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Animal model: the evaluation of the thoracic drainage simulator for small animal surgery training

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Abstract: There is a growing interest in using simulators for training in veterinary surgery. However, there are few training aids available for thoracic drainage, which is an important technique and procedure. Therefore, this research aims to develop and validate a thoracic drainage simulator to support surgical practice classes. This simulator was constructed with acrylic ribs covered with silicone and synthetic tissue layers to simulate skin, subcutaneous, and muscle layers. The artificial model was compared to the standard cadaver training using a five-point Likert scale questionnaire to evaluate its effectiveness. The questionnaire was completed by 25 veterinary students using this simulator during the practical classes on the Small Animal Surgery Rotation. The students responded positively to most questions, indicating that the simulator performed well when compared to cadaver training. The answers were evaluated using the Diagnostic Content Validation (DCV) method. The questions that received the highest scores were related to the number of ribs (DCV= 0.79), the location of the incision on the skin (DCV= 0.77), and the amount of fluid drainage (DCV= 0.81). The simulator was useful for surgical practice classes, as it provided satisfactory training (DCV = 0.85) and increased students' confidence (DCV = 0.85).
Keywords: Alternative methods; Learning curve; Skills training; Thoracocentesis; Thoracostomy tube insertion.

1. Introduction

There has been a trend to prioritize animal welfare during veterinary training (Hunt et al., 2021; Buyukmihci, 2022; Cordeiro et al., 2023), seeking a balance between a satisfactory education and the humane use of animals. New laws in Brazil have resulted in an increasing use of cadavers in preference to live animals for surgical training (Brasil, 1998; Pedro and Bento, 2023). New Brazilian legal norms now allow for more frequent use of animal cadavers instead of live animals for surgical training. Federal Law 9605 (Article 32, §1º) considers using live animals for educational purposes a harmful method when alternative methods are available. Additionally, technical guidance nº 9 (Brasil, 2016) recognizes cadavers as a valid alternative method for surgical training classes.

Although live animal surgical training remains a possibility, animal use is declining in most parts of surgical classes due to concerns about animal welfare (Cordeiro et al., 2023). Most recently, the normative resolution 54 from CONCEA in 2022 (Brasil, 2022a) recognized alternative methods for using animals in teaching and scientific research activities. This requires that alternative methods are used where practical, reinforced by the normative resolution 55 of the same year (Brasil, 2022b), which requires a preference for alternative methods even if they have not been validated. There are three different ways to classify alternative methods: valid methods that have not been validated but are known to reproduce the technique reliably; validated methods that have been tested for their relevancy and reliability for a specific technique; and recognized methods that are validated methods recognized by CONCEA as a suitable replacement for live animals, making their use mandatory (Pedro and Bento, 2023).

Cadaver surgery is a method considered valid by CONCEA for surgical training (Brasil, 2022b) and is one of the most common methods for surgical training. However, several factors limit the use of cadavers, including putrefaction, biological risks, availability, and religious factors (Meyer-Pflug et al., 2022), as well as potential negative implications of the preservation method. In Brazil, cadavers are commonly preserved by freezing, but the putrefaction process rapidly denudes the advantages of cadavers and precludes the reuse of cadavers in the long term (Moon et al., 2020). This makes it very difficult to acquire and store sufficient cadavers to support training for a whole class of students (Merino et al., 2018). Another risk posed by frozen cadavers without preservatives is the potential for the professionals handling them and students to be exposed to diseases (Silva et al., 2004). Indeed, in this research university, a laboratory technician recently acquired sporotrichosis from a cadaver.

Cadavers can also be preserved in a variety of solutions. However, some of these, such as Thiel's solution, contain formaldehyde, which can cause chronic toxicosis, pulmonary diseases, mucosal injuries, and environmental risks (Veronez et al., 2010; Silva et al., 2016). Furthermore, the International Agency for Research on Cancer (IARC) has classified formaldehyde as a teratogen and carcinogen (Protano et al., 2022). Unfortunately, there are high costs associated with using alternative agents, such as a tenfold increase in price when using glycerin without formaldehyde (Moon et al., 2020; Waerlop et al., 2021). For these reasons, better alternatives for cadavers, such as synthetic simulators, are being sought (Hunt et al., 2021).

Many types of simulators have been developed to teach various skills during surgical classes (Hunt et al., 2021). These include silicone suture pads (Cruz et al., 2020), small animal spay simulators (Au Young et al., 2019), and models for basic surgical skills training (Andrade et al., 2021). Thoracic drainage is a technique commonly taught in theoretical classes in the veterinary curricula. This technique is essential in routine and emergency surgery and should be considered when pleural effusion or pneumothorax is present (Fossum et al., 2019). The Association of American Medical Colleges classifies thoracostomy tube insertion as one of the

13 surgical skills every student should master (Meyer-Pflug et al., 2022). However, in veterinary medicine, there are few practical methods for teaching this without using live animals or cadavers (Williamson, 2014; Haller et al., 2020). An alternative method is a priority (Hunt et al., 2021). This study aimed to develop a thoracic drainage simulator to complement practical surgical classes and to conduct concurrent validation using the cadaver as the gold standard.

