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Education

EMERGENCY DEPARTMENT THORACOTOMY: A COST-EFFECTIVE MODEL FOR SIMULATION TRAINING

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☐ **Abstract—Background: Simulation provides a safe learning environment where high-stakes, low-frequency procedures can be practiced without the fear of being unsuccessful or causing harm. Emergency department thoracotomy (EDT) is one such procedure. Realistic thoracotomy models are expensive and not readily available. Objective: Our objective is to describe a cost-effective, realistic, reproducible, and reusable thoracotomy model for simulation training. Methods: We modified a commercially available clothes mannequin torso to expose the chest and abdominal cavity. A plastic skeleton composed of a spinal cord and ribs was placed inside the torso. Tubing was used to simulate the aorta and esophagus; both tubes were secured to the distal spine with zip ties. Commercially available lungs and heart were placed inside the chest cavity. A small rubber ball simulated the left lung to be able to maneuver the lung. The heart was covered with plastic wrap to simulate the pericardium. Thick tape was used to simulate the pleural cavity. Yoga mats were used to simulate the intercostal muscles, subcutaneous tissue, and skin. Results: This model was tested with Emergency Medicine (EM) residents during a simulation session. A voluntary survey was available for residents to provide feedback. Survey results confirmed that the model provided valuable education, with overall positive feedback. Conclusion: This EDT model provides a valuable teaching opportunity to EM residents who otherwise might not have the opportunity to perform this procedure. Residents agreed that the model improved their confidence and is an effective method in providing the opportunity to practice this low-frequency, high-stakes procedure.** © **2019 Elsevier Inc. All rights reserved.**

☐ **Keywords—thoracotomy; education; simulation; emergency medicine**

INTRODUCTION

Emergency department thoracotomy (EDT) is a high-stakes, low-frequency Emergency Medicine (EM) procedure. When necessary, EDT must be performed in a quick and competent manner to capitalize on its life-saving potential. However, due to the low frequency of patients who meet criteria for EDT, opportunities to perform this procedure are limited. This results in a lack of confidence in performing the procedure should the opportunity arise.

EM educators are faced with the obstacle of providing residents with an effective learning environment for this procedure. Cadaver and animal models are available and have been used in the past; however, these models are time and resource intensive (1,2). Unless numerous models are available, most residents do not have the opportunity to completely perform the entire procedure. Simulation is an established alternative to bedside, live practice in the field of EM (3).

Thoracotomy models have been described in the surgical literature; one is a commercially available trainer with a cost of $14,500 and the other is not designed for ED thoracotomy (4,5). There is limited literature describing a cost-effective EDT model for EM residents.

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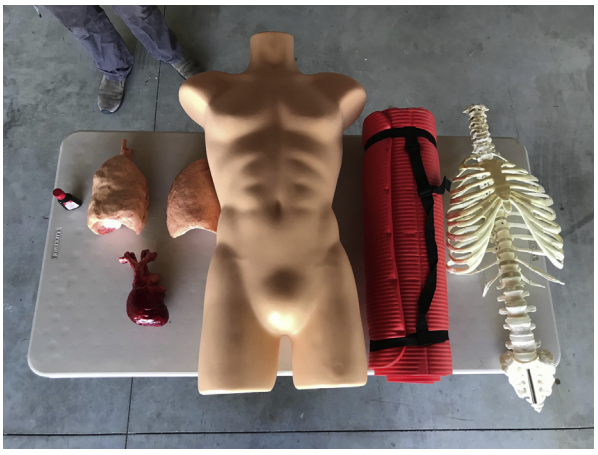

Figure 1. Materials.

We aimed to develop and evaluate a cost-effective, reproducible, and reusable EDT simulation model for resident training. We hypothesized that the model would improve resident confidence with EDT performance.

METHODS

We modified a commercially available clothes mannequin torso (Figure 1). Using commercially available anatomic models as well as readily available material, we sought to create a cost-effective, easily reproducible, and reusable EDT trainer (Figure 2). Table 1 provides the itemized cost of the EDT model we designed for a total of $337.

We removed the anterior chest and abdominal wall to expose the underlying empty cavities. We affixed a plastic skeleton composed of a spinal cord and ribs through the neck of the torso. We ran silicone and rubber tubing through the neck of the torso and along the spine to simulate the aorta and esophagus; we secured both tubes to the distal spine with zip ties. We placed the commercially available lungs and heart inside the chest cavity. We placed a rubber band around the heart model to simulate the phrenic nerve. We covered the heart with plastic wrap to simulate the pericardium. We used gaffer tape to simulate the pleura. We used yoga mats to simulate the intercostal muscles, subcutaneous tissue, and skin. We placed a rubber ball inside the abdominal cavity to keep the intrathoracic components in place. We felt that replacing only the left side of the chest wall would minimize downtime between practice sessions. Total construction time was 2 h.

