Detection of oesophageal intubations using cuff pressures in a pig trachea–oesophagus model

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Background. The cuff pressures may be different in oesophageal and tracheal intubations. We conducted a study to evaluate if cuff pressures of endotracheal tubes (ETTs) could provide information to distinguish tracheal or oesophageal intubations in a pig trachea–oesophagus model.

Methods. In each preparation of pig trachea–oesophagus model, the trachea and the oesophagus were intubated separately with a cuffed ETT, and the cuff pressures were measured after each 1 ml increment of air (1–10 ml) during inflation. The cuff pressures and the pressure–volume relationships in both intubations were compared.

Results. The cuff pressures of oesophageal intubations were significantly higher than those of tracheal intubations in all comparisons from 1 to 10 ml of cuff volumes (P<0.05). The cuff pressure–volume curve was steeper in the oesophageal intubation group, and the difference between the two curves was the largest when the cuff volume was 4–5 ml.

Conclusions. We conclude that the cuff pressures may be useful in detecting oesophageal intubations. This method is faster than other confirmation measures as it can detect inadvertent oesophageal intubations at the time of inflating the cuffs.


Keywords: airway; airway, intubation, cuff pressure; complications, intubation tracheal; equipment, tubes tracheal; oesophageal intubation

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used to measure the cuff pressures. The cuff pressures were measured after each 1 ml increment of air (1–10 ml) during inflation. After completion of the trachea measurements, the cuff of the tube in the trachea was deflated. Then the cuff of the tube in the oesophagus was inflated and the same procedures were repeated. The procedures were carried out on 20 pig trachea–oesophagus preparations.

We used the Wilcoxon signed rank test to evaluate differences in the cuff pressures between the two intubations and obtained the \( P \)-values using small sample tables. All statistical analyses were performed using the SPSS package at the two-sided significance level of 0.05.

**Results**

The diameters of the slaughtered pig trachea ranged from 2.1 to 2.7 cm. The measured cuff pressures increased as the cuff was inflated from 1 to 10 ml in each test (Table 1). The cuff pressures of oesophageal intubations were significantly higher than those of endotracheal intubations in all comparisons from 1 to 10 ml of cuff volumes (\( P < 0.05 \)).

The cuff pressure–volume curve of the oesophageal intubations was steeper than that of the tracheal intubations in the first 5 ml of cuff inflation (Fig. 1). During the inflation of the cuff, the difference between the two curves was the largest when the cuff volume was 4–5 ml (Fig. 2).

**Discussion**

The early detection of oesophageal intubation is crucial in preventing hypoxic brain injuries in patients undergoing endotracheal intubations. However, all the current methods of verifying the proper placement of ETT may fail or be impractical under certain circumstances.\(^6\)–\(^{11}\) This study was planned to evaluate if measurements of cuff pressures of tracheal tubes at different cuff volumes could be used to distinguish endotracheal and oesophageal intubations. A pig trachea–oesophagus model was chosen for this study because of the anatomic similarities with those of humans.

Cardoso and colleagues\(^{12}\) reviewed portable devices for detecting endotracheal intubation and recommended that the oesophageal detector device (TubeChek) may be considered ideal in emergency situations in the pre-hospital setting. However, Zaleski and colleagues\(^{13}\) reported slow reinflation in 6% of the instances using oesophageal detector devices, and also that false negative tests might occur. End-tidal CO\(_2\) monitoring is imperfect and not practical in pre-hospital settings.\(^{14}\) Therefore, new confirmatory methods to detect tube misplacement at a higher accurate rate in the pre-hospital setting are desirable.

The human oesophagus is a hollow muscular tube about 1.5–1.9 cm in luminal diameter.\(^{15}\) On the other hand, the human trachea consists of a supporting layer of connective and muscular tissues in which are embedded C-shaped rings of hard cartilage that encircle the front of the tube. It is about 11 cm long and about 2–2.5 cm in diameter in

### Table 1

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<th>Volume</th>
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**Fig 1** The pressure–volume curves in endotracheal and oesophageal intubations. Error bars show mean (SE).
Since the oesophagus has a thick muscular wall, the cuff pressure should increase more rapidly if misplacement of the ETT into the oesophagus occurred, which is confirmed by the data in the current and our previous studies. In the current study, cuff pressures of oesophageal intubations were significantly higher than those of endotracheal intubations in all comparisons from 1 to 10 ml of cuff volumes ($P<0.05$). The cuff pressure–volume curve was steeper in the oesophageal intubation (Fig. 1), and the difference between the two curves was the largest when the cuff volume was 4–5 ml (Fig. 2). So, measurements of the cuff pressures at the cuff volume of 4–5 ml would be most useful to distinguish oesophageal and endotracheal intubations.

Taking into account the anatomical similarities between swine and human, most researchers chose pigs to establish animal models for airway and resuscitation studies, and we followed this in the current study. We had conducted a previous study using six live pigs to compare the cuff pressures in oesophageal and endotracheal intubations, and the current study aimed at confirming the findings with a larger sample size. We modified a well-established pig trachea model that had been used commonly in the training for cricothyrotomy and tracheostomy. In addition to avoiding the sacrifice of a large number of animals, this pig trachea–oesophagus model has the following advantages: (i) the slaughtered pig trachea and oesophagus preparations are easy to obtain, (ii) the position of the tube can be directly visualized, (iii) the study will not involve anaesthetic procedures and thus is free from potential confounding effects related to the procedures and medication, and (iv) the diameter of the trachea can be measured directly.

The major limitation of this slaughtered tissue preparation model is that the cadaveric tissues had no contraction of oesophageal smooth muscles, which would increase the cuff pressure. Consequently, the cuff pressures of oesophageal intubations in the slaughtered tissues were lower than those in the live pigs as reported earlier ($192.0 \text{ cm } H_2O$ at the cuff volume of 10 ml) and thus led to smaller differences between the endotracheal and oesophageal intubations. Nonetheless, in the current study, the cuff pressures in the oesophageal intubation group were still significantly higher than those in the endotracheal intubation group, and therefore this limitation did not affect the conclusion of the current study.

In conclusion, a pig trachea–oesophagus model was used to evaluate the feasibility of using cuff pressure differences to distinguish oesophageal and endotracheal intubations. Cuff pressures were significantly higher in oesophageal than in endotracheal intubations all the way from 1 to 10 ml of cuff volumes, and therefore, we conclude that the cuff pressures may be useful in detecting oesophageal intubations. This method would be faster than other secondary confirmation measures as it can detect inadvertent oesophageal intubations at the time of inflating the cuffs.

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