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Emergency Surgical Airway Model for Procedural Skills Simulation

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ABSTRACT:

Audience: Emergency medicine medical students, interns, residents, fellows and attending physicians.

Introduction: Most residents graduate residency without having the opportunity to perform emergency cricothyrotomy in a real failed airway scenario. Simulation training is therefore often utilized to fulfill residents' procedural education. Animal tracheas are common models, but there is difficulty maintaining the unattached trachea in appropriate alignment and exposure. This manuscript outlines the materials and steps to reproduce a realistic, reusable cricothyrotomy simulation model and utilize it in training.

Objectives: At the end of this educational session, learners will be able to: 1) practice the manual and cognitive skills necessary to perform a successful and rapid surgical cricothyrotomy, and 2) successfully complete a cricothyrotomy within a time frame of 90 seconds.

Methods: Supplies from a local hardware store plus beginner woodworking skills and tools were used to build a pig trachea holding device. This simulation model has been used by the site's emergency medicine residents as a tool for procedural airway training since 2011. The inexpensive, reusable surgical airway model using a pig trachea holder and cadaveric skin is a useful, high fidelity procedural training tool. It has successfully fulfilled trainees' need to practice this rare but potentially life-saving procedure.

Topics: Cricothyrotomy, failed airway, simulation training.



USER GUIDE

List of Resources:

Abstract	39
User Guide	40

Learner Audience:

Medical Students, Interns, Junior Residents, Senior Residents, Fellows, Attending Physicians

Time Required for Implementation:

Preparation: approximately 30 minutes per unit

Didactics: 30 to 90 minutes

Learners per Instructor: 2:1

Topics:

Cricothyrotomy, failed airway, simulation training.

Objectives:

At the end of this educational session, learners will be able to:

1. Practice the manual and cognitive skills necessary to perform a successful and rapid surgical cricothyrotomy.
2. Successfully complete a cricothyrotomy within a time frame of 90 seconds.

Linked objectives and methods:

Emergency physicians must achieve mastery in emergent airway management. With proper planning and scaled approaches, intubation is often routine and usually successful. On rare occasion, a patient's presentation leads to a circumstance where the patient cannot be ventilated or intubated. A "failed" or "crash" airway defined as a "can't oxygenate, can't ventilate" situation requires an immediate cricothyrotomy. Emergency physicians must perform this low-frequency, high-stakes procedure with proficiency and equanimity.

The ACGME mandates that Emergency Medicine (EM) residents must be able to "competently perform all medical, diagnostic and surgical procedures considered essential for the area of practice." EM residents must demonstrate competence in performing key index procedures and invasive procedures including cricothyrotomy.¹

Many approaches and models for simulated cricothyrotomy have been attempted. Different animal tracheas and skin coverings, from artificial to natural, have been used. Some models are quite basic while others are complex and may include the ability to simulate bleeding into the model.² Some EM programs have used cadavers to teach the skill, but they are

extremely expensive and do not allow for multiple attempts per cadaver.

To achieve competency, speed, and skill retention for this critical procedure, most residency programs use a simulation model for teaching and practice.³ Wake Forest has historically used pig tracheas as models, but these have limitations. Without overlying skin, these models lack the reality of requiring the learner to locate key landmarks through skin and subcutaneous tissue. They are also difficult to stabilize in a way that mimics proper anatomic position during the procedure. In an attempt to address these limitations, a simple structure was developed to allow for both stability and for skin to lie over the pig trachea. This manuscript describes an educational advancement on how to build an inexpensive, reusable and very functional high-fidelity model for teaching surgical cricothyrotomy.

Goals: To develop the manual and cognitive skills necessary to perform a successful and rapid surgical cricothyrotomy. This goal can be measured by successful completion within a time frame of 90 seconds.

The goals and objectives can be achieved by this innovation by (1) demonstrating the procedure to learners, and (2) allowing learners to gain hands-on practice of the surgical cricothyrotomy. An instructor can observe the learner and determine if goals/objectives are being met by the learner.

