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A novel simulation model for tube thoracostomy

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Abstract

Objective: Tube thoracostomy is a life-saving procedure that must be performed competently and expeditiously by emergency care providers. The primary objective of this project was to develop a simple, easily-reproducible, and realistic simulation model for tube thoracostomy placement by learners of emergency medicine.

Methods: This chest tube simulator utilizes two slabs of pork ribs with associated intercostal muscle and fascial planes to aid learners in identifying anatomic landmarks, palpating intercostal spaces, and performing blunt dissection in a manner that approximates human anatomy. Holes are cut on both sides of a 1.8-bushel capacity rectangular plastic clothing hamper, and rib slabs are secured to the hamper with zip ties or metal wire. A bed pillow with plastic cover is then placed inside of the plastic hamper to simulate lung tissue. The rib-hamper complex is then wrapped with cellophane or elastic compression bandages to further anchor the rib slabs and simulate skin and subcutaneous tissues.

Results: The initial cost of our thoracostomy model is approximately $50, much less than the $1,000–$3,000 cost for a commercial model. Although the hamper and pillow can be reused an indefinite number of times, the other components of our model must be replaced occasionally. Assuming a lifespan of 1,000 uses, our model costs approximately $1.78 per attempt, compared to $4.00 per attempt with the cheapest commercial mannequin system. In fact, assuming a longer useful lifespan for the mannequin does not substantially improve this comparison (e.g. $3.10 versus $1.77 per attempt for a 10,000 attempt lifespan for the commercial mannequin), largely due to the higher cost of commercial replacement skin pads when compared to the components consumed in our model with each attempt.

Conclusions: We describe a porcine thoracostomy model that simulates the look and feel of human ribs for purposes of tube thoracostomy training, although it could also be used for thoracentesis and thoracotomy simulation. This model is relatively cheap (costing around $50) and easy to produce within a few minutes utilizing commonly-available materials. Further study is needed to determine whether an inexpensive model like ours provides the same educational value as more expensive commercial mannequin models.

Keywords

Education, teaching, training, thoracostomy, chest tube, simulation, pneumothorax

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Introduction

Chest tube insertion is a potentially life-saving procedural skill that must be performed competently and expeditiously by healthcare providers. It can be used to treat a wide variety of medical conditions, including pneumothorax, hemothorax, chylothorax, empyema, and esophageal rupture into the pleural space.[1,2] However, chest tube placement can also lead to ineffective decompression of the pleural space or even life-threatening visceral and vascular injury if performed improperly. Between 3% and 26% of chest tube placements are complicated by an adverse event, and many are attributable to poor placement technique.[3–10] This underscores the need for improved techniques for training learners in performance of this procedure, including simulation.[11,12] Unfortunately, those chest tube simulators that have been previously reported in

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the literature are either expensive or do not offer a realistic simulation experience.[13,14]

Commercially-available chest tube simulator models range in price from $1,000 to $3,000 for the mannequin, with an additional $75–$100 per unit for replacement surgical skin pads. In order to provide a realistic experience, these surgical skin pads must be replaced frequently. The cost of these models requires a substantial initial investment for the base model with a cost for replacement pads that is greater than the entire cost of the proposed model described in this report. Here we describe an economical device that has a "life-like" feel very similar to human tissues, and it is both easy and inexpensive to produce.

Objective

The primary objective of this project was to develop a simple, easily-reproducible, and realistic simulation model for tube thoracostomy placement by learners of emergency medicine.

