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Developing a low-cost model for chest drainage simulation training

Desenvolvendo um modelo sintético de baixo custo para treinamento de drenagem torácica em ambiente de simulação

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RESUMO: *Objetivo*: Descrever a construção de um simulador de baixo custo de drenagem torácica para capacitar a realização deste procedimento. *Métodos*: A concepção do modelo se deu em 2014 por integrantes do Programa de Educação Tutorial do curso de Medicina da UNIFOR. A seguir, o modelo foi testado por 10 especialistas e posteriormente aprovado para ser aplicado em quatro edições de um curso teórico-prático de procedimentos invasivos com acadêmicos de Medicina de diferentes universidades. Para avaliar o simulador e o desempenho no seu uso, aplicou-se questionários semiestruturados e *checklist*. Os dados foram analisados pelo *Statistical Package for the Social Sciences v. 22* usando estatística descritiva. *Resultados*: Usou-se um manequim plástico comercial em que foi realizado um corte de 8x8 cm na região lateral do tórax, correspondente ao local da drenagem. Neste local, foram posicionadas folhas de E.V.A. (simulando pele e músculos intercostais), esponja de estofado (subcutâneo) e folha de PVC (pleura). Na parte interna do manequim foi colocada uma estrutura de madeira contendo duas costelas e, entre elas, um copo plástico recoberto por E.V.A. contendo líquido vermelho (simulando um hemotórax). O custo inicial do modelo completo foi de R$ 81,00/US$ 21,00. Quando testado por especialistas, todos concordaram que o modelo pode ser usado para o ensino na graduação. Durante o curso de procedimentos invasivos, 129 acadêmicos realizaram o procedimento, em que 64,3% dos alunos inseriram corretamente o dreno e 79,1% conectaram ao sistema de drenagem. Apesar de um percentual de erros importante visto em passos iniciais básicos, os alunos conseguiram executar a técnica proposta de forma suficiente. *Conclusão*: O simulador de drenagem de tórax mostrou-se ser de fácil acesso e reprodução nas universidades, o que o torna uma ferramenta útil para o ensino.

Descritores: Educação médica; Simulação; Ensino; Drenagem; Tubos torácicos; Treinamento por simulação.

ABSTRACT: *Objective*: To describe the construction of a low-cost simulator of chest drainage for the training of undergraduate medical students. *Methods*: The model was conceived in 2014 by members of the Tutorial Education Program - UNIFOR. It was tested by 10 specialists and approved for application in four editions of a theory and practice course on invasive procedures with medical students from different universities. To evaluate the simulator and its performance, semi-structured questionnaires and checklists were applied. Data were analyzed in the Statistical Package for the Social Sciences v. 22, using descriptive statistics. *Results*: A commercial mannequin was used to build the model. An 8 x 8 cm square cut was made in the lateral wall of the chest. Inside this region, EVA sheets (simulating skin and intercostal muscles), foam padding (subcutaneous tissue) and transparent PVC sheet (pleura) were placed. In the inner part of the mannequin, a wooden structure containing two ribs was constructed and a plastic cup containing red-dyed water was placed between the two ribs. The complete model had an initial cost of R$ 81,00/ US$ 21,00. The medical specialists agreed (100%) that it can be used for undergraduate teaching. During the course on invasive procedures, 129 students performed the procedure; 64.3% of them were able to correctly insert the drain and 79.1% connected it to the drainage system. Despite of the high percentage of errors in basic initial steps, the students were able to execute the technique satisfactorily. *Conclusion:* The low-cost chest drainage simulator was easy to access and to reproduce in universities, which makes it an important tool for teaching.

Keywords: Education, medical; Simulation technique; Teaching; Drainage; Chest tubes; Simulation training.

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INTRODUCTION

Chest drainage is an important medical procedure in the treatment of pleural complications, and it is widely used both in elective situations and in urgent and emergency cases[1,2].

Although this procedure is apparently simple to apply in different hospitals in the country, medical professionals must be able to perform it with appropriate technique[2]. This fact is corroborated by the National Curricular Guidelines, which establish that, in the surgical clinical area, the student must learn chest drainage procedures and practice them, at least through simulation[3].

