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Use of the injection test to indicate the oesophageal balloon position in patients without spontaneous breathing: a clinical feasibility study

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Abstract

Objective: To investigate the clinical feasibility of the injection test for balloon placement during oesophageal pressure measurement in patients without spontaneous breathing.

Methods: The injection test was performed in 12 mechanically ventilated patients under deep sedation and paralysis. During withdrawal of the balloon from the stomach and air injection into the gastric lumen of the catheter, the presence of the injection test wave in the balloon pressure tracing indicated that the whole balloon was positioned above the lower oesophageal sphincter (LES). The positive pressure occlusion test was performed at different balloon positions.

Results: In each patient, the injection test wave appeared at a distinct balloon depth, with a mean ± standard deviation of 41.9 ± 3.3 cm and range from 37 cm to 47 cm. The optimal ratio of changes in the balloon and airway pressure (0.8–1.2) during the positive pressure occlusion test was obtained when the balloon was located 5 cm and 10 cm above the LES in nine (75%) and three (25%) patients, respectively.

Conclusions: The injection test is feasible for identification of the whole balloon position above the LES during passive ventilation. The middle third of the oesophagus might be the optimal balloon position.

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Introduction

Oesophageal pressure (P_{ES}) has been used as a surrogate for pleural pressure in respiratory mechanics research for many years, but the technique has not been widely adopted in the clinical setting.[1,2] Catheters with air-filled balloons are commonly used, and the correct balloon position is crucial for the accuracy of the measurement. Confirmation of the optimal balloon position has been well established in patients with spontaneous breathing.[1–5] The balloon is first inserted into the stomach, where a positive pressure deflection can be observed during spontaneous inspiration. The balloon is then slowly withdrawn until a negative pressure deflection replaces the positive deflection, indicating that the balloon is traversing across the lower oesophageal sphincter (LES) and entering the oesophagus. After entrance of the whole balloon into the oesophagus, the optimal position with which to reliably reflect the pleural pressure can be adjusted by the dynamic occlusion test, as originally described by Baydur et al.[5] These procedures require the presence of spontaneous breathing; however, breathing is not always preserved in mechanically ventilated patients, including those who are heavily sedated and paralyzed.

Recent studies have demonstrated the utility of P_{ES} monitoring for ventilator management in patients with acute respiratory distress syndrome.[6–9] In these studies, respiratory mechanics were measured in a static condition during passive ventilation, which required the elimination of spontaneous breathing. In this situation, the oesophageal positioning of the balloon was usually estimated by qualitative changes in the P_{ES} waveforms (e.g., the presence of a cardiac artefact or P_{ES} fluctuation during the ventilation cycle) and this process was empirical and largely dependent on the operator's experience. Although a modified positive pressure occlusion test has been used to identify the proper balloon position in animal models and patients,[8,10–12] only one clinical study[12] has investigated the test at different balloon positions. Because an inappropriate balloon position can lead to inaccurate and variable measurements of P_{ES}, a more consistent method is needed to determine the precise oesophageal level at which the whole balloon is placed.

In this pilot study, we modified a commercially available oesophageal balloon catheter and introduced a new method, referred to as the injection test, as an indicator for positioning of the whole balloon just above the LES. We primarily investigated the clinical feasibility of the injection test in patients without spontaneous breathing. In addition, we performed the positive pressure occlusion test at different balloon depths and determined the optimal balloon position.

Patients and methods

Study population and ethics

This prospective observational study was carried out in the Intensive Care Unit (ICU) of Beijing Tiantan Hospital, Capital Medical University, Beijing, China. From June to September 2015, we enrolled 12 postoperative patients with delayed emergence from general anaesthesia who had been admitted to the ICU for mechanical ventilation. The exclusion criteria were an age of < 18 years; a history of oesophageal, gastric, or lung surgery; diagnosis or suspicion of oesophageal varices; evidence of an active air

leak from the lung, including bronchopleural fistula, pneumothorax, pneumomediastinum, or an existing chest tube; a history of chronic obstructive pulmonary disease; and evidence of severe coagulopathy.