2. Materials e Methods

Firstly, a single cylindrical arch was made from cold porcelain to simulate a generic rib. This arch was used to make a silicone mold that could be filled with self-curing acrylic to produce the model ribs. Ten ribs, representing ribs 4 to 13, were created. These artificial ribs were positioned at 2 cm intervals and fixed with acrylic bases, mimicking the osseous structure of the rib cage (Figure 1).

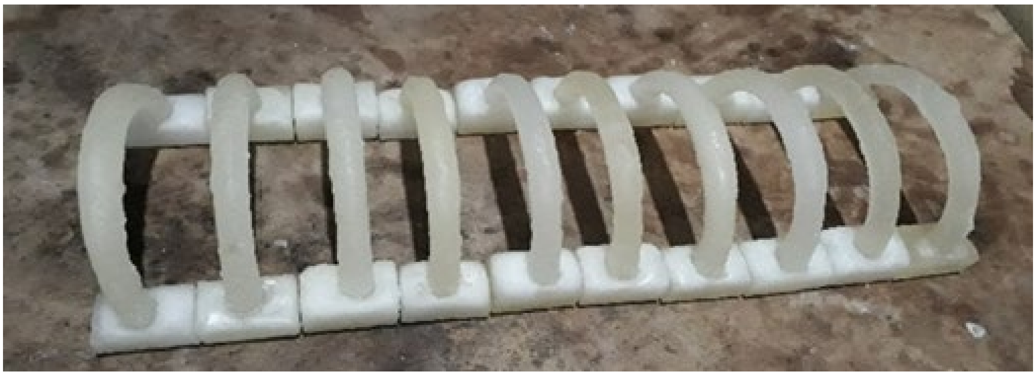

Figure 1 – Costal arch constructed with the ten acrylic ribs.

These ribs were used as the scaffold for the soft tissue layers. The muscle layer was created using a piece of neoprene dipped in silicone rubber. The fat layer was simulated with a slime made of transparent glue, body oil, yellow coloring, sodium bicarbonate in a water dilution, and borax water. A tulle fabric dipped in platinum silicon Ecoflex (shore 00-30) was used for the simulated skin. The muscle layer was affixed over the ribs using acetic silicon (Figure 2A), then the skin layer was similarly attached by its edges to the muscle layer. A space was left on one side so that the slime could be introduced between the two layers before the tissues were affixed on the upper edge of the simulator (Figure 2B).

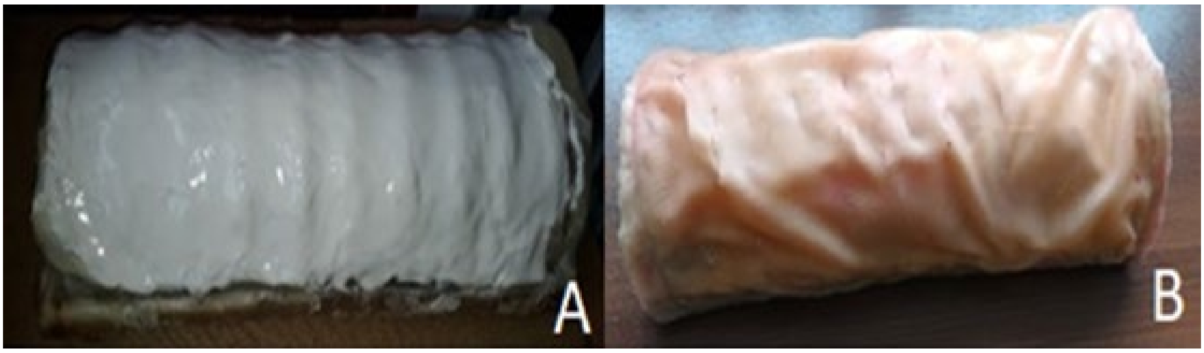

Figure 2 – Muscle layer fixed over the costal arch (A) and skin layer fixed over the muscle layer to complete the upper side of the simulator for thoracic drainage (B).

A receptacle was added to complete the structure. The receptacle had the exact dimensions as the synthetic rib cage and was deep enough to contain fluid (Figure 3).

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Figure 3 – Upper and lower sides joined to complete the thoracic drainage simulator.