Methods

The nature of this study was to create a low-cost, high-fidelity simulator model for tube thoracostomy placement for learners of emergency medicine. This chest tube simulator utilizes two slabs of pork ribs with accompanying intercostal muscle and fascial planes. This representation of chest wall anatomy allows the learner to locate landmarks, palpate intercostal spaces, and perform blunt dissection, featuring a palpable "pop" with penetration into the simulated pleural space. Holes are cut on both sides of a 1.8-bushel capacity rectangular plastic clothing hamper, and the rib slabs are secured to the hamper with zip ties or metal wire. The rib-hamper complex can then be wrapped with cellophane or elastic compression bandages to further secure the rib slabs and simulate skin and subcutaneous tissues (Figure 1). Additonal materials can be applied more superficially to better simulate skin, including fabric, leather, chamois, and even neoprene (Figure 2). If the instructor wishes to produce a more realistic skin and subcutaneous tissue, pigskin with or without underlying pork belly from a local butcher could be used to allow the learner to practice securing the chest tube to real skin tissue. A bed pillow with plastic cover is placed inside of the hamper to simulate lung tissue (Figure 2). A plastic bag with clear or red-colored fluid inside can be taped on the inside of the hamper to simulate pleural effusions or hemothorax, although we did not do this in our model. Although the pork ribs are discarded after a certain number of attempts, the plastic hamper may be disinfected, cleaned, and reused for an indefinite number of attempts. The total time required to set up this simulation model is approximately 20 min. The materials required for construction of the simulation model are provided below in Table 1.

Figure 1. View of the thoracostomy simulation model, showing rib slabs anchored to the plastic clothing hamper and covered with polyethylene food wrap, prior to application of the simulated "skin" layer and outer coverings.

Figure 2. View of the thoracostomy model showing the outer elastic bandage covering ("skin") externally, as well as a pillow surrounded by plastic bag placed within the plastic clothing hamper to simulate lung and parietal pleura.

Table 1. Materials needed for initial construction of the simulation model, including approximate costs.

Material	Cost
Plastic rectangular clothing hamper (1.8-bushel capacity, $20 \times 13 \times 24$ inches)	$10
Pork spareribs (3 pounds each) $\times 2$	$20
Pillow (20×26 inch) with plastic casing	$10
ACE bandage (6-inch width)	$10
Total	$50

This study did not involve live animals, and the pork ribs and plastic hamper used in this study were purchased at a local grocery store.

Table 2. Estimated cost per thoracostomy attempt using the proposed thoracostomy model, for the first 1,000 attempts.

Material	Cost	Lifespan (# of attempts)	Cost/attempt (1,000 attempts)
Plastic rectangular clothing hamper	\$10	1,000	\$0.01
Pork spareribs (3 pounds each) ×2	\$20	24	\$0.83
Pillow (20 × 26 inch)	\$10	1,000	\$0.01
Plastic pillow casing (or plastic bag replacement)	\$0.10	1	\$0.10
ACE bandage (6-inch width)	\$10	12	\$0.83
Total	\$50	n/a	\$1.78

Results

While the initial cost of our thoracostomy model is approximately \$50, much less than the \$1,000–\$3,000 cost of the commercial model, longevity of the model must also be considered in estimating cost per attempt. In our model, the useful lifespan of the clothing hamper is near infinite, as long as the hamper is cleaned and sterilized adequately after each session, although we will claim 1,000 chest tube insertions as the lifespan for purposes of calculating comparison data. On average, pork spareribs have 12 intercostal spaces, so each pair of ribs can accommodate at least 24 (but usually more) insertions without compromising tissue quality. The pillows can last a near infinite amount of time, as they can be laundered at home and reused, and the plastic pillow casing can be replaced with any small garbage bag that is made to be airtight. Again, we will assume 1,000 chest tube insertion lifespan for the pillows, and assume that the plastic casing is replaced for each insertion (though it need not be). The 6-inch ACE bandages can be purchased for \$2–\$10 each, depending upon the manufacturer. For purposes of calculating a "per insertion" cost, we have assumed the highest identified cost for our model and the lowest identified cost for the commercial simulator. The estimated per cost insertion for our model (assuming a 1,000 insertion lifespan for the hamper and pillow) is about \$1.78 per insertion (Table 2).

