

Edible Cricothyrotomy Model: A Low-Cost Alternative to Pig Tracheas and Plastic Models for Teaching Cricothyrotomy

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ABSTRACT:

Audience: This edible cricothyrotomy trainer is designed to teach residents and faculty the procedure of cricothyrotomy.

Introduction: Cricothyrotomy is an essential procedure for any provider in the emergency department where the estimated incidence of a failed airway leading to surgical airway is 0.5%.^{1,2,3} It is challenging to obtain cost-effective and realistic models to train clinicians and provide further opportunities for practice and skills maintenance.

We created a novel edible cricothyrotomy (EC) model that is made entirely of edible materials, other than the trachea, which is represented by a piece of ventilator tubing. There is a tortilla base layer, with great vessels represented by colored licorice, thyroid cartilage made from Hershey's chocolate, cricoid from gummy worm, and fruit leather platysma topped with an additional tortilla to complete the skin layer.

Objectives: At the end of this educational session, learners will be able to: 1) list the steps involved in performing a cricothyrotomy, 2) identify the laryngeal landmarks necessary to perform a successful cricothyrotomy, 3) successfully perform a cricothyrotomy, 4) deliberately practice to perform the procedure quickly and safely.

Method: An edible cricothyrotomy model was built for each participant from the ingredients listed above. An educational session was developed to test the EC in comparison to the more traditional pig trachea (PT) and plastic model (PM). A pre- and post-survey was administered to participants to assess the usability and realism of the models as well as the learners' comfort with the procedure. During the session, a lecture was given, and then participants rotated to all three models and were videotaped and timed performing a scalpel-finger-bougie cricothyrotomy. Times to successful completion, participant satisfaction with the models, and cost of the models were compared.

INNOVATIONS

Results: 43 participants completed the educational session. All completed the pre-survey and 40 of 43 completed the post-surveys (93% response rate). Times to complete a cricothyrotomy were faster for PT (median 32 sec, Interquartile Range [IQR] 24-41 sec) and PM (median 33 sec, IQR 28-39 sec) than on the EC (44 sec, IQR 35-63). There was a statistically significant divergence in preference ($p=0.0001$) with participants rating the PT first (median rank 1, IQR 1-1), the EC second (median rank 2, IQR 2-2), and the PM third (median rank 3, IQR 2.5-3). Cost of the models at the time of analysis (October, 2104) was \$2.77 for EC and \$7.64 for PT. The plastic model was built from materials obtained in the emergency department (ventilator tubing, 4-inch white foam tape, ½ inch white tape, and Coban.) These materials were not purchased, so cost per plastic model was not calculated.

Conclusion: A novel, edible cricothyrotomy training model is a suitable and cost-effective alternative to a pig trachea and has a role for learners seeking multiple attempts at the procedure for skills maintenance and retention.

Topics: cricothyrotomy, airway management, critical procedures.



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Learner Audience:

Medical students, interns, junior residents, senior residents, faculty

Time Required for Implementation:

Each model takes approximately five min to construct. These can be constructed prior to the learning session, or participants can build the models during the session. The benefit of building the model during the session is the improved awareness of anatomical structures in and around the larynx.

The edible cricothyrotomy session will require one hour of prep time prior to the session to set up the room and open the various ingredient packages to facilitate shorter build times for the participants.

An ideal session would be one hour in length. This would give time for a 20-minute didactic session on the procedure of cricothyrotomy, then 40 minutes for practice. Each participant can perform multiple cricothyrotomies during this time.

Recommended Number of Learners per Instructor:

15:1

Topics:

Cricothyrotomy, airway management, critical procedures.

Objectives:

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

1. List the steps involved in performing a cricothyrotomy
2. Identify the laryngeal landmarks necessary to perform a successful cricothyrotomy
3. Successfully perform a cricothyrotomy
4. Deliberately practice to perform the procedure quickly and safely

Linked objectives and methods:

This format provides short term, spaced repetition, with a didactic description of the procedure, then a video-based demonstration, then a live demonstration, then deliberate practice with immediate feedback.

Recommended pre-reading for instructor:

- The instructor should prepare a 20-min didactic session covering the indications, contra-indications, and technique of cricothyrotomy.

- The instructor will need to have practiced assembling and using the edible cricothyrotomy model prior to the session.

Learner responsible content (LRC):

- The learners should review the edible cricothyrotomy video prior to the session.
 - <https://youtu.be/SqpYf0P41Vs>

Implementation Methods:

- Instructor gives 20-min didactic session covering the indications and technique of surgical cricothyrotomy.
- Instructor plays the video demonstrating how to build the edible cricothyrotomy.
 - <https://youtu.be/SqpYf0P41Vs>
- Instructor supervises learners building the edible cricothyrotomy model.
- Instructor supervises and provides feedback while learners practice cricothyrotomy.

List of items required to replicate this innovation:

Equipment: (per model) All of the items other than the ventilator tubing can be purchased at Target™.

