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ORIGINAL ARTICLE

A low-cost, non-biologic, thoracentesis and thoracostomy simulator

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Abstract

Background: Increasing emphasis is being placed on simulation for education of practitioners. Simulation has been validated as a useful educational tool for learning invasive procedures in a low-stress environment where expert guidance can be used to increase proficiency and confidence for multiple skills. A low-cost, non-biologic simulator does not currently exist for thoracentesis. **Materials and Methods:** A home-made thoracentesis and percutaneous thoracostomy simulator was constructed from readily available materials. After viewing instructional videos and after a lecture and demonstration, students were asked to perform thoracentesis and thoracostomy. **Results:** All students were eventually able to use the model to perform the procedures without prompting or guidance. Some students had minor technical errors in catheter placement or advancement, which were corrected. After reviewing the error, they were then able to go on to successful placement of the catheter. No student caused a pneumothorax in the simulation. **Conclusions:** The model is a cost-effective, easy to make solution for teaching thoracentesis and thoracostomy.

Keywords: *Thoracentesis; thoracostomy; simulator; surgical education*

Introduction

There is an increasing trend nationally to focus on simulation-based training for common bedside procedures in general surgery. With the days of “see one, do one, teach one” fading into the past, emphasis is now placed on competency and familiarity with procedures prior to the learner ever attempting one on a real patient. Changes in surgical education have been implemented over the past decade and starting in 2007, simulation experience outside of the operating room was required by the Residency Review Committee.[1] Once an optional course, the laparoscopic skills simulation of Fundamentals of Laparoscopic Surgery (FLS) is now mandatory for the completion of residency.[1] Courses in Advanced Trauma Life Support and Advanced Cardiovascular Life Support rely exclusively on models and simulation. Randomized controlled trials of colonoscopy and FLS simulations have shown that the skills learned in simulation correlate to real-world performance.[2,3]

Multiple commercial simulators for thoracentesis are available; however they can be cost prohibitive. Simulators for thoracentesis start at US$825.00, and can be in excess of US$1,200.00. Commercial simulators require replacement parts that generate recurring costs with repetitive use. Some of these models are exceedingly artificial; some have barely a passing resemblance to a human torso while others are anatomically correct. The expense of commercial simulators has led to many training programs developing their own models.[1,4] Several instructions exist in the literature for home-made thoracentesis models.[4,5] Unfortunately, they all use some form of biological tissue to act as the chest wall, such as pork, beef, or turkey ribs. This can pose a problem in simulation laboratories where all biological tissue is banned. After reviewing the available models, we sought an alternative that was cost-effective, durable, and as realistic as possible.

Materials and Methods

Population

Acute care nurse practice students (n=9) from Georgia Regents University were used to evaluate the model. No student had previously seen or performed a thoracentesis or placed a percutaneous thoracostomy tube. Prior to the course, all students reviewed videos and computerized literature that included step-by-step instructions for performing both procedures. After a 15-min instructional lecture and a step-by-step introduction, the students were observed placing chest tubes and thoracentesis catheters. Supervision was by a trauma and surgical critical care attending and a fourth-year general surgery resident.

Thorax Model

A simulation of the human torso was created using a life-size thorax and spine model, complete with scapulae (Fig. 1) for the foundation. Two 1-l saline bags were used to simulate the lung and pleural effusion. Red dye was infused into the saline bag simulating the lung, while 250 ml of saline was removed from the saline bag simulating the effusion. More saline can be removed from the effusion bag to decrease the size of the effusion and increase the level of difficulty. The bags were then taped onto each other with the effusion bag slightly inferior and overlapping the lung bag (Fig. 2). These were then placed into the thoracic cavity of the model; with the saline bag simulating the lung placed anterior to the bag simulating the effusion (Fig. 3). Towels were used to tightly pack the remaining space in the thoracic cavity (Fig. 4). This is required so that when the model is rolled over, the effusion bag remains firmly pressed into the ribs posteriorly. The model was then rolled over and cotton batting, usually used to stuff upholstery, was packed into each rib space to simulate the intercostal spaces. Felt was placed over the entire posterior thorax to simulate the subcutaneous tissues. Left-over synthetic skin discarded from other simulators after their initial use was then recycled for the skin of the thoracentesis model. Finally, a layer of Ioban (3M Health Care, St. Paul, MN) antimicrobial drape was used to hold all the layers in position (Fig. 5). Three models were built for use in the simulation, and were placed at a 45° angle on the simulation table. Table 1 provides a list of the materials required.