The study was approved by the Institutional Review Board of Beijing Tiantan Hospital, Capital Medical University, Beijing, China (no. KY-2015-CCM-002). We obtained written informed consent from each patient or an appropriate substitute decision-maker. The study was registered at ClinicalTrials.gov (NCT02446938 on 14 May 2015). The study design, performance, and reporting are in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[13]

Mechanical ventilation and pressure measurements

During the study, the patients remained in the supine position with the head of the bed elevated to 30°. They were ventilated with a SERVO-i ventilator (Maquet Co., Solna, Sweden) through an endotracheal tube. The ventilator was set for volume-control ventilation with a constant inspiratory flow of 50 to 60 L/min, tidal volume of 6 to 8 ml/kg predicted body weight, and inspiratory:expiratory phase ratio of 1:2 (inspiratory pause time of 0.3 s). The respiratory rate, inspired oxygen fraction, and positive end-expiratory pressure were maintained at baseline settings. During the procedures, the patients were deeply sedated and paralyzed by intravenous infusion of midazolam (0.05–0.2 mg/kg/h) and fentanyl (0.1 mg/h) as well as an intravenous bolus of vecuronium at the beginning of the procedure (0.1 mg/kg) and subsequently every 30 min (0.05 mg/kg). The elimination of spontaneous inspiratory effort was closely observed by inspection of the airway pressure (P_{AW}) and flow tracing. The physician in charge accompanied the patient and ensured the patient's safety.

The P_{AW} and balloon pressure (P_B) were measured using different pressure transducers (KT 100D-2; KleisTEK di Cosimo Micelli, Monopoli, Italy; range: $\pm$ 100 cmH_2O; sample rate: 200 Hz), which were connected to a dedicated acquisition system (ICU-Lab; KleisTEK Engineering, Bari, Italy). The signals were continuously displayed and saved on a laptop for further analysis. The P_{AW} transducer was located between the Y piece and the endotracheal tube.

Modification of balloon catheter and injection test

An adult nasogastric tube with an oesophageal balloon (SmartCath-G, 7003300; CareFusion Co., Yorba Linda, CA, USA) was used in this study. The catheter consists of a 16-Fr nasogastric tube with multiple small holes in the distal portion and one thin-walled polyethylene balloon (length of 10 cm) incorporated into the lower portion of the tube. The distal edge of the balloon is 20 cm away from the tip of the catheter. We modified the catheter as shown in Figure 1. Multiple small holes in the distal gastric lumen were sealed by a 10-cm-long segment of a 20-Fr latex T-drainage tube (2660382; Zhanjiang Star Enterprise Co., Ltd., Guangdong, China), and a new side port with a 0.3-cm diameter was made in the gastric lumen 2 cm away from the distal edge of the balloon. Because the inner diameter of the latex T-tube (4.0 mm) was slightly smaller than the outer diameter of the catheter (5.2 mm), the elastance of the latex material produced a seal tight enough to avoid dislodgement. The distance to the distal edge of the balloon was marked from 25 cm to 65 cm at 5-cm intervals. In this study, the depth of the catheter was defined as the distance from the distal edge of the balloon rather than from the tip of the catheter. The modification of the catheter was consistent with the principles of aseptic technique.