Manufacturers of commercial models and replacement skin pads do not report the useful lifespans of their devices, but our experience has been that commercial skin pads (which cost \$15–\$20 each) have a lifespan of approximately five uses. After this time, the synthetic tissue is too badly damaged to provide much resistance, and skin pads can only be rearranged a limited number of times before they are no longer useful. The lifespan of a commercial thoracostomy mannequin is unknown, but we believe it is likely the same as the lifespan of a properly cared-for plastic clothing hamper—in this exercise, we will assume 1,000 uses. Using these estimates, the "per insertion" cost of the cheapest available commercial mannequin would be \$4.00 per attempt, with most of the cost (\$3.00 per attempt) used to purchase replacement skin pads. Assuming larger lifespans for the mannequin/hamper does not improve this comparison. At a lifespan of 2,000 uses, the cost per attempt for our model does not change substantially (\$1.77), while the cost for the commercial system only decreases to \$3.50 per insertion. Assuming 10,000 uses, the commercial cost decreases to \$3.10 per attempt, which is still far greater than the cost for our model (\$1.77).

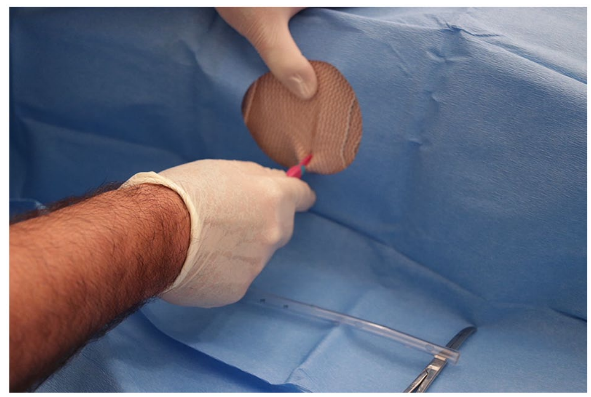

Figure 3. View of the thoracostomy model, showing initial incision being made through aperture in sterile field.

Discussion

Cadaveric simulation has been shown to be superior to non-cadaveric simulation in tube thoracostomy training, presumably due to improved landmark and tissue fidelity.[13,14] The pork-rib model presented here is able to provide the tissue fidelity and land marking of the cadaveric model without the expense normally seen with this approach. Our group has used this simulator with great success in a variety of medical student and EM categorical resident training sessions, adding blue drapes and a mannequin head to the model for increased simulation effect (Figure 3).

The primary advantage of our model over commercially-available simulators is the low cost of the proposed model (\$50) compared to a cost of \$1,000 to \$3,000 for commercial simulators. Also, most of the materials needed to construct this model are readily available, and cost very little to replace when necessary. The plastic hamper frame is reusable, although it should be sterilized thoroughly between uses, which is a small disadvantage over synthetic models. However, pork ribs provide a texture and feel that is more similar to human muscle and bone than the foam and rubber skin pads used by commercial simulators, and learners can reuse the ribs at different intercostal levels allowing each set of ribs to provide up to a dozen thoracostomy attempts before they must be discarded. Once cut and separated, synthetic materials retain a noticeable gap in the tissue, which makes subsequent placement attempts less realistic. Natural soft tissues, on the other hand, retain some degree of soft tissue memory that allows the muscle tissue to more closely re-approximate anatomic alignment after each tube placement and removal. Holes in the simulated pleura (i.e. plastic bag encasing the pillow) can also be taped over to allow for subsequent insertion attempts. While a cadaveric model is the gold standard for realistic thoracostomy simulation, human cadavers are not portable, readily available for all learners, or easily repairable for subsequent procedure attempts.

