Interactive CardioVascular and Thoracic Surgery 20 (2015) 248–253
doi:10.1093/icvts/ivu382 Advance Access publication 21 November 2014

**ORIGINAL ARTICLE – THORACIC**

# A home-made animal model in comparison with a standard manikin for teaching percutaneous dilatational tracheostomy

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Received 28 August 2014; received in revised form 20 October 2014; accepted 23 October 2014

## Abstract

**OBJECTIVES**: As airway management specialists, thoracic surgeons should be familiar with percutaneous dilatational tracheostomy. To optimize the learning curve, we propose a home-made pig model obtained from a slaughterhouse for training residents in the technical aspects of performing percutaneous dilatational tracheostomy. The satisfaction of the residents' training experience using this model was compared with that using a standard manikin model.

**METHODS**: Fifty residents participated in the present study. At the end of the session, each participant completed a questionnaire assessing the pig model and the manikin by assigning a score (ranging from 1 to 4) to five specific characteristics including (i) reality of skin turgor; (ii) landmark recognition; (iii) feasibility of the procedure; (iv) reality of the model and (v) preference of each model. The differences between models were statistically analysed.

**RESULTS**: Forty-five participants completed the study. The pig model, compared with the manikin model, presented a higher value regarding the reality of skin turgor (1.7 ± 0.5 vs 0.4 ± 0.8; respectively, $P < 0.0001$); landmark recognition (3.8 ± 0.5 vs 2.0 ± 0.5; respectively; $P < 0.0001$) and reality of the model (3.0 ± 0.8 vs 1.3 ± 1.0; respectively; $P < 0.0001$). No difference was found regarding the feasibility of the procedure (3.7 ± 0.6 vs 3.5 ± 0.5; respectively, $P = 0.1$). The pig model was preferred to the manikin (3.2 ± 0.7 vs 1.6 ± 1.0; respectively, $P < 0.0001$).

**CONCLUSIONS**: Our pig model allowed residents to develop the skills required for successful percutaneous dilatational tracheostomy. In particular, they developed confidence with certain manoeuvres such as needle and guide-wire placement, dilatation of the trachea and insertion of a cannula, before attempting the procedure on a live patient.

**Keywords:** Percutaneous dilatational tracheostomy • Manikin • Animal model

## INTRODUCTION

Percutaneous dilatational tracheostomy (PDT) has been recommended as the procedure of choice for elective tracheostomy in selected intensive care unit (ICU) patients, since it seems to be associated with a lower incidence of postinterventional complication rates than standard surgical tracheostomy (3.9–31 vs 6–66%, respectively) [1, 2]. Nevertheless, significant complications including rupture of the tracheal rings and injury to the posterior trachea may occur also after PDT, especially if performed by junior residents with minimal operative experience. Thus, some authors have recommended that a minimum skill level for trainees should be attained before the first live procedure is ever perormed [3–6]. There are many models for PDT training including manikins, animals, cadavers and newly dead subjects. Traditionally, training for PDT has been performed using manikins and anaesthetized animal models. The manikin model is economical and may be used anywhere; however, it does not represent a realistic clinical experience compared with an animal model. As airway management specialists, thoracic surgeons should be familiar with PDT, which has surprisingly been underutilized. Here, we report a cheap, home-made animal model for PDT training and its evaluation in comparison with a commercially available manikin model.

## MATERIALS AND METHODS

### Study design

It is prospective crossover study performed at Department of Thoracic Surgery and Anesthesia of Second University of Naples. After the demonstration of PDT from two expert operators, each participant performed PDT on both models in a random order to avoid any biases arising from having used the manikin before the pig or vice versa. At the end of the procedure, each participant rated both models using a 4-point scoring system and the results were statistically analysed.

Inclusion criteria for participants were as follows: (i) trainee having performed less than three live PDTs; (ii) not attending similar training before and (iii) no previous experience with PDT models similar to those used in the present study. Exclusion criteria were: (i) performing PDT in only one of the two models; (ii) partially completing questionnaire and (iii) the lack of signed informed consent. To procure the animal models, porcine models were collected as 'by products' of routine pig processing for human consumption; no pigs were killed for the purpose of this study.

All the participants and instructors were prepared with universal precautions regarding the possibility of infection due to the animal model; all the animal models were incinerated according to the hospital policy at the end of the procedure. The present study was approved by Ethics Committee of Second University of Naples and a written informed consent was obtained from each participant and instructor before entry to the study.