The simulator was evaluated by 25 undergraduate veterinary students who were completing their surgical rotation in the third year of the Veterinary Medicine program. The students first attended a theoretical class on thoracocentesis and thoracostomy chest tube insertion. The technique was taught: the ribs are counted to reach the seventh or eighth intercostal space, and then a skin incision is made three to four ribs caudal to the previously selected intercostal space. A flexible chest tube is inserted into this incision using hemostatic forceps, tunneling it through the subcutaneous layer until it reaches the selected intercostal space. Then, the muscle layers of the chest are pierced to insert the tube into the chest. Once the tube is correctly placed and fluid drainage is confirmed, it is then secured to the skin using the Chinese finger-trap technique, completing the procedure (Fossum et al., 2019).
The students performed the thoracic drainage procedure on cadavers of different sizes, the current standard method of training in the class, and the simulator (Figure 4) for comparison.

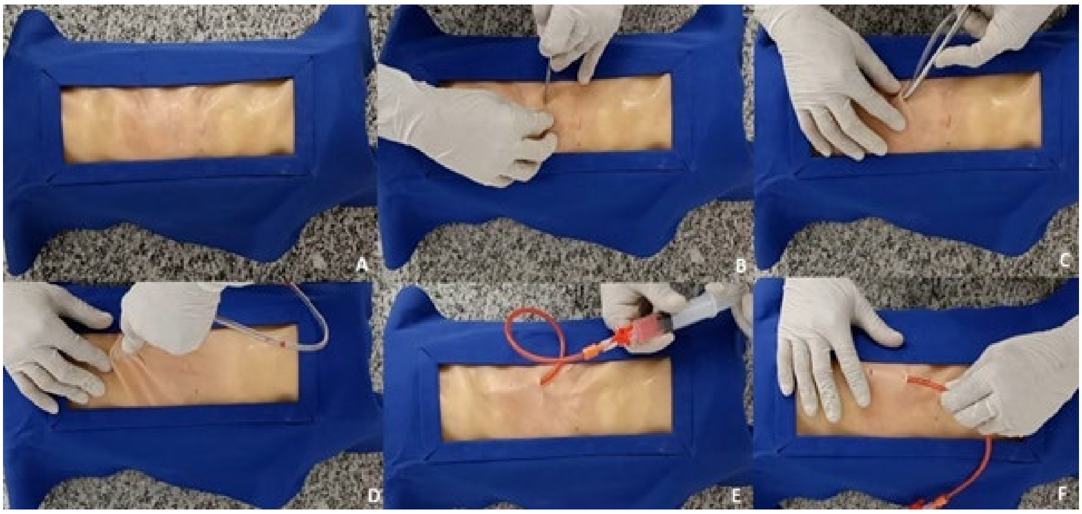

Figure 4 – The sequence of thoracic drainage simulation: the operation site is prepared (A), skin incision (B), tube tunneling through the subcutaneous tissue (C), piercing the muscle layer (D), suction is applied to confirm correct tube insertion (E), fixation of the chest drain (F).

The students then answered a questionnaire based on a 5-point Likert scale, which included questions on the simulator's structure (Figure 5) and function (Figure 6).

1.Counting the ribs to identify the desired intercostal space is similar between simulator and cadaver
2.The skin incision using the scalpel is similar between simulator and cadaver
3.The resistance of the subcutaneous layer when tunneling the drain is similar between simulator and cadaver
4.The resistance to piercing the muscle layer to enter the thoracic cavity is similar between simulator and cadaver
5.The progression of the drain into the thorax is similar between simulator and cadaver
6.The fixation of the drain is similar between simulator and cadaver
7.The fluid drainage using the three-way valve is similar between simulator and cadaver

Figure 5 – Questionnaire of structure questions completed by students using a five-answer Likert scale to evaluate the thoracic drainage simulator by comparison with a cadaver.

8.The simulator provides appropriate training for thoracic drainage technique
9.The training using the simulator provides confidence to perform the technique in a live animal
10.The training using the simulator could be used to replace the cadaver training
11.I would recommend the use of the simulator in the Surgical Technique discipline for training in practical classes

Figure 6 – Questionnaire of functional questions completed by students using a five-answer Likert scale to evaluate the thoracic drainage simulator by comparison with a cadaver.

The statistical analysis was based on the Diagnostic Content Validation (DCV) (Fehring, 1987), where values from 0 to 1 are divided equally between the five answers (0, 0.25, 0.50, 0.75, 1), and a weighted average was calculated for the 25 answers. Results for each question ranged from 0 to 1, where values less than 0.50 were considered poor, from 0.50 to 0.80 good, and over 0.80 excellent. This evaluation technique has previously been reported in a review study, which considered it a valid method for assessing simulators (Peñata et al., 2020).