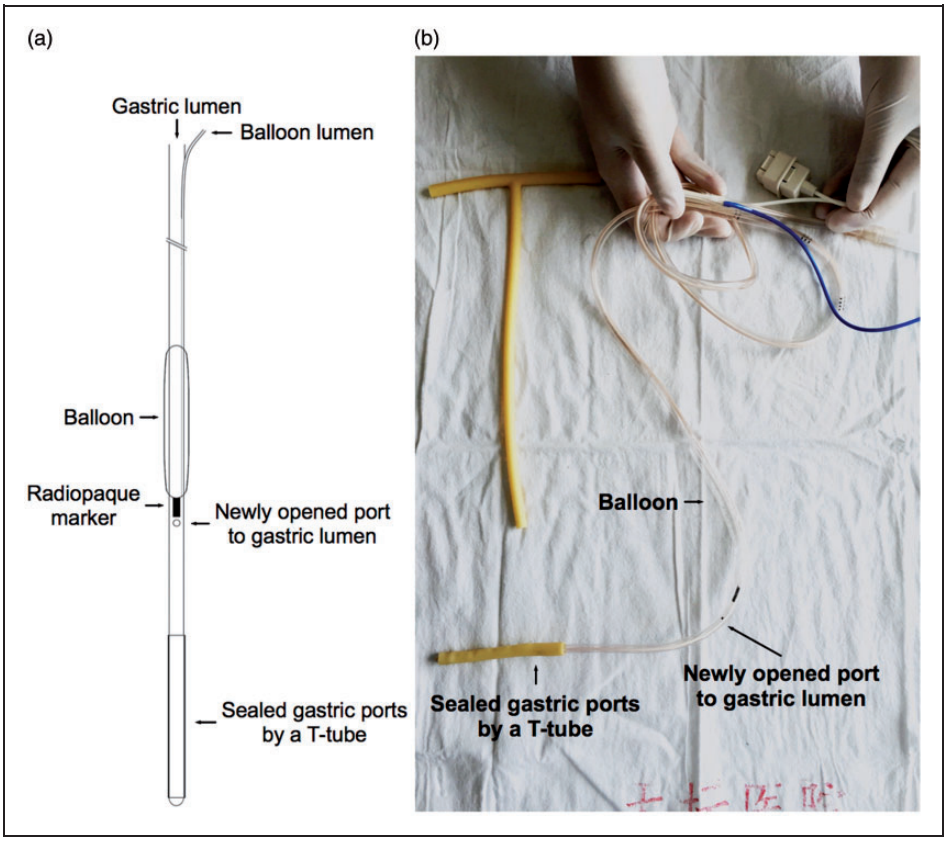

Figure 1. Modification of the catheter.

We developed an injection test based on the assumption that if the balloon was located in a large space (such as the stomach), injecting a small amount of air into this space would not significantly increase the surrounding pressure of the balloon; in contrast, if the balloon was located in a narrow space (such as the oesophagus), injecting the same amount of air would markedly increase the balloon's surrounding pressure. The LES constitutes the border between the stomach (the large space) and the oesophagus (the narrow space). Because the original multiple holes in the gastric lumen were 15 cm apart from the distal end of the balloon, we sealed these holes and opened a new side port near the balloon (2 cm apart).

Before the catheter was placed, the balloon was emptied of air and closed by a three-way stopcock. The modified catheter was inserted through the mouth to a depth of 55 cm (from the distal edge of the balloon to the maxillary central incisors), and the intragastric position was confirmed by aspiration of gastric juice and auscultation of air insufflation into the stomach. The gastric lumen was drained as much as possible. The balloon was inflated with 1.5 ml of air; this balloon volume was within the working volume range previously reported for this catheter type.[14,15] The intragastric balloon position was confirmed by a concurrent rise in the P_B tracing during manual epigastric compression. An injection test was performed by insufflating 30 ml of air via

the gastric lumen of the catheter at end-expiration. If the newly opened side port of the gastric lumen was in the stomach, no disturbance was found in the P_B tracing. The catheter was intermittently withdrawn, and the injection test was repeatedly performed. Once the port was located above the LES, a sharp positive waveform could be observed just after the air injection. This P_B waveform was termed the injection test wave. As the catheter was withdrawn, the presence of the injection test wave indicated that the whole balloon was located just above the LES in the oesophagus. The magnitude of the injection test wave was usually $>20\,cmH_2O$ and was easily detected. To avoid possible over-distension of the stomach and oesophagus during the injection test, we aspirated the gastric lumen of the catheter before and after each air injection. The patients were closely observed for adverse effects during the injection test, including retching, vomiting, coughing, bleeding, and changes in the oxygen saturation, respiratory rate, heart rate, and blood pressure.

Positive pressure occlusion test at different balloon positions

After confirming the presence of the injection test wave, we documented the catheter depth as the distance between the distal end of the balloon and the maxillary central incisors. At this depth, the distal end of the balloon was just above the LES. A bedside chest X-ray examination was performed to confirm the catheter position. The balloon was then reinserted into the stomach. The following three procedures were performed at seven balloon positions (distal end of the balloon 15 cm, 10 cm, and 5 cm below the LES; just above the LES; and 5 cm, 10 cm, and 15 cm above the LES) (Figure 2).

(1) The injection test was repeated to confirm the originally obtained depth of the injection test wave.
(2) The airway was occluded for 5 s at end-expiration and end-inspiration, and the P_{AW} and P_B were measured.
(3) A modified positive pressure occlusion test was performed by applying gentle manual compression to the lower third of the sternum during end-expiratory occlusion.[7,12] The ratio of the increase in the P_B to P_{AW} during chest compression ($\Delta P_B/\Delta P_{AW}$) was calculated. A reliable $\Delta P_B/\Delta P_{AW}$ ratio was defined as 0.8 to 1.2.[1,2] The test was repeated three times at each balloon position, and the best ratio was selected.