## Participants

Fifty residents participated in the present study. At the end of the session, each participant completed a questionnaire assessing the animal model and the manikin by assigning a score to five specific characteristics including (i) reality of skin turgor; (ii) landmark recognition; (iii) feasibility of the procedure; (iv) reality of the model; (v) and preference of each model. A previously validated 4-point scale ranging from 1 to 4 was used for scoring each characteristic as follows: 1 = poor; 2 = fair; 3 = good; 4 = excellent and UA = unable to assess [7].

## Preparation of the animal model

An adult pig larynx and trachea bought from the slaughterhouse was used to mimic the patient's anatomy. The larynx and trachea were freed from perilaryngeal and peritracheal tissue; it was wrapped with plastic film for food and stored frozen to avoid tissue desiccation. Then, it was warmed to body temperature for preparing the model. The porcine laryngo-tracheal block was placed on a hard backing and a simulated skin and soft tissue interface was created using the placement of sponge and plastic wrapping over the tissue construct (Fig. 1). The distance between the sponge and the trachea was ∼1 cm. Then, the pig larynx–trachea was inserted into the neck of a resuscitation manikin (Fig. 2A).

## Procedure

The PDT was performed according to the Blue-Rhino-Ciaglia method using a commercially available kit (Cook® Ciaglia Blue Rhino™ Percutaneous Tracheostomy Introducer Set with EZ-Pass™ Hydrophilic Coating—Cook Critical Care, Bloomington, IN, USA). The demonstrations to participants were performed by two operators (A.F. and F.F.) who had experience with the Ciaglia-Blue-Rhino method in the clinical setting and with the model. A video-bronchoscope (Olympus BF-XT-160) was used during the entire procedure. This allowed both the participant performing the procedure to see the results of their manipulations and the teacher to monitor and advise as they proceeded (Fig. 2B). Two to four PDTs were performed on each animal model. Thus, to maximize the number of PDTs, the first puncture was initiated at the most inferior available portion of the trachea.

Briefly, the bronchoscope was inserted into the larynx and passed down the trachea. The light reflex (transillumination) was used to choose the best spot for the introducer needle (usually at the level of the II–III tracheal ring). At this level, the finger compressed the anterior wall of the trachea (Fig. 3A) and then the needle was introduced and directed caudally into the tracheal lumen to avoid lesion of the posterior tracheal wall. The needle was removed and a guide-wire was advanced through the catheter sheath. Then a plastic guiding catheter was inserted over the guide-wire (Fig. 3B) and the dilator, loaded on the guiding catheter, was gently pushed through the tracheal wall (Fig. 3C). When a large fistula was created, the tracheostomy tube was inserted and placed above the carina (Fig. 3D). Finally, the trachea was opened and examined for showing signs of damage.

## Statistical analysis

Data are expressed as means with standard deviation. The differences between scores were assessed using Student's *t*-test. A *P*-value of <0.05 was considered statistically significant. The MedCalc statistical software (Version 12.3, Broekstraat 52; 9030 Mariakerke; Belgium) was used for analysis.

# RESULTS

Among 50 participants, 45 completed the study. Five were excluded because they performed the PDT procedure in only one model ($n = 1$), and partially completed the questionnaire ($n = 4$). The animal model compared with the manikin model presented a higher value regarding the reality of skin turgor (1.7 ± 0.5 vs 0.4 ± 0.8; $P < 0.0001$), landmark recognition (3.8 ± 0.5 vs 2.0 ± 0.5; $P < 0.0001$) and reality of the model (3.0 ± 0.8 vs 1.3 ± 1.0; $P < 0.0001$). No difference was found regarding the feasibility of the procedure (3.7 ± 0.6 vs 3.5 ± 0.5; $P = 0.1$). The animal model was preferred to the manikin (3.2 ± 0.7 vs 1.6 ± 1.0; $P < 0.0001$). No signs of tracheal damage was found in the animal model after the procedure.

# DISCUSSION

PDT is the procedure of choice for elective tracheostomy in selected ICU mechanically ventilated patients, since it appears to be associated with a lower overall incidence of post-interventional complications, bleeding and stomal infections than surgical tracheostomy [1, 2]. Generally the side-effects related to PDT are mild and easy to overcome, but some major, life-threatening complications are also described.