Training of surgical procedures helps acquiring specific skills in a safe and controlled way, through the simulation of real situations. Therefore, there are efforts to build models that can mimic human anatomy in detail with a low cost and high reproducibility, with the objective of disseminating teaching on safe procedures in health facilities and universities[4,5].

The literature describes the manufacture of low-cost models of chest drainage for practical learning as an alternative to commercial models. However, these simulators use animals or other materials that are difficult to access[6-9].

Conversely, this article presents a model that is cheaper than the alternatives for chest drainage practice and that does not pose a risk of biological contamination. It is a model that uses low-cost synthetic materials to simulate the procedure, with a cost of less than US$ 100.00, which improves access and reproduction in academic circles.

In view of this, this article seeks to describe the construction of a chest drainage mannequin with low cost and high reproducibility, as well as its use for training, with a focus on this procedure.

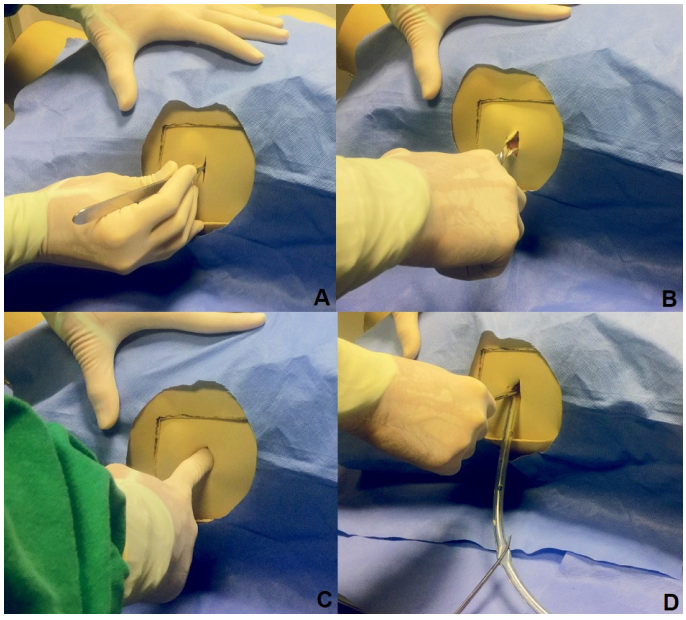
MATERIAL AND METHODS

The first step of this study occurred in 2014, when students in the Medical Tutorial Education Program (PET) of the UNIFOR designed chest drainage models using a low-cost plastic mannequin, similar to those used in commercial stores. After that, a cost estimate was made, along with the identification of accessible materials to simulate human anatomy. Finally, the model was constructed, with adjustments to simulate the dynamic of the procedure.

The next step of the study was testing the model. For this, 10 specialist doctors who acted as preceptors in the training of general surgery or emergency care residents tested the mannequin for use in teaching in a simulation environment. To evaluate the model, doctors answered a semi-structured questionnaire with quantitative aspects, assessed through a Likert scale, and qualitative aspects.

In addition, the authors developed a checklist to assess the performance of students during training. The checklist was based on a literature review that included detailed and didactic step-by-step information on the procedure[2,10-12].

After this process, the model was used in four editions of a theory and practice course on invasive procedures for undergraduate students, devised by the Medical PET of the UNIFOR and carried out from 2015 to 2017 (Figure 1). The course had theory classes taught by previously trained tutors, including aspects such as: initial concepts, indications and contraindications for the procedure, and step-by-step instructions for chest drainage. After that, the tutors provided a practical demonstration of the technique for the students, who later individually performed the procedure and were evaluated through the checklist (Table 1).



Source: Elaborated by the authors

Figure 1 - Chest drainage model showing the step-by-step procedure. (A) Skin incision; (B) Spreading the intercostal muscles; (C) Digital exploration of the drainage hole; (D) Insertion of the drain.