The cardiac artefact in the P_B waveform was measured as the difference between the minimal and maximal value in P_B tracing

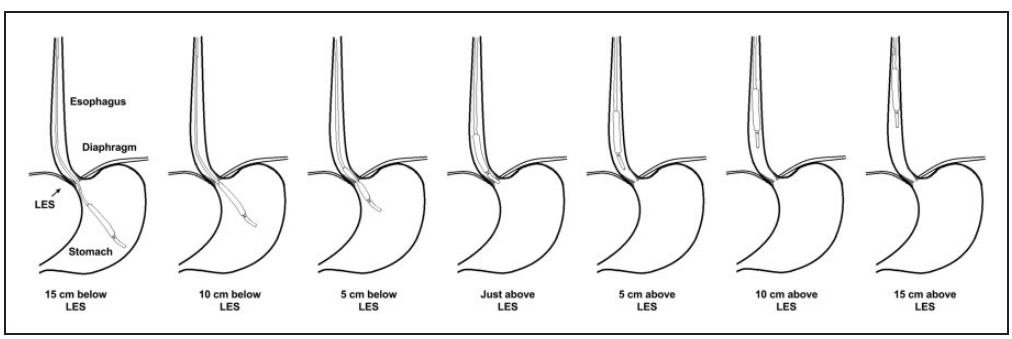

Figure 2. Schematic of relationship between whole balloon and lower oesophageal sphincter (LES).

during one cardiac cycle at end-expiratory occlusion.[16]

The balloon volume was checked at each position. We removed the catheter immediately after the procedure and inspected whether the T-tube segment was dislodged from the catheter.

Statistical analysis

Categorical variables are reported as numbers and percentages. Continuous data were checked for normal distribution by the Shapiro–Wilk test and are presented as mean ± standard deviation or median and interquartile range (IQR), as applicable. Changes in the P_{AW}, P_B, and P_B due to a cardiac artefact were compared among different balloon positions by one-way analysis of variance followed by Student–Newman–Keuls pairwise comparison. The $\Delta P_B/\Delta P_{AW}$ ratio and absolute deviation of the $\Delta P_B/\Delta P_{AW}$ ratio from unity were calculated and compared among different balloon positions using the Kruskal–Wallis test with pairwise comparison by Bonferroni correction. The analysis was performed using the statistical software package SPSS 20.0 (IBM Corp., Armonk, NY, USA). A *P*-value of < 0.05 was considered statistically significant.

Results

Table 1 shows the baseline characteristics of the patients. Individual pressure measurements and the results of the positive pressure occlusion test are presented in the journal's platform as supplementary materials. For each patient, the injection test wave appeared at a distinct depth (mean ± standard deviation: 41.9 ± 3.3 cm; range: 37–47 cm), measured from the distal end of the balloon to the maxillary central incisors. No adverse effects were observed during the injection test, and no dislodgement of the T-tube segment occurred. In three (25%) patients, the injection test induced a slight short-lived oesophageal contraction.

Table 1. Baseline characteristics of the patients at study entry (n = 12)

Age, years	64 (44–66)
Male sex	7 (58.3)
Height, cm	164 ± 7
Weight, kg	68 ± 17
BMI, kg/m^2	25.2 ± 5.5
Mechanical ventilation settings	
Tidal volume, ml	405 ± 51
PEEP, cmH_2O	7.7 ± 1.9
Airway plateau pressure, cmH_2O	16.8 ± 3.0
FiO_2	0.4 (0.4–0.5)
PaO_2, mmHg	95.7 ± 23.4
$PaCO_2$, mmHg	36.6 ± 7.1
PaO_2/FiO_2	219 ± 51
SAPS II	41 ± 15
Type of surgery	
Intracranial	6 (50.0)
Orthopaedic	4 (33.3)
Vascular	2 (16.7)

Data are presented as median (interquartile range), n (%) or mean ± standard deviation.

BMI: body mass index; PEEP: positive end-expiratory pressure; FiO_2: fractional inspired oxygen; PaO_2: arterial partial pressure of oxygen; $PaCO_2$: arterial partial pressure of carbon dioxide; PaO_2/FiO_2: ratio of arterial partial pressure of oxygen to fractional inspired oxygen; SAPS: Simplified Acute Physiology Score.