Despite being less invasive, PDT undoubtedly requires high surgical expertise and, similar to other surgical techniques, it has a steep learning curve [8]. Several authors have supported the theory that PDT complications appear to decrease as the operator gains experience [9, 10]. Donalds *et al*. [9] found that complications (13 vs 33%, $P = 0.030$), operative time (12 vs 24 min, $P < 0.0001$) and total procedure time (37 vs 80 min, $P < 0.001$) were significantly reduced in the PDT group when compared with standard

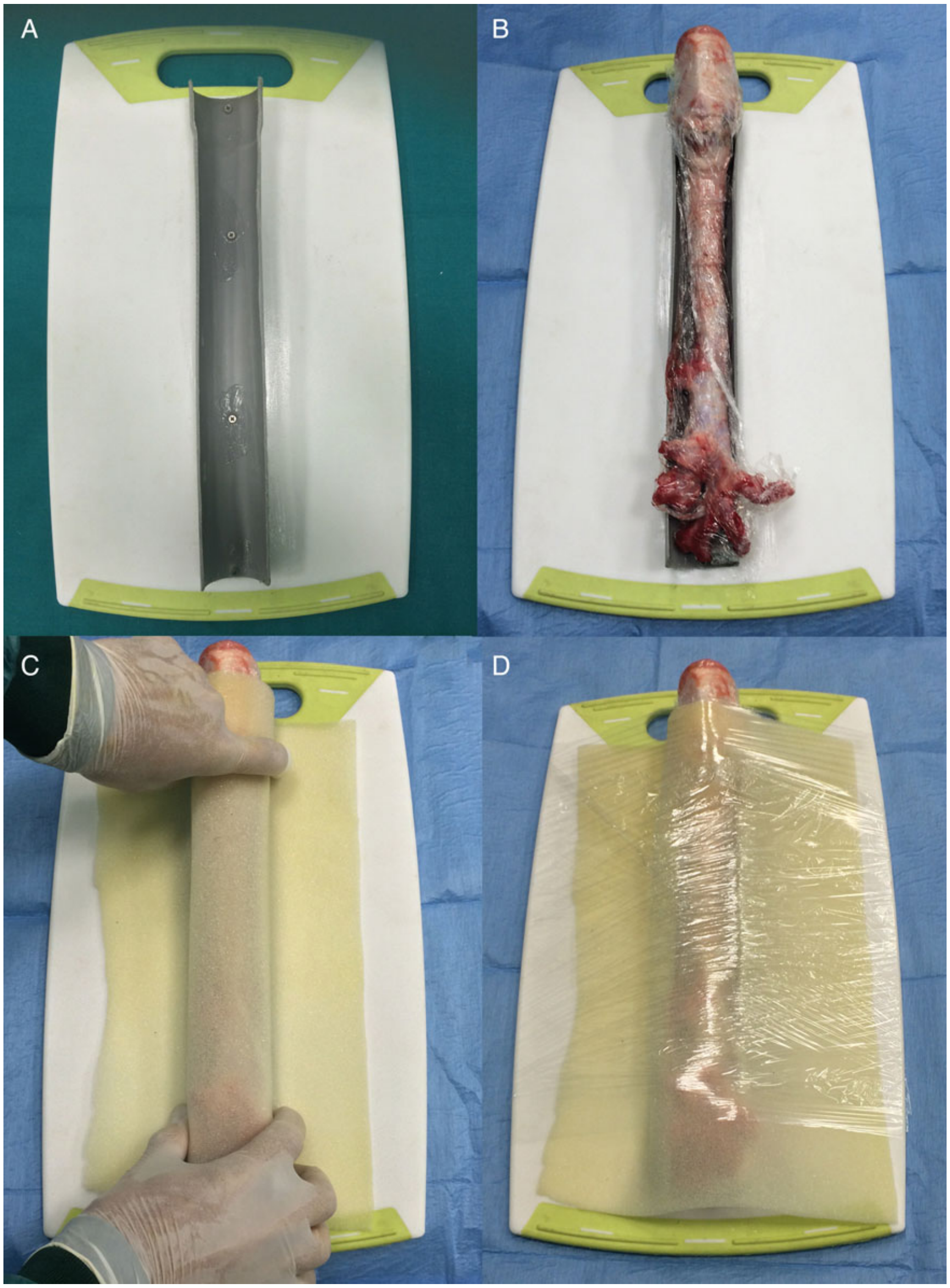


**Figure 1:** A hard backing with a tubular construction attached to a board (**A**) was prepared to support a porcine laryngo-tracheal block (**B**). It was then covered with a thin sponge (**C**) and waterproof tape (D) in order to mimic the skin.