There are limitations to our model, of course, including the need to thoroughly clean and sanitize the hamper and pillow between uses, to prevent bacterial growth due to contamination from the pork animal products. Some skill learners or teachers may object to the use of animal products in this training model, although we have not encountered any such objections in our experience with the technique. While commercial thoracostomy simulators offer a synthetic human torso with other anatomic landmarks (e.g., clavicle, breast nipple, axillary anatomy, etc) that are important in the identification of the appropriate insertion site, our model does not provide these visual cues for insertion site selection, which is another potential limitation of our model. The proposed model also has more parts than most commercial models, which necessitates more time and effort to assemble. The most obvious limitation to our cost analysis is the lack of data on longevity of thoracostomy skill training mannequins or replacement pads from the device manufacturers or other users of these models. Costs for materials may also differ in different geographical regions, which could influence the overall cost of the model. However, we have tried to use conservative estimates of cost in our calculations to minimize the effects of such differences.

Conclusions

This model utilizes pork ribs to simulate the look and feel of human ribs for purposes of thoracostomy tube placement training. Thoracentesis and thoracotomy could also be readily performed with this model. Cost and convenience are important considerations in the development of a tissue simulator. This model is relatively cheap, costing around $50, and is easy to produce in a few minutes with commonly-available materials, and it is much cheaper than available simulation models. Further study is needed to determine whether low-cost simulation models like ours provide the same educational value as more expensive commercially-available simulator models.

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None.

Author contribution

SK developed the educational intervention, provided the images, and participated in the writing and editing of the manuscript. JHP and MAV participated in the writing and editing of the manuscript.

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References

1. Dev SP, Nascimiento B Jr, Simone C, et al. Videos in clinical medicine. Chest-tube insertion. *N Engl J Med* 2007; 357: 15.
2. Kirsch T and Sax J. Tube thoracostomy. In: Robert JR, Custalow CB, Thomsen TW, et al. (eds.) *Robert and hedges clinical procedures in emergency medicine*. 6th ed. Philadelphia, PA: Elsevier, 2014, pp. 189–211.
3. Sethuraman K, Duong D, Mehta S, et al. Complications of tube thoracostomy placement in the emergency department. *J Emerg Med* 2008; 40(1): 14–20.
4. Kwiatt K, Tarbox A, Seamon M, et al. Thoracostomy tubes: A comprehensive review of complications and related topics. *Int J Crit Illn Inj Sci* 2014; 4(2): 143–155.
5. Etoch SW, Bar-Natan MF, Miller FB, et al. Tube thoracostomy: factors related to complications. *Arch Surg* 1995; 130(5): 521–526.
6. Baldt MM, Bankier AA, Germann PS, et al. Complications after emergency tube thoracostomy: assessment with CT. *Radiology* 1995; 195(2): 539–543.
7. Hernandez MC, Laan DV, Zimmerman SL, et al. Tube thoracostomy: increased angle of insertion is associated with complications. *J Trauma Acute Care Surg* 2016; 81(2): 366–370.
8. Filosso PL, Guerrera F, Sandri A, et al. Errors and complications in chest tube placement. *Thorac Surg Clin* 2017; 27(1): 57–67.
9. Mao M, Hughes R, Papadimos TJ, et al. Complications of chest tubes: a focused clinical synopsis. *Curr Opin Pulm Med* 2015; 21(4): 376–386.
10. Reed RC, Waters BL and Siebert JR. Complications of percutaneous thoracostomy in neonates and infants. *J Perinatol* 2016; 36(4): 296–299.
11. Chung TN, Kim SW, You JS, et al. Tube thoracostomy training with a medical simulator is associated with faster, more successful performance of the procedure. *Clin Exp Emerg Med* 2016; 3(1): 16–19.
12. Hishikawa S, Kawano M, Tanaka H, et al. Mannequin simulation improves the confidence of medical students performing tube thoracotomy: a prospective, controlled trial. *Am Surg* 2010; 76(1): 73–78.

13. Takayesu JK, Peak D and Stearns D. Cadaver-based training is superior to simulation training for cricothyrotomy and tube thoracostomy. *Intern Emerg Med* 2017; 12(1): 99–102.
14. Hall AB. Randomized objective comparison of live tissue training versus simulators for emergency procedures. *Am Surg* 2011; 77(5): 561–565.