Table 1. Chest drainage checklist

	Steps of the procedure	Hits	Misses
1.	Correctly checked the equipment: syringe, needles, scalpel, Kelly forceps, drain, underwater seal and suture kit.		
2.	Correctly positioned the patient in the supine position, with the head of the bed at a 45-degree angle and ipsilateral arm abducted with the hand on the head.		
3.	Located the incision: in the 5th intercostal space, between the anterior axillary line and the middle axillary line.		
4.	Put on surgical attire.		
5.	Performed asepsis and antisepsis.		
6.	Applied local anesthesia with lidocaine 2% on the skin, subcutaneous tissue, periosteum (on the upper border of the lower rib) and pleura.		
7.	Correctly performed skin incision of 1-2 cm.		
8.	Correctly spread subcutaneous tissue and intercostal muscles.		
9.	Correctly spread the pleura.		
10.	Digitally explored the space.		
11.	Correctly measured the drain (from the jugular notch to the incision site).		
12.	Inserted the drain in the cranial and posterior position with all the holes inside the pleural cavity.		
13.	Connected the underwater seal and positioned it below the bed, checking the drain outlet.		
14.	Performed a U suture and secured the tube with a surgical knot.		
15.	Performed the dressing.		

Thus, the study sample also included medical students from different semesters who were regularly enrolled in higher education institutions, registered for the theory and practice course and agreed with the Informed Consent Term.

The data collected were analyzed in the Statistical Package for the Social Sciences (SPSS) v. 22 using descriptive statistics. This project was approved by the Research Ethics Committee of the University of Fortaleza under number CAAE: 30964514.0.0000.5052 and report number 688.827. The Kolmogorov Smirnov test was used to evaluate the normality of the sample. Values with $p < 0.05$ were considered statistically significant.

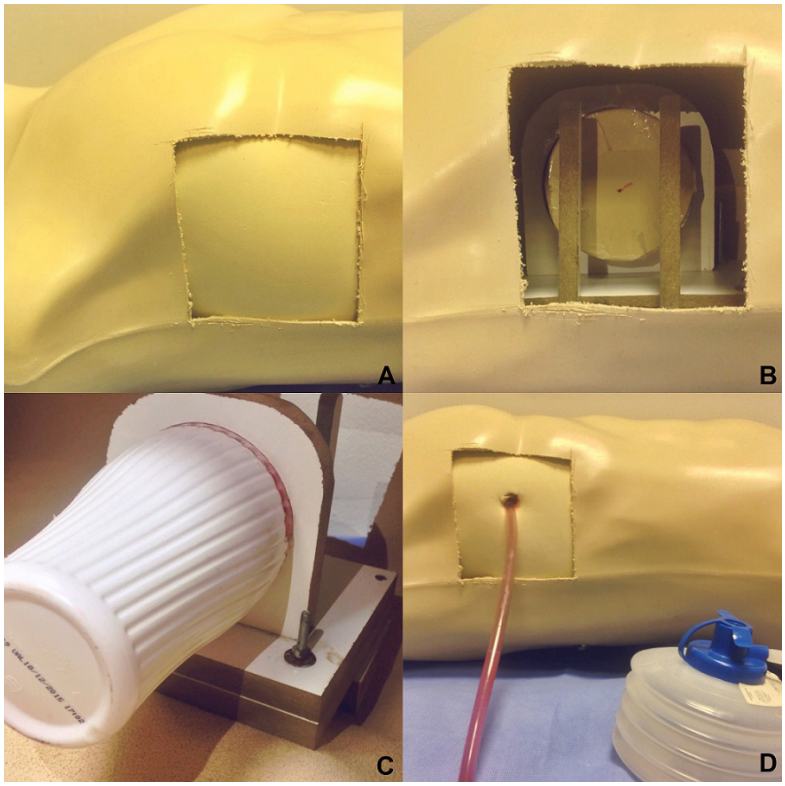
RESULTS

Construction of the model

An 8x8 cm square cut was made in the lateral wall of the chest and, inside this region, blocks with square layers of 12x12 cm were added. The first layer, corresponding to the skin, was made with a beige EVA sheet; foam padding was used for the second layer, which simulates the subcutaneous tissue; the third layer, simulating the muscles of the chest wall, was made with two red EVA sheets; finally, the last layer, representing the pleura, was made with a transparent PVC sheet.