Station 1: Thoracentesis

Thoracentesis was performed using a commercially available thoracentesis kit (Arrow-Clarke, Teleflex, Limerick, PA). The kit included a thoracentesis catheter over a needle and tubing set with an aspiration/discharge device and collection bag. Students first verbally reviewed the landmarks and steps of the procedure, demonstrated where the landmarks were on the model, and then performed the procedure.

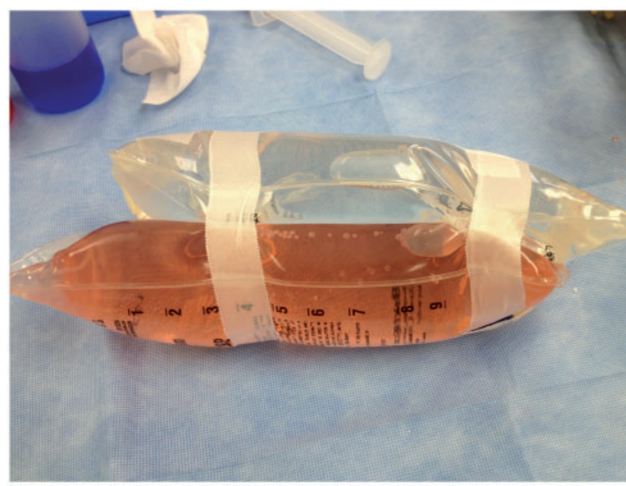

Figure 2. One-liter saline bags simulating effusion and the lung, with the effusion bag taped slightly inferiorly to the lung bag.

Figure 1 Model of the thorax, complete with scapulae, ribs, and spine.

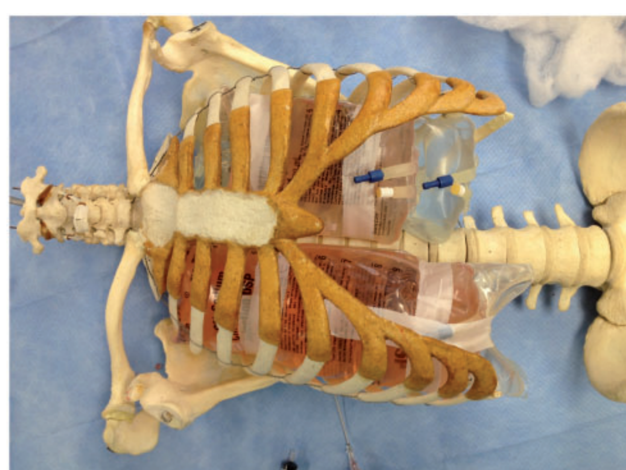

Figure 3 Taped saline bags placed into the thorax.

Figure 4 Remaining space in the thorax packed tightly with towels.

Figure 5 Thorax with intercostal packing, the felt layer, and simulated skin covered by Ioban.

Station 2: Percutaneous Thoracostomy Tube

Thoracentesis was performed using a commercially available Seldinger thoracostomy kit (Cook Medical, Bloomington, IN). The kit included a 14-Fr pigtail catheter, needle, wire, syringe, dilator, and tubing. Students performed the same steps as in Station 1, and additionally discussed the Seldinger technique and wire management prior to performing the procedure.

Results

All students were able to demonstrate knowledge of the indications, landmarks, and steps of the procedure prior to attempting thoracentesis. Four students did not correctly advance the needle deeply enough on the first attempt. The catheter was displaced into the subcutaneous tissues on three students' attempts at advancing the catheter. All students were able to make multiple attempts, and by their second or third attempt, all were able to safely enter the effusion, and none penetrated the lung. By their final attempts, all students could perform the procedure from start to finish with minimal coaching. Percutaneous thoracostomy was not performed by all learners due to the lack of available kits for the entire course. The students who attempted percutaneous thoracostomy (n=2) were able to place the tubes, with coaching, into the appropriate spaces.