We initially used the anatomic model for the left lung, but noted that cardiac exposure was inadequate. We replaced it with a small deflated rubber ball, which provided better exposure.

We created a video demonstration of the trainer and uploaded it to YouTube (https://youtu.be/ko0E3xD5OWM).

We trialed the thoracotomy model with EM residents. Each resident performed the entire thoracotomy procedure (Figure 3). We replaced parts of the model in between sessions so that each resident could perform the EDT in its entirety.

We created a survey and asked participants to complete it prior to leaving the session. We asked residents to report the number of thoracotomies they had performed, and rate their confidence prior to and after performance of EDT on the model on a 5-point Likert scale ranging from

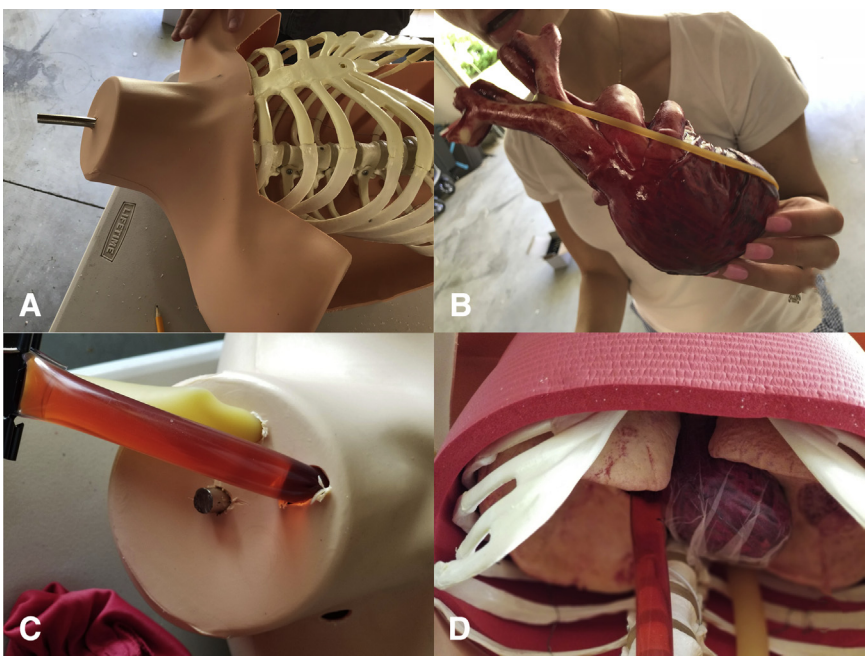

Figure 2. Affixing the skeleton to the torso (A). Heart with phrenic nerve (B). Esophagus and aorta placement (C). Heart and lung anatomic models (D).

Table 1. Materials

Item	Cost ($)
Mannequin torso https://tinyurl.com/y45hczrm	45
Ribs with spine model https://tinyurl.com/y69ljtxl	63
Anatomic models (heart and lungs) https://tinyurl.com/yyz9g2yq https://tinyurl.com/y2ou6j4k	147
Rubber balls https://tinyurl.com/yxnltc2z https://tinyurl.com/y3dp8chr	28
Yoga mat https://tinyurl.com/y4nz9ue7	18
Miscellaneous: Tubing (aorta and esophagus), plastic wrap Bought at local hardware store	20
Gaffer tape https://tinyurl.com/y2ofytr7	16
Total	337

"unconfident" to "extremely confident." We also asked them to rate the realism of the model and provide qualitative feedback about the model (Figure 4).

RESULTS

Seventeen residents were able to perform the procedure in a 2-h session with a single model, for an average of 7 min per participant. This included 1–2 min to reset the model for the next resident. We collected responses from all participants (n = 17). Two residents had performed EDT in the past. Ten residents felt unconfident and seven felt minimally confident in their ability to perform EDT prior to the simulation session. After the session, five residents felt minimally confident, eight felt confident, and four felt very confident performing EDT. The seventeen residents indicated that the thoracotomy model felt realistic.

Residents commented on aspects of the model that seemed realistic (n = 16). These included cutting through skin and muscle, rib spreading, aorta pumping, exposure window, anatomic positioning of the organs, pushing the lung away to deliver the heart, level of difficulty, better than cadaver, presence of pericardium, and identification of the phrenic nerve.

Residents also commented on aspects of the model that seemed unrealistic (n = 13). These included the missing chest wall, lack of body fluids, less stressful setting during the simulation session, and the relative ease of cutting through simulated soft tissue and muscles.

DISCUSSION

We created a cost-effective, reproducible, and reusable EDT model. The model was well received by a group of 17 participants and offered each the ability to perform a complete simulated EDT.

The importance of fidelity has been a topic of debate in simulation. Although realism is certainly a consideration, it can come at great cost. Fidelity is thought to be multidimensional. Physical fidelity is the degree to which the model resembles the physical characteristics of the real subject, and functional fidelity is the degree to which the simulator captures all of the skills that compromise the real task (6). The general term "fidelity" is traditionally attached to physical fidelity. High fidelity has not shown an advantage over low fidelity (7). Functional fidelity, the more important of the two types, is still achievable with self-built models such as ours, when they are detailed enough to allow all important steps of a procedure to be performed.