In addition, two rectangular timbers measuring about 6 cm were placed on the inside of the mannequin and fixed by screws on a wooden base to simulate two ribs and the intercostal space where the drain should be inserted (Figure 2). Initially, the authors of the work constructed the model for the practice of chest drainage in a clinical situation of hemothorax. Thus, a plastic cup was attached to this wooden base, exactly between the two ribs, and covered by an EVA sheet in its upper opening. This cup contains water dyed red with gouache paint, to simulate the hemorrhagic pleural fluid. Thus, the chest drain goes through the layers that simulate the soft tissues and between the two wooden ribs, then enters the device containing red-dyed waterand, with the aid of a closed vacuum system (Portovac®), the liquid goes through the drain.

Low-cost synthetic materials were used. The materials and their prices are specified in Table 2. The initial complete model cost R$ 81.00/US$ 21.00. It was observed that the model needed maintenance before each new edition of the course, to adjust the support and the wooden ribs (carpentry), which cost R$ 15.00/US$ 4.00, with an additional cost of R$ 4.00/US$ 1.00 for each block that simulates the soft parts of the chest wall (skin, subcutaneous tissue, muscles and pleura). In each edition of the surgical procedures course, an average of 50 chest drainage simulations are performed. Thus, the total cost of 50 procedures, therefore, of each edition of the course, was R$ 215.00/US$ 55.00. Up to the time of the present study, the model constructed lasted 4 editions of the course, totaling about 200 procedures.



Source: Elaborated by the authors.

Figure 2. Details of the chest drainage simulator. (A) Synthetic model and drainage location; (B) Internal region of the model showing the wooden ribs and the plastic cup that is covered on its upper opening, with a hole for the entrance of the drain; (C) Fixed cup containing liquid composed of water and red gouache pain; (D) Model showing the inserted drain, the Portovac® system and the drainage of hemothorax

Table 2. Materials for the construction of the mannequin

Simulated structure	Material	Cost (R$)
Thorax	Commercial plastic mannequin	R$ 30.00/US$ 7.70
Skin + Subcutaneous tissue + Muscles	3 EVA (12 x 12 cm) + Foam padding (12 x 12 cm)	R$ 3.50/US$ 0.90
Pleura	Transparent PVC sheet (12 x 12 cm)	R$ 0.50/US$ 0.12
Thoracic fluid	Plastic cup with water + wooden support + 6 screws	R$47.00/US$ 12.00

Legend: * Maintenance cost per semester course (50 procedures); R$ 215.00/US$ 55.00.

Testing and application of the simulator

The model was tested by professors linked to universities and residency programs in Fortaleza, who specialized in General Surgery (3), Digestive Surgery (3), Plastic Surgery (2) and Emergency Medicine (2). All these participants reported that they had performed or assisted chest drainage in patients *in vivo* on average 100 times. The professionals answered a perception questionnaire about the mannequin. The data obtained from the questionnaire are shown in Table 3.

Table 3. Results of the perception questionnaire on the chest drainage model applied to professionals

Questions	TA	PA	IN	PD	TD
The model can be used for teaching undergraduate students.	100%	0%	0%	0%	0%
Before performing the procedure on patients, one should practice on a mannequin like this.	100%	0%	0%	0%	0%
The model is realistic.	50%	50%	0%	0%	0%
The model can be reproduced in other teaching centers.	100%	0%	0%	0%	0%

Legend: TA: totally agree; PA: partially agree; IN: indifferent; PD: partially disagree; TD: totally disagree.

The authors were able to use the final version of the model in editions of the theory and practice course on invasive procedures. The sample was composed of 129 undergraduate medical students who performed the procedure individually, 41.9% male and 58.1% female, of varied ages (between 17 and 32 years) and from 7 different education institutions, in the states of Ceará and Rio Grande do Norte. Of these, 93.7% were in the basic cycle of the medical course and 95.3% had no experience with the chest drainage procedure (theory or practice). The results found in the correction of the checklist, as well as the hits and misses in the chest drainage procedures in the proposed simulator are summarized in Table 4.