- Ventilator tubing (approx. 6-8 inches)
- 2 Mission™ flour tortillas (medium size) (This brand works better, and is more 'skin-like' than other non-flour based, or thinner tortillas.)
- 2 paper plates
- Peanut butter (3 oz.)
- Hershey's™ chocolate, 3 mini bars. (The size and shape of these work better than other brands)
- One square marshmallow
- One gummy worm
- 2 pieces red rope licorice
- 2 pieces black or chocolate Licorice
- 1 red fruit leather square or fruit roll-up
- 1 inch of red cake frosting (from squeezable tube, see video)

The ventilator tubing can be obtained from most respiratory therapy departments, and then cut into 6-8 inch sections.

Approximate cost of items to create this innovation:

Other than the vent tubing, the cost per model is \$2.77 for an edible cricothyrotomy. This compares favorably to the cost of a single use pig trachea (\$7.64). The plastic model was built from materials obtained in the emergency department (ventilator tubing, 4-inch white foam tape for skin, ½ inch white tape wrapped in multiple layers for cricoid, and Coban tape wrapped in multiple layers for thyroid cartilage.) These materials were not purchased, so cost per plastic model was not calculated.



USER GUIDE

Detailed methods to construct this innovation:

See YouTube video for demonstration of construction and use:

- <https://youtu.be/SqpYfOP41Vs>

Step One:

Place one tortilla on one of the paper plates.
Spread a generous layer of peanut butter to act as 'glue' for the pieces of the model.

Step Two:

Place the vent tubing in the middle of the peanut butter. Apply peanut butter to the sides, and anterior surface of the area that will become the larynx.

Step Three:

Apply two Mini Hershey's™ chocolate bars along the sides of the vent tubing to form the lamina of the thyroid cartilage; then apply one Mini Hershey's™ chocolate bar to form the anterior portion of the thyroid cartilage.

Step Four:

Place the gummy worm below the thyroid /chocolate cartilage, leaving about a 1 cm gap to form the cricothyroid membrane.

Step Five:

Place one piece of red and one piece of black licorice on each side of the chocolate /gummy larynx to represent the carotid artery and internal jugular vein.

Step Six:

Tear along the mid portion of the square marshmallow to simulate the thyroid isthmus, and place this below the gummy worm. (see Figure 1. Image of edible cricothyrotomy before adding platysma.)

Step Seven:

Spray a one inch line of red cake frosting in the cricothyroid membrane space between the chocolate thyroid and gummy worm cricoid cartilage.

Step Eight:

Layer the fruit leather (platysma) and then second tortilla over the model.

Step Nine:

Mark the inferior (tracheal) aspect of the plate to orient users, and place the second plate over the model, then place in a gallon size zip lock bag. Model should remain fresh and useable for 24 hours. Drawing a face on the second paper plate can help further orient the user and add some better anatomic familiarity to the simulated procedure.



Figure 1. Edible cricothyrotomy model showing trachea (vent tubing), great vessels (licorice), thyroid cartilage (Hersheys bars), cricoid cartilage (gummy worm), and thyroid gland (marshmallow)

Methods:

An educational session was developed to review the cricothyrotomy procedure and compare the edible cricothyrotomy (EC), pig trachea (PT), and plastic models (PM). This occurred during 2 hours of weekly didactic teaching conference in which EM residents, faculty, advance practice clinicians, and rotating medical students participate. Participants were asked to complete a pre-and post-survey evaluating their airway experience and the realism and usability of the three models. Questions for the pre-and post-survey were similar in format to other studies comparing models, cadavers, and manikins for cricothyrotomy studies.^{4,7,8}

A twenty-minute didactic presentation was given covering the indications, anatomy, and technique of open surgical cricothyrotomy. Participants were taught the scalpel-finger-bougie rapid 4-step technique for cricothyrotomy.⁹ The participants then rotated to 3 surgical airway stations each featuring PT, EC, or PM. The groups were mixed to include equal proportions of students, residents, and faculty to facilitate a supportive learning environment. The pig models were obtained from a medical supply company (<http://www.enasco.com/product/LS03612>). They were assembled in a similar fashion to that described by Petteneo et al.¹⁰: The pig tracheas were placed into notched green florist



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foam blocks (www.michaels.com product no. 46501408914), and white foam tape was placed over top to simulate the skin. The 4" foam tape for the skin was used for both the porcine and plastic models.

Three groups were formed. Each group was assigned a starting model, then rotated through the models in the same order. Participants were videotaped and timed during their attempts at cricothyrotomy using the scalpel-finger-bougie rapid 4-step technique.⁹

Participants were asked to provide feedback on the educational session and the models used.

Results:

A total of 43 participants completed the surgical airway lab. Pre-surveys were completed by all, and post-surveys were completed by 40 of the 43 participants (93% response rate). Participants consisted of 12 4th year medical students, 1 EM nurse practitioner, 21 EM residents and 9 EM attending physicians.