There was no significant difference in the P_{AW} at different balloon positions. However, the P_B exhibited a significant change during withdrawal of the balloon ($P < 0.001$) (Figure 3). At either end-expiratory or end-inspiratory occlusion, the P_B significantly increased from depths of 15 cm and 10 cm below the LES to the highest level at 5 cm below and just above the LES, and then gradually decreased thereafter. The P_B at the depth of just above the LES (12.1 ± 3.2 and 14.5 ± 2.8 cmH_2O at end-expiratory and end-inspiratory occlusion, respectively) was significantly higher than that at depths of 10 cm and 15 cm above the

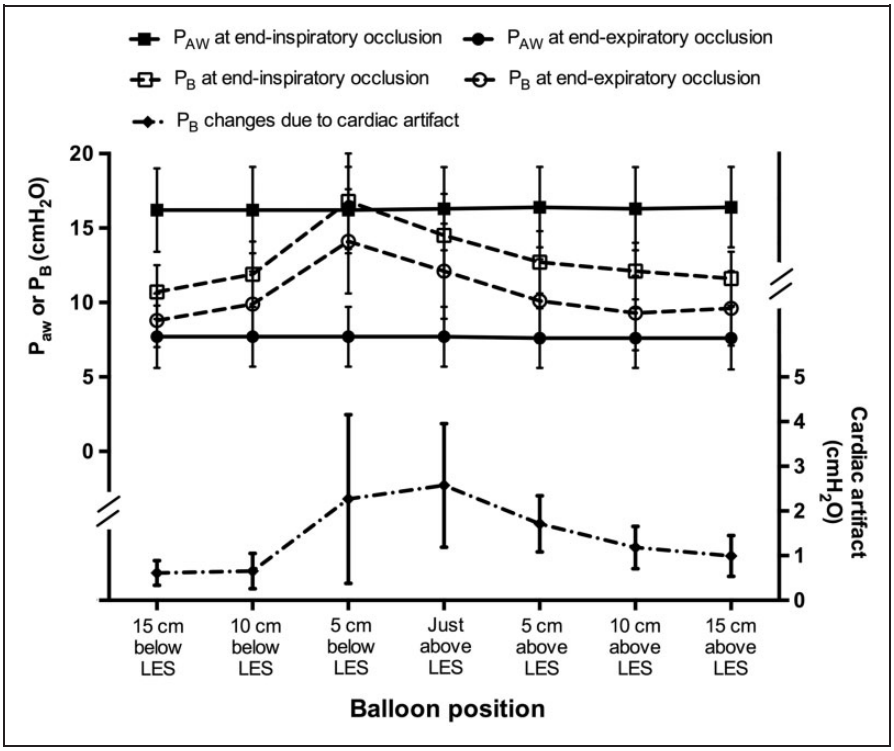

Figure 3. Changes in airway pressure (P_{AW}), balloon pressure (P_B), and cardiac artifact in P_B tracing at different balloon positions. Mean and standard deviation are also shown.

LES ($P = 0.002$–0.014); however, there was no significant difference at depths of 5 cm to 15 cm above the LES. The change in P_B secondary to cardiac artifact was significantly different among the various balloon positions, with a tendency similar to that observed in the measurement of P_B ($P < 0.001$) (Figure 3). Cardiac artifacts at depths of 5 cm below the LES ($2.3 \pm 1.9\,cmH_2O$) and just above the LES ($2.6 \pm 1.4\,cmH_2O$) were significantly larger than at all other depths ($P < 0.001$ to $P = 0.032$); however, there was no significant difference among depths of 5 cm to 15 cm above the LES (1.0 ± 0.5 to $1.7 \pm 0.6\,cmH_2O$).

The $\Delta P_B/\Delta P_{AW}$ ratios at different balloon positions are shown in Figure 4(a). The percentage of the $\Delta P_B/\Delta P_{AW}$ ratio within 0.8 to 1.2 was > 80% at depths of 15 cm and 10 cm below the LES and 5 cm and 10 cm above the LES. However, this percentage was < 50% at all other depths (5 cm below the LES, just above the LES, and 15 cm above the LES). The $\Delta P_B/\Delta P_{AW}$ ratio changed significantly at different balloon positions ($P < 0.001$) (Figure 4(a)). The median (IQR) of the ratio at depths of 15 cm and 10 cm below the LES was 0.93 (0.84–0.98) and 0.95 (0.85–1.05), respectively. During balloon withdrawal, the ratio increased significantly at the depth of 5 cm below the LES (1.33 (1.16–1.48)) and just above the LES (1.28 (1.15–1.57)). The ratio then decreased at the depth of 5 cm (1.04 (1.01–1.12)) and 10 cm (0.92 (0.84–0.98)) above the LES. The lowest $\Delta P_B/\Delta P_{AW}$ ratio was obtained at the depth of 15 cm