Table 4. Sequence of steps during the chest drainage procedure (n=129)

Checklist	Hits	Misses	*p*
Selecting material	65.1%	34.9%	<0.05
Positioning the patient	67.4%	32.6%	<0.05
Incision site	76.0%	24.0%	<0.05
Surgical atire	88.4%	11.6%	<0.05
Asepsis and antisepsis	85.3%	14.7%	<0.05
Anesthesia	58.9%	41.1%	<0.05
Skin incision	76.0%	24.0%	<0.05
Spreading	74.4%	25.6%	<0.05
Digitally exploring	82.2%	17.8%	<0.05
Measuring the drain	89.1%	10.9%	<0.05
Correctly inserting drain	64.3%	25.7%	<0.05
Connecting the drainage system	79.1%	20.9%	<0.05
Securing the drain	83.7%	16.3%	<0.05

Legend: Statistical analysis generated by the Kolmogorov Smirnov test.

DISCUSSION

In medical education, students go through different levels to deepen the knowledge about skills acquired when training for procedures[5,13]. One of these levels is the ability to demonstrate the technique in a simulation environment. This was proposed during the application of the chest drainage model in the theory and practice course.

There is a big price difference between this simulator and commercial models, which cost around R$ 10.000,00 / US$ 2.500. Considering that most of the simulations of invasive procedures in the academic environment are performed with high-cost commercial mannequins, this model can be an affordable alternative due to the use of low-cost synthetic materials, which makes it easier to reproduce[6,14].

In the evaluation of the chest drainage simulator conducted by specialist doctors, all participants totally agreed with its use for teaching the technique to medical students. They also agreed that the model has anatomical and functional parameters that enable students to use it as a training equipment before performing the procedure on real patients[13,15].

As for the perception of anatomical correlation, it was found that the model has limitations regarding the tactile sensation of the pleura when digitally exploring the space, with the objective of correctly locating the insertion site. However, even with such a limitation, the model allows training all steps of the chest drainage technique in a satisfactory way.

In the checklist, the steps with the highest rate of hits were asepsis and antisepsis, adequate dressing and identification of the incision site. These basic starting points are of paramount importance, since, when performed correctly, they reduce the risk of failures in the procedure and complications to the patient[16].

However, the items with higher percentage of errors were: proper selection of material, correct positioning of the patient and application of anesthesia. The errors in these items can be explained by the lack of previous contact with the procedure, since most of the students did not have previous theoretical or practical experience. However, even without previous contact with the procedure, most students managed to perform the technique satisfactorily.

It was also observed that a training procedure based on a checklist allows simple checks before and during the

procedure, which contributes to prevent complications and, consequently, reduce morbidity and mortality[17].

The use of low-cost simulators like this one allows students to practice in different settings, minimizing the possibility of future complications in the procedure due to improper technique. In addition, this methodology enables real-time feedback, generating an educational development that allows learning from errors and thus improving the technique[18,19]. This reinforces the relevance of spreading the use of accessible simulators to other medical schools.

CONCLUSION

Considering that the synthetic materials used in the model have a low cost and are easy to access, the chest drainage simulator described can be reproduced in university centers, making it an additional tool available for the training of undergraduate students. However, it is necessary to conduct further research on low-cost models of invasive procedures, so that they can be used on a large scale in medical education.

Participation of the authors: *Oliveira MA*: Construction of the model, collection of data, writing of the article, elaboration of figures and final review. *Queiroz EF:* Construction of the model, analysis of data, writing of the article, elaboration of tables and final review. *Mesquita DAK:* Literature review, collection of data and writing of the article. *Marques LM:* Literature review, tabulation of data and writing of the article. *Fernanda Martins Maia:* Orientation for the project and final review. *Rafaela Vieira Correa:* Orientation for the project, writing of the article and final review.

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