Data were entered into an Excel spreadsheet (Excel for Mac 2011 version 14.5.8, Microsoft Corp, Redmond, WA), then imported into Stata statistical software for analysis (Stata/IC 14.1 for Mac, StataCorp, College Station, TX). Variables are summarized as means \pm standard deviation or medians \pm interquartile range (IQR) according to the underlying distribution. Proportions were compared using Fisher's exact test. To compare participant rankings of the three models and times to successful completion, we performed the Kruskal-Wallis equality-of-populations rank test. Where pre- and post-measurements were performed, we report mean differences with their 95% confidence intervals. We considered a p value of <0.05 to be statistically significant. All reported p values are two sided.

When participants rated their comfort performing the procedure in a clinical setting, the average level of comfort (1 very uncomfortable, 5 very comfortable) improved from 2 ± 1 on the pre-survey to 3.5 ± 1 on the post-survey. The number of participants feeling very uncomfortable with the procedure decreased from 11/41 (27%) to 1/40 (2.5%), $p > 0.0001$. The number of participants feeling comfortable with the procedure increased from 5/41 (12%) to 18/40 (45%), $p < 0.0001$.

Despite the material for the skin on both the PT and PM being represented by the same material (foam tape) the scoring for realism of skin turgor was significantly different (3.600 for PT vs 2.025 for PM).

Times to perform cricothyrotomy were similar using the pig model (median 32 sec, Interquartile Range [IQR] 24-41 sec) or the plastic model (median 33 sec, IQR 28-39 sec, $p = 0.51$ for pairwise comparison) and were both faster than the edible model (44 sec, IQR 35-63, $p = 0.0001$ both pairwise comparisons).

When asked to rank their preferred future training model if only one model were available participants showed a preference for the pig model (median rank 1, IQR 1-1) over the edible model (median rank 2, IQR 2-2) and the plastic model (median rank 3, IQR 2.5-3). The observed divergence in model preference was statistically significant (Kruskal-Wallis $p = 0.0001$).

The cost per edible model was \$2.77 compared to \$7.64 per pig model, which includes the \$1.26 for the plate and florist block. Thus, for the cost of the pig model students can perform 2.75 cricothyrotomies on the edible model.

Discussion:

Our study found that a novel edible cricothyrotomy model was an inexpensive but feasible model for procedural education of EM providers. Many models have been proposed and studied, and we sought to identify an easy to make, easy to use model that could be easily reproduced.^{4,7,8,10} In order to evaluate our model we needed to compare it to other models and found that, similar to previous studies, the pig model was preferred. A previous study found that the pig model was a more useful training tool than the manikin model for cricothyrotomy when using a percutaneous cricothyrotomy kit.⁷ This demonstrates a need for a cost-effective, anatomically correct alternative to the manikin model.

Other models utilized to increase the accuracy of animal tracheas include the use of synthetic skin placed over bovine tracheas and using a combination of plaster molds and silicone skin to increase the fidelity of low fidelity procedural trainers using sheep tracheas.^{8,10} Residency programs and are increasingly required to identify ways to provide cost-effective education and our edible cricothyrotomy model presents a relative cost savings over the pig model.

When teaching medical procedures two goals should be considered: the realism of the procedure, and the acquisition of muscle memory when performing the procedure. In this comparative airway lab, the study subjects clearly favored the pig model for realism. For further skill acquisition and the development of muscle memory that comes from performing multiple iterations of the same procedure, it is feasible to consider the use of a cheaper model to allow multiple attempts at a lower cost.



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Limitations:

This was a single center study with a small sample size. The participants knew that they were being timed, and this may have affected the study in two different ways: the participants may have attempted to perform the procedure faster than they would have in an actual clinical scenario, been more prone to errors, and as a result could have taken longer than they would have in a clinical scenario.

Tips and Reflections:

All participants liked the absolute anatomical realism of the pig trachea; this is likely the reason the PT was rated first. But for a cost-effective, fast, and clean refresher for the procedure the edible cricothyrotomy model is ideal. With careful palpation, there was no difficulty with landmark identification on the edible model. Some participants had difficulty orienting the model because the superior and inferior borders of the model feel similar. Therefore, having the models oriented appropriately with the “face plate” identifying the superior end of the model is helpful. The edible models were reasonably resilient to firm pressure, but did tend to break apart when excessive force was used. The items that were most likely to break were the chocolate bars. When performing this activity in a warm environment it is advisable to refrigerate the chocolate bars prior to use. The vent tubing is very supple, and provided the cricothyroid membrane incision was made large enough, there was no difficulty passing the ET tube over the bougie. Situations where the incision was not big enough brought up the good procedural point of the need for an adequate incision. With the non-dominant hand stabilizing the edible model, the plates did not slide around.

Conclusions:

This comparative observational study shows that the novel educational innovation of an edible cricothyrotomy model is a suitable and cost-effective alternative to pig tracheas and plastic models for teaching the procedure of surgical cricothyrotomy. Although pig tracheas are the preferred tool to use when learning / practicing surgical cricothyrotomy, they cost almost three times as much as their edible counterpart. The edible cricothyrotomy model has a role for learners seeking multiple attempts at the procedure for skills maintenance and retention.

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