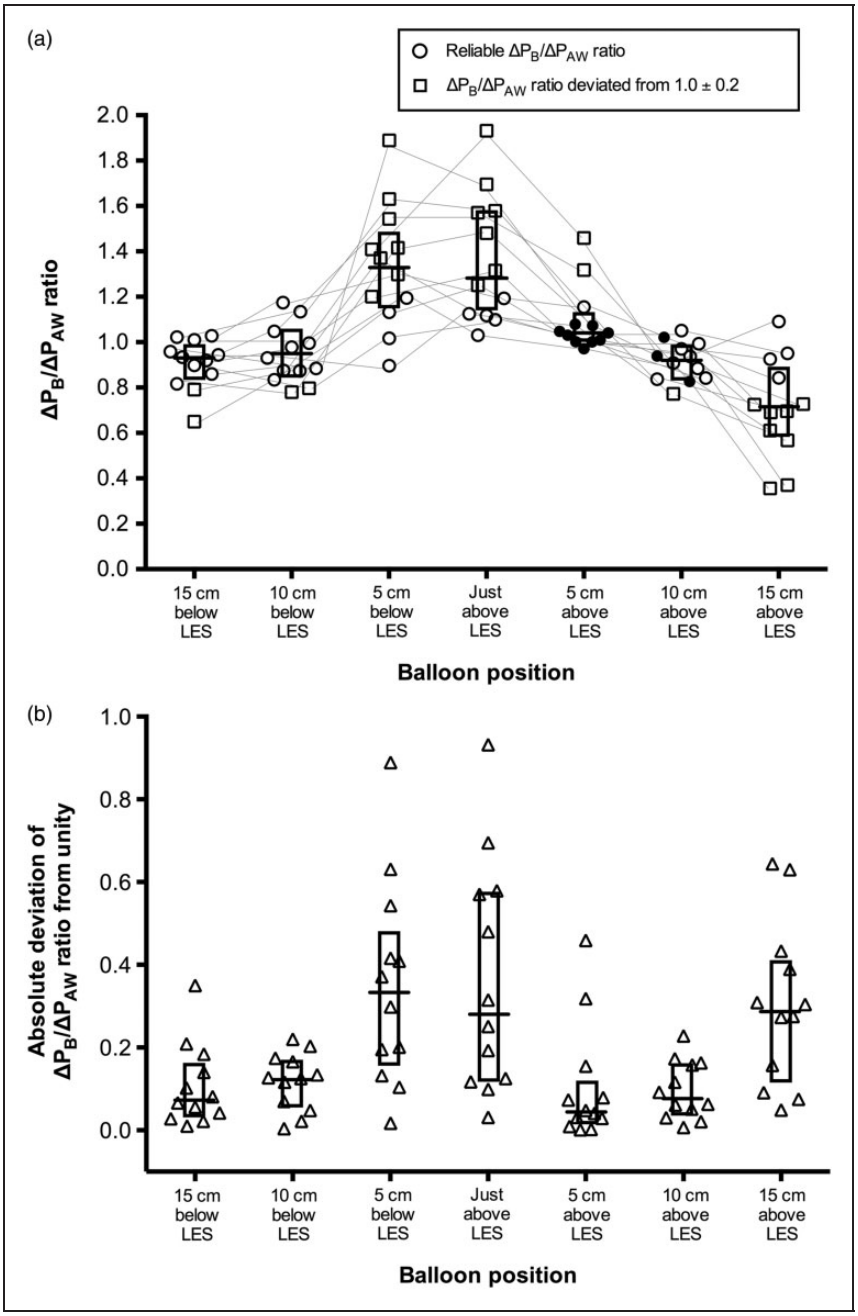

Figure 4. Ratio of change between balloon pressure and airway pressure ($\Delta P_B/\Delta P_{AW}$) during positive pressure occlusion test (a) and the absolute deviation of the $\Delta P_B/\Delta P_{AW}$ ratio from unity (b) at different balloon positions in each patient. Solid marks represent the $\Delta P_B/\Delta P_{AW}$ ratio that was closest to unity in each patient when the whole balloon was positioned above the lower oesophageal sphincter (LES); the median (horizontal line) and interquartile range (box) are also shown. Each grey line represents a single patient.

above the LES (0.71 (0.59–0.88)), which was significantly lower than that at 5 cm above the LES ($P = 0.002$). The lowest absolute deviation of the $\Delta P_B/\Delta P_{AW}$ ratio from unity occurred at the depth of 5 cm above the LES (0.04 (0.02–0.12)), which was significantly lower than that at the depth of 5 cm below the LES (0.33 (0.16–0.48), $P = 0.021$), just above the LES (0.28 (0.15–0.57), $P = 0.017$), and 15 cm above the LES (0.29 (0.12–0.41), $P = 0.042$) (Figure 4(b)).