tracheotomy after a training programme, while the initial outcome data were equal in both groups. Similarly, Massick *et al.* [10], in a case series of 100 consecutive community hospital PDT patients, found that the first cohort of 20 patients accounted for the majority of the perioperative, postoperative and late complications, while a significant reduction in the overall complication incidence rate was seen after the first 20 procedures, confirming the importance of the learning curve.

Although easy, PDT is a blinded procedure and an experienced operator can do essentially little when a trainee advances the dilator and/or the tracheostomy tube [11]. Thus, the standard method for teaching clinical skills described as 'seen one, do one, teach one' seems to be not ethically acceptable for PDT that requires practice using a simulation before performing it for the first time on a patient. This is because mistakes made using the model had no consequences in terms of patient care but those made on live patients may be disastrous [12].

Generally, training in PDT consists of explanation and seeing the technique. Owing to the rapid turnover of residents in university teaching hospitals (rotations of 1–3 months), most of them have the opportunity to see the procedure only once or twice before performing it in a clinical setting. Occasionally, residents may perform PDT on a manikin before their first live procedure. However, the manikin model is not similar enough to the human anatomy and does not provide a realistic model for learning this technique. An anaesthetized animal is the ideal model to develop the skills required for successful PDT but only a limited number of residents may have this opportunity due to the high cost of this


**Figure 2:** The complete artificial manikin (**A**) and the percutaneous dilatational tracheostomy procedure (**B**).

model and the inability to use it everywhere. Thus, PDT is often carried out by young residents who have not had sufficient experience with such a technique.

Surprisingly, thoracic surgeons have limited confidence with such a procedure and no thoracic surgeon teaching programmes are reported. The preference for an open approach might explain such a tendency, but, as airway management specialists, thoracic surgeons should increase their familiarity with PDT, which is not only an elective procedure but also allows one to achieve an urgent access to the trachea.

To guarantee the patient's safety and to optimize the learning curve, we propose a home-made animal model as the teaching model for PDT and its evaluation with a standard manikin model.

We have chosen pig as our model because the anatomy and size of pig tracheas are similar to those in humans. Among the various techniques of PDT, in our training programme we employed the Ciaglia-Blue-Rhino technique using a single, bevelled and curved dilator (Blue-Rhino) rather than multiple dilators. The single-step dilator has the advantage of not requiring a change in dilator, thereby reducing potential complications and tidal volume loss until the tracheostomy tube is ready to be inserted [13].

Yet, we used video-endoscopic guidance during the whole procedure because it has been reported to decrease PDT complications [14, 15]. Furthermore, it helped instil confidence in the residents who learned the procedure and allowed the participants performing the procedure to see the results of their manipulations and the teacher to monitor and advise as they proceeded.

In our study, the home-made animal model showed significantly higher scores compared with the manikin in all settings, except the feasibility of the procedure, which showed no particular difference in both models.

Obviously these results should be evaluated with caution considering that they were assessed by residents with limited experience in the live tracheostomy procedure; in addition, the study design did not include provision of scores by the instructors, who had experience with PDT, regarding the reality of both models and/or whether the trainee's performance with the pig model was truly better or worse than when using a manikin. However, in the light of the trainees' comments and the reviews of each resident's performance, we believe that the animal model is more realistic than the manikin model especially in creating in residents the 'tactile feeling' when passing through the anterior wall of the trachea. It is crucial considering that posterior tracheal injury is the main disadvantage of any PDT with the anterior dilatational approach and may be incidentally caused by introduction of the needle, by kinking of the guide-wire or during dilatation of the stoma using either dilatation or a screw-like device [16–18]. All these manoeuvres are reproduced and replicated by residents in a way closer to the real procedure using a pig model rather than a manikin model. Compared with an artificial trachea, the elasticity of pig trachea, despite being dead, is more similar to that of humans and allows one to replicate realistic situations such as the collapse of the anterior tracheal wall when pressure is applied during the procedure. In addition, because all PDTs were performed under endoscopic view, the residents observed in real-time the results of their manipulations. It allowed the teachers to supervise and advise as they proceeded, identifying and correcting the 'mistakes' made during the procedure even though such actions were not quantified (i.e. number of mistakes; number of times the instructor had to intervene and so on).