EM training programs must teach complex, multistep procedures such as EDT while working within a fixed budget. Commercial trainers often cost tens of thousands of dollars. Much of this cost reflects increased physical fidelity. With some creativity, functional fidelity is achievable on a modest budget, and with the extent of materials now available online, a degree of physical fidelity is also achievable. Advantages in physical fidelity offered by commercial trainers are likely not proportional to cost. Ease of re-use and cost may be more important considerations for EM training programs tasked with offering trainees the flexibility to perform a simulated procedure repeatedly and at multiple locations and times.

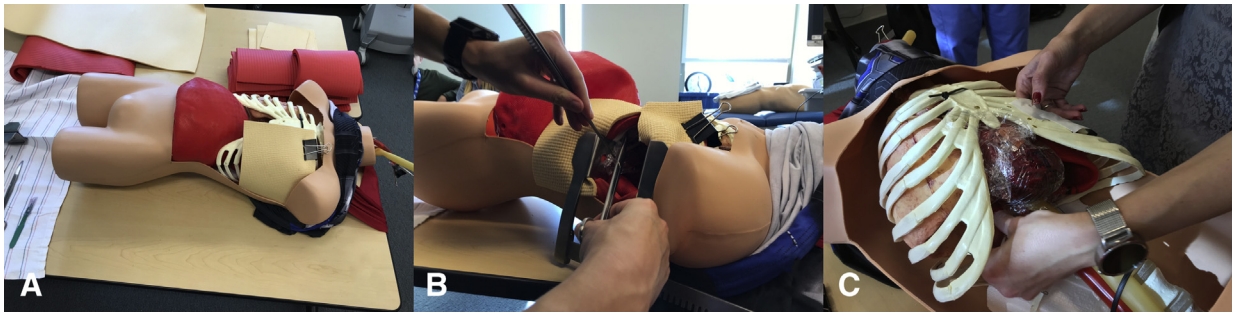

Figure 3. Our EDT model on simulation day (A). A resident opening the simulated pericardium (B). Replacing parts between practice sessions (C).

How many thoracotomies have you performed on coding patients?

How confident did you feel in your ability to perform a thoracotomy PRIOR TO this session?
- Unconfident
- Minimally confident
- Confident
- Very Confident
- Extremely Confident

How confident did you feel in your ability to perform a thoracotomy AFTER this session?
- Unconfident
- Minimally confident
- Confident
- Very Confident
- Extremely Confident

Was the thoracotomy simulator realistic overall?
- Yes
- No

What aspects, if any, were particularly REALISTIC?

What aspects, if any, were particularly UNREALISTIC?

Please use this space to provide any additional feedback you have about the thoracotomy model.

Figure 4. Survey.

The number of repetitions in our trial (n = 17) was limited only by setup time between participants, and cost of the nonreusable parts, gaffer tape, and yoga mats. These were the least expensive components of the model. Replaceable tissue for commercial models is often very costly. Cadavers, which we previously utilized for practicing EDT, do not offer repeatability and require special facilities. Our model is storable and can be reused on demand. For larger sessions, multiple models would easily allow an entire residency complement the size of our program (n = 45) the chance to participate.

Limitations

There are limitations to our study. We evaluated only trainee reaction to the model. The EDT was performed in isolation and not in the setting of an immersive simulation scenario. We believe it important to ensure that resident learners have the opportunity to perform the steps of the EDT prior to increasing the cognitive load in an immersive simulation scenario. Our group of participants was relatively small. In the future we plan to utilize multiple models with a larger group of EM residents and faculty, and expand the EDT model's availability to surgical residents and faculty.

CONCLUSIONS

Our low-cost, reproducible, and reusable EDT model provided EM residents with the ability to perform a complete thoracotomy. Training programs seeking a solution for teaching this high-stakes, complex procedure may find the model valuable.

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ARTICLE SUMMARY

1. Why is this topic important?

This article describes a cost-effective do-it-yourself emergency department (ED) thoracotomy model with easily replaceable components to allow each resident to complete the procedure in its entirety. In the current literature, ED thoracotomy models are either commercially available and expensive, or are cadaveric models providing only a few opportunities to perform the complete thoracotomy.

2. What does this study attempt to show?

This study is showing the importance of providing Emergency Medicine residents with the opportunity to perform a high-stakes, low-frequency procedure such as ED thoracotomy without the fear of harm or discomfort with the procedure.

3. What are the key findings?

Emergency Medicine residents found the ED thoracotomy very useful to increase their confidence in performing the procedure.

4. How is patient care impacted?

These findings indirectly impact patient care as the ED thoracotomy model increased their confidence in performing a procedure that they may otherwise not be able to perform completely.