothyrotomy. For logistical reasons, we decided to schedule the workshop twice over the course of the residency. As suggested by some participants, more frequent assessment/retraining would prevent competency decay.[14,18]

Physical Distancing Recommendations

This workshop was designed and evaluated before the COVID-19 pandemic. Arrangements can be made to adapt the workshop to follow physical distancing recommendations. A separate simulation should validate the proper use of personal protective equipment for high-risk situations. We suggest giving the lecture using secure web conferencing. Only four participants at a time should practice, each with their own simulator, ideally in different rooms. Instructors could be watching at a distance (adjusted for local regulations). If available, a live video feed showing a close-up of each simulator would limit the need to be in close range to the trainee.

All material should be cleaned after each participant in accordance with local best practices. When available, instructors should follow the regulations regarding the use of fresh cadavers and animal models in the context of COVID-19 and refrain from using them in the meantime. If access to a simulation lab is restricted, the workshop could be given remotely using

telesimulation. The material could be given to participants as a take-out simulation box. Web conferencing and secure live video feeds could be used to guide the participants remotely. If a 3D printer is available, free open-access models of a larynx can be printed and distributed at a lower cost.[22] Assessing the feasibility, effectiveness, and educational impact of those measures opens a new area for scholarship and research.

Conclusion

We developed a surgical cricothyrotomy simulation workshop for anesthesiology and emergency medicine residents. Residents in two specialities uniformly appreciated its format and content. We identified common pitfalls when executing the procedure that instructors should pay close attention to. We provide practical tips and material to facilitate implementation, in particular to face the COVID-19 pandemic.

Appendices

A. Equipment.docx

B. Schedule.docx

C. Surgical Cricothyrotomy in CICO Situations.docx

D. Adult Surgical Cricothyrotomy Checklist.docx

E. Silent Video Demonstration.mp4

F. Presentation.pptx

G. Presenters Manual.docx

H. Two Clinical Scenarios.docx

I. Postworkshop Survey.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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Ethical Approval

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