The only area in which the mean value score of our animal model was under 2.0 was the reality of skin turgor. Despite being more realistic than the manikin model, the sponge and plastic film used to cover the larynx–trachea cannot closely resemble the true anatomy of skin. Yet, the operator had several external landmarks including cricoid cartilage and peritracheal tissue, along with transillumination to choose the level at which to perform tracheostomy; even though all external landmarks as the sternal notch were not reproduced. Obviously, our model may improve in quality by covering the larynx–trachea with a piece of thinned pigskin as proposed by Cho et al. [19] and McLure et al. [20] in their animal model. It also might reduce the ratio between the trachea and the neck which is higher in our model than in

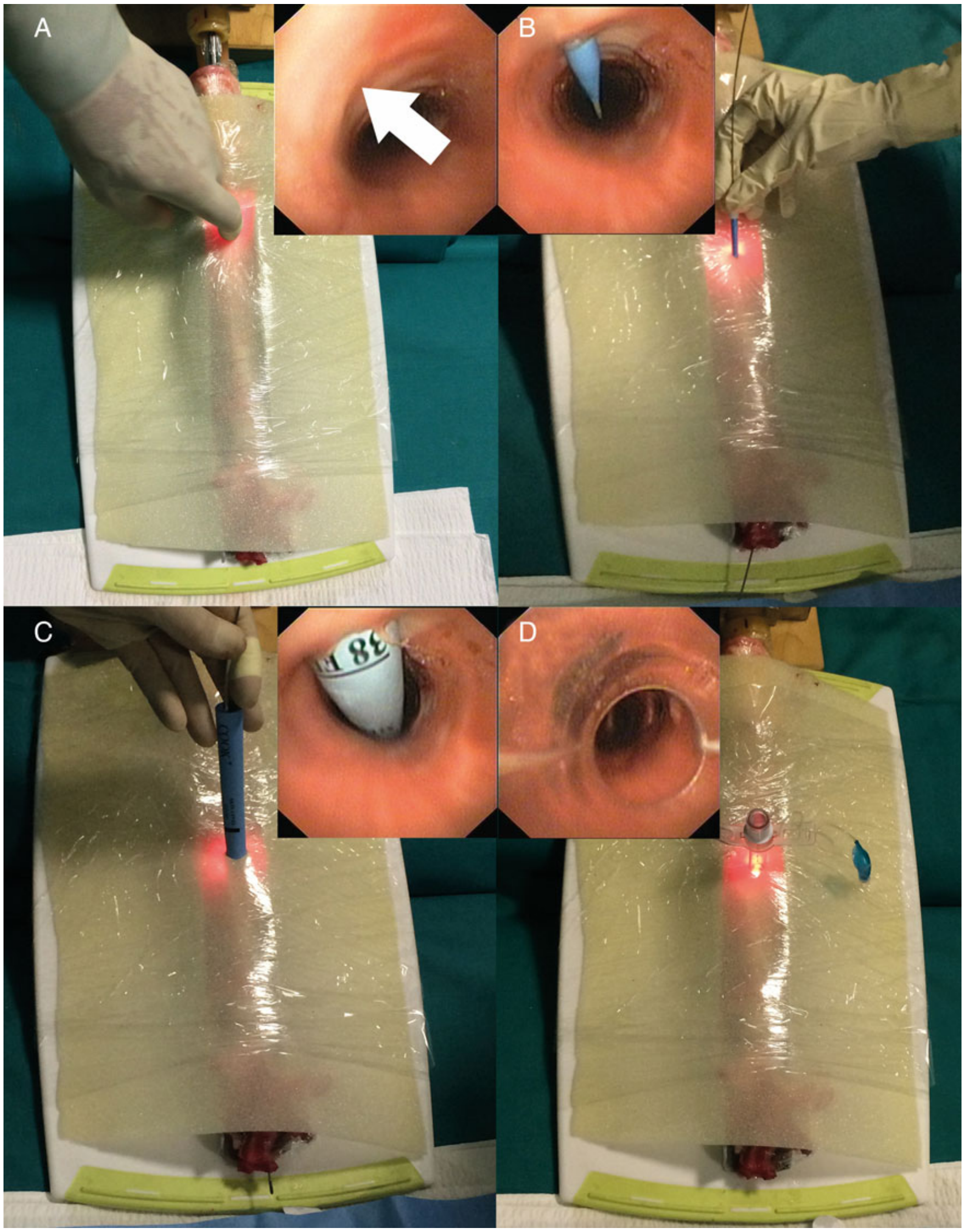


**Figure 3:** (**A**) The light reflex of bronchoscopy was used to choose the best spot for the introducer needle. At this level, gentle pressure was applied with a finger against the anterior wall of the trachea and visualized endoscopically (inset) to confirm a midline approach. (**B**) A plastic guiding catheter was inserted over the guidewire previously introduced and its progression in the tracheal lumen was confirmed by an endoscopic view (inset). (**C**) The dilator was loaded on the guiding catheter and gently pushed through the tracheal wall until a large tracheal fistula was obtained (inset: endoscopic view). (**D**) The tracheostomy tube was inserted and the final position within the trachea was confirmed by the endoscopic view (inset).

humans. However, more efforts are needed to simulate the true anatomy of the neck and the more complicated the model becomes, the more difficult it is to assemble.

Lack of funds is a continuing barrier to the purchase of training equipment, and therefore the low cost of our model and the readily available components are additional advantages. The porcine laryngo-tracheal block can be bought in the market for €5. Despite being more difficult to assemble, the porcine larynx–trachea could be obtained directly from a slaughter house, which would certainly save cost. An additional €10 is needed for the hard backing, the thin sponge and the waterproof tape for a total cost of €15, compared with €350 for the training manikin. Considering that 2–4 procedures may be performed on each pig model, for a course of 50 participants (as the present) the total cost for pig models is about €260 compared with €1000 for manikins, due to manikin cost and new components for repeated use. Apparently, our model is more difficult to manage on a daily basis and more difficult to preserve compared with the classic manikin. For example, the pig model should be stored in a refrigerator to avoid tissue desiccation if one wants to reutilize it the next day.