Because all or part of the balloon was in the stomach at depths of 15 cm to 5 cm below the LES (Figure 2), we did not include data from these three positions when selecting the individual best $\Delta P_B/\Delta P_{AW}$ ratio to indicate the optimal balloon position in the oesophagus. After the whole balloon was withdrawn above the LES, at least one ratio within 0.8 to 1.2 was obtained for each patient, with the closest to unity at a depth of 5 cm above the LES in nine patients (75%) and 10 cm above the LES in three patients (25%) (Figure 4(a)). The best $\Delta P_B/\Delta P_{AW}$ ratio was 1.02 (0.99–1.04).

Discussion

Confirmation of the proper balloon position is difficult during P_{ES} monitoring in patients without spontaneous breathing.[1–4,6–9] In the present study, we introduced a new method, the injection test, to assess the positional relationship of the balloon with the LES. In each patient, while withdrawing the balloon from the stomach, the injection test wave appeared at a distinct catheter depth, which could be used to confirm that the whole balloon was positioned just above the LES within the oesophagus. Unexpectedly, using the positive pressure occlusion test with chest compression, a "reliable" $\Delta P_B/\Delta P_{AW}$ ratio could be obtained even when the balloon was still located in the stomach (Figures 2 and 4). This result suggests the clinical significance of confirmation that the whole balloon was located above the LES before the performance of the positive pressure occlusion test.

In patients without spontaneous breathing, the position of the balloon in relation to the LES could be easily clarified using our novel method. When the balloon was still in the stomach, no disturbance occurred in the P_B tracing while injecting air through the gastric lumen of the catheter. However, as the balloon was withdrawn, a typical injection test wave appeared at a distinct depth in each patient. According to the anatomical relationship among the newly opened side port, balloon, and LES, the appearance of the injection test wave indicated that the distal edge of the balloon was just above the LES and that the whole balloon was therefore located within the oesophagus (Figure 2). The presence of the injection test wave mimicked the inversion point of pressure deflection during inspiratory effort in patients with spontaneous breathing. To ensure safety, the injection test was similar to the traditional method of confirming the gastric tube position by air insufflation.[17] Additionally, we aspirated the gastric lumen of the catheter before and after each air injection to avoid possible overdistension of the stomach and oesophagus. No short-term side effects occurred during the injection test. These findings preliminarily suggest the clinical feasibility of the injection test. Because no formal fixation of the T-tube and catheter was used during the catheter modification, dislodgement of the T-tube might be a potential risk during the injection test. Although no dislodgement occurred in our group of patients, we recommended that clinicians pay close attention to this safety issue.

According to the balloon depth, which was indicated by the presence of the injection test wave, we determined P_B-related parameters at seven balloon positions. These seven positions sequentially represented the whole balloon being positioned within the stomach, the balloon just passing

through the LES, and the whole balloon being positioned in different oesophageal segments (Figure 2). In deeply sedated and paralyzed patients without spontaneous breathing, performance of the positive pressure occlusion test is recommended to allow for optimal adjustments in the balloon position, and a $\Delta P_{ES}/\Delta P_{AW}$ ratio of 0.8 to 1.2 is considered reliable.[1,2] Our data suggest that the positive pressure occlusion test should be used only after confirming that the whole balloon is located within the oesophagus. At depths of 15 cm and 10 cm below the LES, the whole balloon was still in the stomach. At these positions, the measured P_B represented the gastric pressure (P_{GA}) and was affected by less cardiac artefact (Figure 3). Unexpectedly, at these two balloon positions, the median (IQR) $\Delta P_B/\Delta P_{AW}$ ratios were 0.93 (0.84–0.98) and 0.95 (0.85–1.05), and a ratio within the range of 0.8 to 1.2 was obtained in 83.3% of the patients (Figure 4). Under these conditions, the increase in P_B during chest compression reflected the transmission of pressure from the chest to the abdomen; thus, these $\Delta P_B/\Delta P_{AW}$ ratios should not be used to confirm the oesophageal positioning of the balloon. When the balloon was bestriding the LES (5 cm below the LES) (Figure 2), the P_B and P_B changes due to cardiac artefacts increased abruptly (Figure 3). At the same time, the $\Delta P_B/\Delta P_{AW}$ ratio increased significantly (1.33 (1.16–1.48)) and became more scattered (Figure 4). This might be explained by local squeezing of the balloon by the LES, which reduced the balloon's working volume. Therefore, the same injected balloon volume might result in overinflation of the balloon, and the measured P_B might overestimate the surrounding pressure and pressure change due to chest compression.