The thorax model produced reliable, repeatable attempts at thoracentesis and thoracostomy. The saline bags were resilient enough to be penetrated by the thoracentesis needle multiple times at different intercostals levels without leaking. The only technical problem encountered in the course was one thorax not being packed tightly enough, allowing the bag simulating the effusion to fall away from the inside of the chest, making it difficult to advance the thoracentesis catheter over the needle. All models were functional, and students were able to aspirate, attach the aspiration/discharge device, and pump the effusion fluid into the collection bag (Fig. 6). It is also important to note that, once punctured, the saline bags will slowly leak over time and should be removed from the model at the end of each simulation day and discarded.

Table 1 List of materials needed to assemble one model

Material	Source
Human thorax skeleton	Anatomic supply store
Four 1-l saline bags	Expired stock from hospital
Red dye	Grocery store
60 ml syringe and 18 gage needle	Expired stock from hospital
4 towels	Operating room surplus
Cotton batting and felt	Craft store
Synthetic rubber skin	Recycled from other simulators
Ioban draping	Expired stock from hospital

Discussion

Simulation and practice of thoracentesis has shown improvements in learners' ability, speed, and confidence in performing the procedure.[4,6] Inspired by these previous

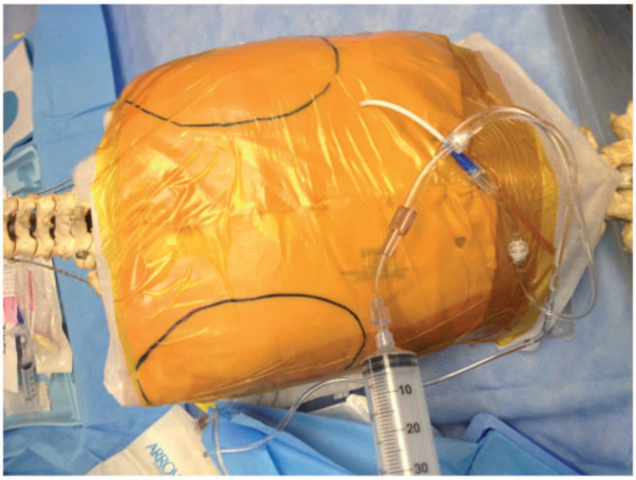

Figure 6 Successful placement of the thoracentesis catheter, affixed to the aspiration/discharge device.

studies, thoracentesis was added to the curriculum. However, our simulation laboratory is located in a facility that does not allow any biological tissues. After evaluating the available models and plans for making home-made models, an alternative was devised that did not use any animal or cadaveric tissue. The thorax and spine models, along with the other construction materials had been previously acquired by the simulation laboratory. The Ioban, 1-l saline bags, thoracentesis kits, and thoracostomy kits were expired items obtained free of charge from the hospital's central supply room. Once the models were complete, several general surgery residents and one trauma surgery attending tested access and aspiration. The combination of multiple different materials composing each layer of the model's simulated tissue was reasonably similar to performing the procedure on a patient. The problem encountered with the saline bag falling away from the posterior chest wall was due to the towels used to fill the residual anterior thoracic volume. This needs to be packed fully so that the simulated lungs and effusion cannot fall away when pressure is placed on the effusion by the person performing the procedure. An additional item to note is that, once punctured, the saline bags will slowly leak fluid and must be removed and discarded at the end of the simulation to avoid saturating the model with saline. Our experience with the thorax model demonstrates that it is a reusable and economical option for instructors who need an alternative to currently available models. In addition, our model could be adjusted for open tube thoracostomy placement and other general surgery procedures to increase the benefit-to-cost ratio further. Future plans for our model include incorporating it into the education schedule for general surgery residency. This use would include general surgery residents from all postgraduate years and include a validation survey and feedback regarding eligibility and usefulness for educational purposes using a global rating scale.

Conflict of interest

No personal or institutional financial conflicts of interest (drugs, materials, or devices) apply to this study.

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