## Study limitations

As reported above in the discussion section, our study design presents several limitations. (i) The lack of feedback of teachers on the models and the trainees' performances, and (ii) the scores that the trainees give on the realism of the two models may not be completely accurate due to their limited experience with the live procedure. In addition, our tracheal model is a useful, but not perfect, training tool for the following reasons. (i) The model is avascular and so there is no bleeding and/or secretion to obscure the surgical field [19]. (ii) The presence of the endotracheal tube has not been taken into consideration, which may render the live procedure more difficult due to the possibility of puncturing the tube and/or its cuff when introducing the needle and/or the dilator in the anterior tracheal wall. (iii) The trachea is placed on a stiff board, not in the living elastic patient and there is no oesophagus beneath. In addition, in our model the neck was long and needle and introducer insertion could be done at any location. Conversely, the human neck may be shorter according to the posture of patient and sometimes it is difficult to find landmarks to find the proper place to insert the introducer, especially in obese patients. Despite all these limitations, our model is helping to teach the residents the order of the PDT manoeuvres and the use of a video-bronchoscope during the introduction and the progression of the needle and the dilator in order to avoid tracheal and oesophageal lesions.

The trainee's assessment of the model is not necessarily translated into practical competence with the PDT technique. Simulation has been shown to be of greatest benefit if the period between simulated practice and practical application of the skill is kept short. Thus, in order to validate the clinical benefit of our model, in the future we should minimize the interval between the training session and the live procedure and then evaluate if the routine use of our model reduces the side-effects of PDT in our hospital.

## CONCLUSIONS

As airway management specialists, thoracic surgeons should be familiar with PDT. Our model can be easily and rapidly reproducible in construction in any department. It allowed residents to develop the skills required for successful PDT. Particularly, they developed confidence with particular manoeuvres such as needle and guidewire placement, dilatation of the trachea and insertion of the cannula before attempting the procedure on a live patient. However, the clinical utility of the learning curve obtained with our model should be corroborated by future evaluations, i.e. the decreased rate of PDT complications in clinical practice.

**Conflict of interest**: none declared.

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