The adult oesophagus is approximately 25 to 30 cm in length.[18] In the present study, we used a balloon that was 10 cm in length. The distal end of the balloon was located just above the LES, 5 cm to 10 cm above the LES, and 15 cm above the LES; these locations approximately represented positioning of the whole balloon in the lower third, middle third, and upper third of the oesophagus, respectively (Figure 2). In accordance with recently published recommendations,[2] our data also suggest that the optimal oesophageal balloon position during passive ventilation might be the middle third of the oesophagus, where the $\Delta P_B/\Delta P_{AW}$ ratio was the closest to unity (Figure 4) and the cardiac artefact was beyond the position with the maximal value (Figure 3). In the supine position, superimposed pressure from structures surrounding the oesophagus has been considered the major source of error in P_{ES} measurements.[1–4,8,19] Obtaining the best $\Delta P_B/\Delta P_{AW}$ ratio at balloon positions above the maximal cardiac artefact indicated a low influence of the heart weight. Additionally, the measured P_B was significantly lower when the whole balloon was located in the middle third than in the lower third of the oesophagus (Figure 3), which also indicated minimal influence of the surrounding structures. Chiumello et al.[12] recently investigated the efficacy of the positive pressure occlusion test in deeply sedated and paralyzed patients using the same balloon catheter as used in our study. Chest wall compression was performed during end-expiratory occlusion, and no difference was found in the $\Delta P_B/\Delta P_{AW}$ ratio between balloon positions at the low and middle part of the oesophagus (15 cm apart). There were two differences in performance of the occlusion test between their study and the present study: the patient's body position (supine position with 0° versus 30° elevation of the head) and the location of chest wall compression (rib cage versus lower third of the sternum). The latter might explain the disparity in the results of the $\Delta P_B/\Delta P_{AW}$ ratio between the two studies. Because the balloon position is

crucial for P_{ES} measurement, further studies are needed to determine the efficacy of the positive pressure occlusion test at different oesophageal levels and which method should be used when performing the test.

In patients without spontaneous breathing, withdrawal of the balloon and performance of the positive pressure occlusion test are usually repeated many times because the exact relationship between the balloon and LES is not clear. This procedure is time-consuming. The main strength of the injection test is that locating the balloon might be simplified by further withdrawal 5 cm after identification of the LES. Additionally, the injection test might provide a reference when positioning the balloon within the oesophagus.

The present study had several limitations. First, this was a pilot study with a small sample size. Although the injection test wave was successfully induced in each patient, indicating the clinical feasibility of the injection test, safety issues should be further investigated. Second, the study mainly included postoperative patients without acute respiratory failure; therefore, the generalizability of our results will also require further study. Additionally, the newly opened side port with a 0.3-cm diameter was large enough for gastric drainage in our postoperative patients who were admitted to the ICU just after general anaesthesia and were fasted for at least 12 hours. However, whether this port size is large enough in patients undergoing gastric feeding requires clarification. Third, the major advantage of the SmartCath-G balloon catheter is that it allows for simultaneous P_{ES} monitoring and gastric drainage and feeding.[14,20] The modification of the catheter eliminated the latter function. However, our study also provides a novel idea for the design of a new oesophageal balloon catheter that incorporates measurement of the P_{ES}, performance of the injection test, and administration of gastric feeding.

In conclusion, for placement of oesophageal balloon catheters in patients without spontaneous breathing, we have introduced a novel method called the injection test to clarify the relationship between the balloon and LES. This method may support the design of a new type of catheter and allow for precise identification of the position of the whole balloon in different oesophageal segments. Using the positive pressure occlusion test, we found that the middle third of the oesophagus (5–10 cm above the LES) might be the optimal balloon position during passive ventilation.

Declaration of conflicting interest

The authors declare that there are no conflicts of interest.

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