3. Results and Discussion

Most students agreed that the simulator provided appropriate training. The results for each question are shown in Table 1 for the structure scores and Table 2 for the functional scores, in which most questions had high DCV values, reaching nearly 0.80.

	SD*	D*	N*	A*	SA*	DCV
Rib count	0	2	1	13	9	0.79
Skin incision	0	2	3	11	9	0.77
Subcutaneous tunnel	0	5	2	10	8	0.71
Muscle perforation	1	0	2	9	3	0.41
Drain progression	0	5	2	10	8	0.71
Drain fixation	0	2	5	11	7	0.64
Fluid drainage	0	2	1	11	11	0.81

*SD: strongly disagree; D: disagree; N: neutral; A: agree; SA: strongly agree; DCV: diagnostic content validation

Table 1 – Responses of the students and the DCV value for questions about structure described in Figure 5.

	SD*	D*	N*	A*	SA*	DCV
Appropriate training	0	0	2	11	12	0.85
Provides security	0	2	0	9	14	0.85
Simulator is more comfortable	0	1	4	7	13	0.82
Recommend the simulator	0	2	1	9	13	0.83

*SD: strongly disagree; D: disagree; N: neutral; A: agree; SA: strongly agree; DCV: diagnostic content validation

Table 2 – Responses of the students and the DCV value for the functional questions described in Figure 6.

All students successfully performed the thoracic drainage in both the cadaver and the simulator. The students could repeat the technique multiple times in both. Repeatability without the need for maintenance is a crucial characteristic of any simulator, as practice is vital to improving learning, as observed by Oliveira et al. (2020) in a human chest simulator. Hunt et al. (2021), in their review of recently developed simulators for various skill training, also concluded that simulators should allow for repeated practice, which facilitates learning.

The first seven questions were about how well the simulator mimicked the feel of a real animal. The highest scores were achieved for rib count (DCV= 0.79), skin incision (DCV= 0.77), and fluid drainage (DCV= 0.81), with only the evaluation of the muscle perforation classified as poor (DCV= 0.41). The overall assessment for construction was good. The poor rating ascribed to the sensation of penetrating the muscle layer was probably due to the variation in size of the cadavers, which included animals smaller than the simulator. Cadavers could not be standardized, as there were limited donations from other institutions or owners. However, all students could practice the technique equally on the model, which means that this size discrepancy did not affect the success of learning. These results are similar to those reported by Haller et al. (2020), which found that students had good perceptions when comparing their low-cost simulator for thoracic drainage (based on a 3D-printed model) with the cadaver. Fortes et al. (2022), who compared different simulators for chest tube placement training, reported good learning with both techniques, independent of their detailed differences, as found in our research. Oliveira et al. (2020) also noted that the students learned the technique correctly despite some limitations regarding the tactile sensation of structures with a low-cost human chest tube simulator. This information was also reinforced by Hunt et al. (2021).

The following two questions were about feelings of confidence and acceptance of the simulator. The scores for this question were higher than those for the questions about the simulator structure, indicating that the simulator provided satisfactory training and increased students' confidence in performing the procedure on a live animal, with a DCV of 0.85 for both questions. This finding concurs with a systematic review of chest tube simulators and cadaver training in human medicine, which concluded that students achieve equivalent confidence using either a cadaver or simulator (Meyer-Pflug et al., 2022). This simulator had other advantages over cadavers, such as the safety of technicians and students from potential diseases in the cadaver, corroborating findings of other studies (Silva et al., 2004; Veronez et al., 2010; Silva et al., 2016), and avoiding the exposure to toxic and carcinogenic agents, like formaldehyde (Protano et al., 2022). Most students agreed with the eleventh question that the simulator could be used as a substitute for a cadaver in the classes (DCV = 0.82). However, some students made additional comments, suggesting that the simulator should be used to complement the cadaver training rather than replace it. This highlights the importance of cadaver training for some students, which aligns with the findings of Varner et al. (2021), who suggested that cadavers allow for the simultaneous integration of other clinical issues with the technique. The simulator can be used as a first step to develop a specific skill, allowing the student to advance to the next step, where they can integrate this skill into a clinical situation using a cadaver.

The final question asked whether the students would recommend the simulator for training classes, and this received a high score of DCV = 0.83. Compared to cadavers, simulators have several advantages: they are more durable, easier to store, more cost-effective, and can be reused multiple times. They also facilitate the development of the learning curve (Fortes et al., 2022), as the training is not affected by autolysis, allowing a standardized and more pleasant training experience.

4. Conclusion

The simulator is an effective tool for training students to perform thoracic drainage in practical classes. It can be used repeatedly and can be constructed by the institution using widely available materials. The simulator helps cultivate the student's skills and confidence just as effectively as a cadaver.

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