Recommended pre-reading for instructor:

- Vissers RJ, Bair AE. Surgical airway management. In: Walls RM, Murphy MF, eds. *Manual of Emergency Airway Management*. 4th ed. Lippincott Williams & Wilkins: Philadelphia; 2012:193-220.
- Smith MD, Yealy DM. Surgical airways. In: Tintinalli JE, Stapczynski J, Ma O, Yealy DM, Meckler GD, Cline DM, eds. *Tintinalli's Emergency Medicine: A Comprehensive Study Guide*. 8th ed. New York, NY: McGraw-Hill; 2016:192-197.
- Davis DP, Bramwell KJ, Vilke GM, Cardall TY, Yoshida E, Rosen P. Cricothyrotomy technique: standard versus the rapid four-step technique. *J Emerg Med*. 1999;17(1):17-21. doi: 10.1016/S0736-4679(98)00118-8

Learner responsible content (LRC):

- Vissers RJ, Bair AE. Surgical airway management. In: Walls RM, Murphy MF, eds. *Manual of Emergency Airway Management*. 4th ed. Lippincott Williams & Wilkins: Philadelphia; 2012:193-220.
- Smith MD, Yealy DM. Surgical airways. In: Tintinalli JE, Stapczynski J, Ma O, Yealy DM, Meckler GD, Cline DM,



USER GUIDE

eds. *Tintinalli's Emergency Medicine: A Comprehensive Study Guide*. 8th ed. New York, NY: McGraw-Hill; 2016:192-197.

Implementation Methods:

The instructional session using this innovation can be implemented by itself, or in concert with other procedural training experiences. We recommend using this tool during a 20-30-minute station during a larger airway training experience with other stations.

List of items required to replicate this innovation:

Supplies from a local hardware store were used to build the high-fidelity surgical airway simulation models (each 10 inches long). Beginner woodworking skills and tools are REQUIRED to safely and easily build these models. The authors would like to stress for safety reasons that this is not a project for someone that has limited experience with a router or circular saw.

Supplies include:

- (1) ½" plywood or board measuring approximately 12 inches by 12 inches
- (2) untreated 2 x 4 lumber cut into 10-inch lengths
- (3) carpet tacking board cut in 10-inch lengths
- (4) 8 small L-shaped hooks
- (5) 4 thick (1/4-inch-wide) rubber bands
- (6) 2 wooden dowel rods ¼ inch diameter cut 10 inches long
- (7) 4-8 broad headed nails about 1 inch long
- (8) spray can of polyurethane.
- (9) Tools required for building the model include a router with ½ inch x 1-inch straight bit, a hammer, a nail setting punch, hand saw, drill with bit (optional), and pliers (optional).

Approximate cost of items to create this innovation:

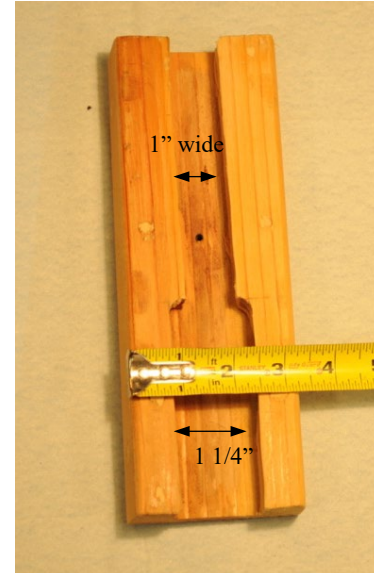
Approximately \$8 per unit

Detailed methods to construct this innovation:

Step 1: The Trachea Furrow

Start by using a router to create a 1-inch wide groove section ¾ of an inch deep longitudinally down the center of the 10-inch 2 x 4 piece of wood. This will leave 1 ¼ inches of wood on either side of the groove. Then use the router to widen each side of the previously made groove by an additional ¼ inch, but only approximately 4 inches in length from one end of the 2x4. This shape will allow the larger thyroid cartilage to fit securely into the groove. The groove is deep enough to hold the pig trachea, but shallow enough that the pig trachea will sit above the face of the 2 x 4 which allows palpation of the thyroid cartilage and cricothyroid membrane.

Figure 1: Building surgical airway model: Trachea Furrow



Step 2: The Tacking Strip

Secure the 1-inch wide carpet tacking strip into the bottom of the groove by using the hammer and nail setting punch with 2 or 3 nails. This strip will help prevent the pig trachea from moving while the procedure is being performed.

Step 3: The Hooks

Attach four of the L-shaped hooks down one long side of the 2 x 4 board. These hooks will hold the rubber bands used to secure the cadaveric skin and trachea to the mount. Position at approximately 1, 2, 8, & 9 inches along the length such that two are on each end of the 2 x 4. Be certain that the middle does not have a hook because this is where the cricothyroid membrane will be located. Position the hook close enough to the top surface of the 2 x 4 such that the L portion of the hook, when facing downward, is about 1/8 of an inch from the bottom of the board. This will allow room to place the rubber bands. Repeat this procedure on the opposite side. Predrilling the holes will make this step much easier.



USER GUIDE

Figure 2: Building surgical airway model: Tacking strip and hooks in place.



Step 4: The Platform

Attach the 12 inch x 12 inch wooden platform to the **back** of the 2 x 4 using 4-6 one-inch broad headed nails. Be careful to line the nails up with the edges of the 2 x 4 board so that they are hammered into the thickest part of the 2 x 4 to prevent protrusion into the area where the trachea will be located.

Figure 3: Building surgical airway model: Attaching the platform



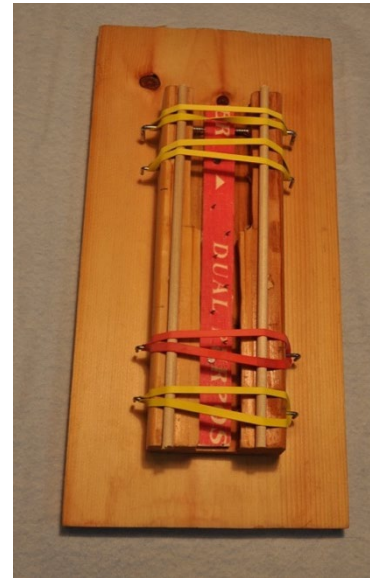
Step 5: The Dowel Rods

Cut the dowel rods to match the length of the 2 x 4 section (10 inches).

Step 6: The Rubber Bands

Attach four rubber bands down both sides of the L hooks on the 2 x 4. This figure shows how to store the model when not in use.

Figure 4: Building surgical airway model: Attaching the dowels and rubber bands



Step 7: The Pig Trachea

To utilize the board, place a pig trachea facing up into the groove. The widening of the groove should accept the larger thyroid cartilage. The carpet tack board will hold the pig trachea in place.

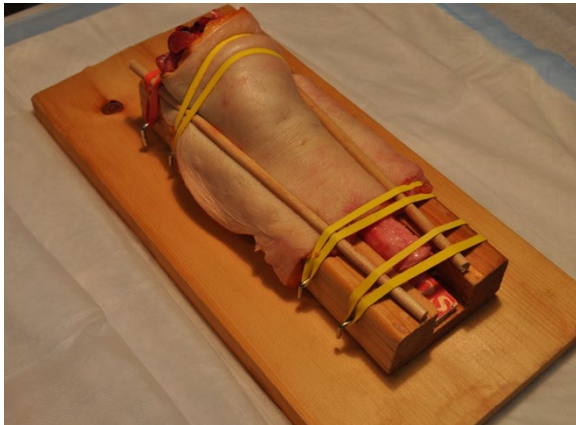
Step 8: The Skin

Place a 6-inch by 6-inch layer of skin (human cadaveric or pig) over the top of the pig trachea. This will simulate the skin over the cricothyroid membrane. Keep the skin taut and in place over the trachea by securing the dowel rods down with the rubber bands. By moving the skin up or down over the pig trachea and by using the inferior tracheal rings instead of the cricothyroid membrane, the model can be reused multiple times by a single trainee or by multiple trainees with one pig trachea.



USER GUIDE

Figure 5: Building surgical airway model: Setting up the model for use



Results and tips for successful implementation:

A survey was created to assess the model presented in this educational advance. Thirteen senior EM residents who rotated through the cricothyrotomy station rated the model on several areas, on a scale from 1 (completely disagree) to 5 (completely agree).

1. The surgical airway model was easy to use.
2. The surgical airway model offered a good simulation for performing a cricothyrotomy.
3. The surgical airway model gets in the way of doing the procedure.
4. The surgical airway model minimized my difficulty in performing a cricothyrotomy.
5. The surgical airway model enhanced my comfort level in performing a cricothyrotomy.

This study qualified for an Institutional Review Board exemption.

Learners had great benefit in performing this procedure multiple times. Each additional time the learner would set up the same model and trachea by rotating the skin ninety degrees. Though the cricothyroid membrane had already been incised and intubated previously the learners became more facile with the procedure with multiple repetitions.

Respondents rated the model an average of 4.54 (out of 5) on ease of use and 4.62 (out of 5) on whether or not it offered a good simulation. A response average of 1.85 suggests that the model did not impede procedural execution. On the issue of providing experience and reducing operator angst, the residents rated the model as 4.31(out of 5) for minimizing their difficulty performing the procedure and 4.69 (out of 5) for enhancing their comfort level.

With beginner level woodworking skills and tools likely already possessed by faculty/residents or staff at your institution, one person can build this trachea holder unit quickly and economically. It will hold the trachea in proper position and keep the skin over the trachea in place to simulate a real patient.

Over the years, small improvements have been made to the trachea holder. A great amount of consideration has been given to increase the model's fidelity. One example of this was the decision not to make the model bleed. Bleeding would obscure visualization of the entry site as well as increasing stress levels of the physician, but it would be very difficult to reliably simulate. The faculty felt that it would be more reasonable to cover the operating area with a towel to force the trainees to perform the skill without being able to see structures within the initial incision made. This would be preferred over blind folding the trainee so they can still access the instruments they need.

If additional pig or cadaveric subcutaneous fat is purchased, this model allows for different amounts of subcutaneous fat to be in place to make the procedure more challenging and more realistic. Determining success is easy because the tube will be seen in the trachea when turned up on its end.

This model has been tested utilizing several methods to perform the cricothyrotomy including open cricothyrotomy with and without a flexible tracheal introducer (eg, bougie), closed cricothyrotomy using needle and Seldinger technique, and the published 4-Step technique to cricothyrotomy.⁴

References/suggestions for further reading:

1. Accreditation Council for Graduate Medical Education. ACGME Program Requirements for Graduate Medical Education in Emergency Medicine, IV.A.5.a).(2).(c).(vi). http://www.acgme.org/Portals/0/PFAssets/ProgramRequirements/110_emergency_medicine_2017-07-01.pdf. Accessed July 11, 2017.
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3. Custalow CB, Kline JA, Marx JA, Baylor MR. Emergency department resuscitative procedures: animal laboratory training improves procedural competency and speed. *Acad Emerg Med*. 2002;9(6):575-586. doi: 10.1111/j.1553-2712.2002.tb02294.x
4. Davis DP, Bramwell KJ, Vilke GM, Cardall TY, Yoshida E, Rosen P. Cricothyrotomy technique: standard versus the rapid four-step technique. *J Emerg Med*. 1999;17(1):17-21. doi: 10.1016/S0736-4679(98)00118-8