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Original Article

Use of the modified left-sided double-lumen tube in thoracic surgeries

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Abstract: This study is aimed to investigate the effectiveness of two endotracheal tubes used in lung isolation: the modified left-sided double-lumen endotracheal tube (DLT) (group M) and the left-sided Robertshaw DLT (group C). A randomized controlled clinical trial was used to assess the effectiveness of two endotracheal tubes in lung isolation. Fifty-six patients with American Society of Anesthesiologists physical status classification (ASA grade) I-II who were undergoing thoracic surgery that required OLV, including esophageal surgery and lobectomy surgery except for surgeries involved in the region of the left mainstem bronchus. Patients were randomly allocated by computer-coded envelopes into two groups (Group C, n = 27 patients; Group M, n = 29 patients) to receive either a left-sided Robertshaw DLT (Teleflex medical, Tecate, Mexico, Group C), or a modified left-sided DLT (Tuoren Medical Device Co., Ltd, Xinxiang, China, Group M). The following variables were recorded: the first intubation success rate; frequency of tube displacement; intraoperative airway pressure; lung collapse; and tracheal and bronchial mucosal injury. The first intubation success rate was significantly better in group M (27 of 29) compared with group C (16 of 27) (P = 0.003). The frequency of tube displacement was significantly superior in group M compared with group C after repositioning (4 vs. 10, P = 0.045) and during OLV (2 vs. 8, P = 0.013). Intraoperative airway pressure changes during the two-lung and one-lung ventilation were comparable. There were better lung collapse (P = 0.03) and less tracheal and bronchial mucosal injuries in group M (P = 0.032). In conclusion, the modified left-sided DLT can be used efficaciously in thoracic anesthesia and causes less injury to the tracheal and bronchial mucosa.

Keywords: Intubation, intratracheal, one-lung ventilation, bronchoscopy, fiber optic technology, thoracic surgical procedure

Introduction

Lung isolation techniques are used to facilitate one-lung ventilation (OLV) in patients undergoing thoracic surgery [1]. Double-lumen tubes (DLTs) are currently the most widely used means of achieving lung separation and one-lung ventilation, and they provide optimal surgical exposure, a motionless surgical field, and a secure airway [2]. They also allow excellent control of ventilation to both lungs. Nonetheless, DLTs have certain disadvantages: as they have high malpositions after intubation and after positioning; and they are associated with more airway injury. A literature search for the incidence of malposition of left-sided DLT [3-7] yielded a weighted mean incidence of malpositioning of the left-sided DLT (or proportion) of 55%. To reduce the rate of malpositions, we modified the left-sided DLT which used widely in clinical practice. The objective of this study was to assess whether the modified left-sided DLT performs clinically better than left-sided Robertshaw DLTs with less injury. To prove the above, we studied the differences of the modified left-sided DLTs and left-sided Robertshaw DLTs in patients undergoing selective left-sided thoracic surgery as well as the feasibility of modified left-sided DLTs in these cases.

Materials and methods

The study was approved by the Ethical Committee on Human Experiments, Shanghai Fifth People's Hospital, Fudan University, Shanghai, China. Before enrollment, written informed consent was obtained from all patients. Sixty patients with American Society of Anesthesiolo-

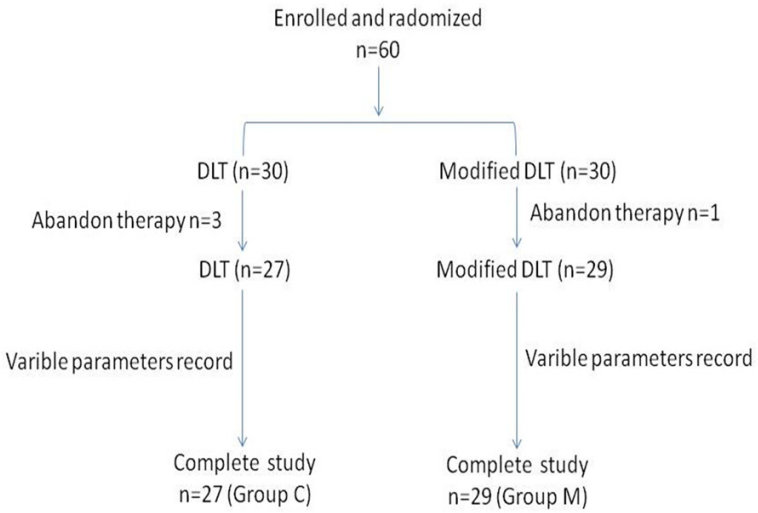

Figure 1. Outcome of all patients enrolled in the trial.

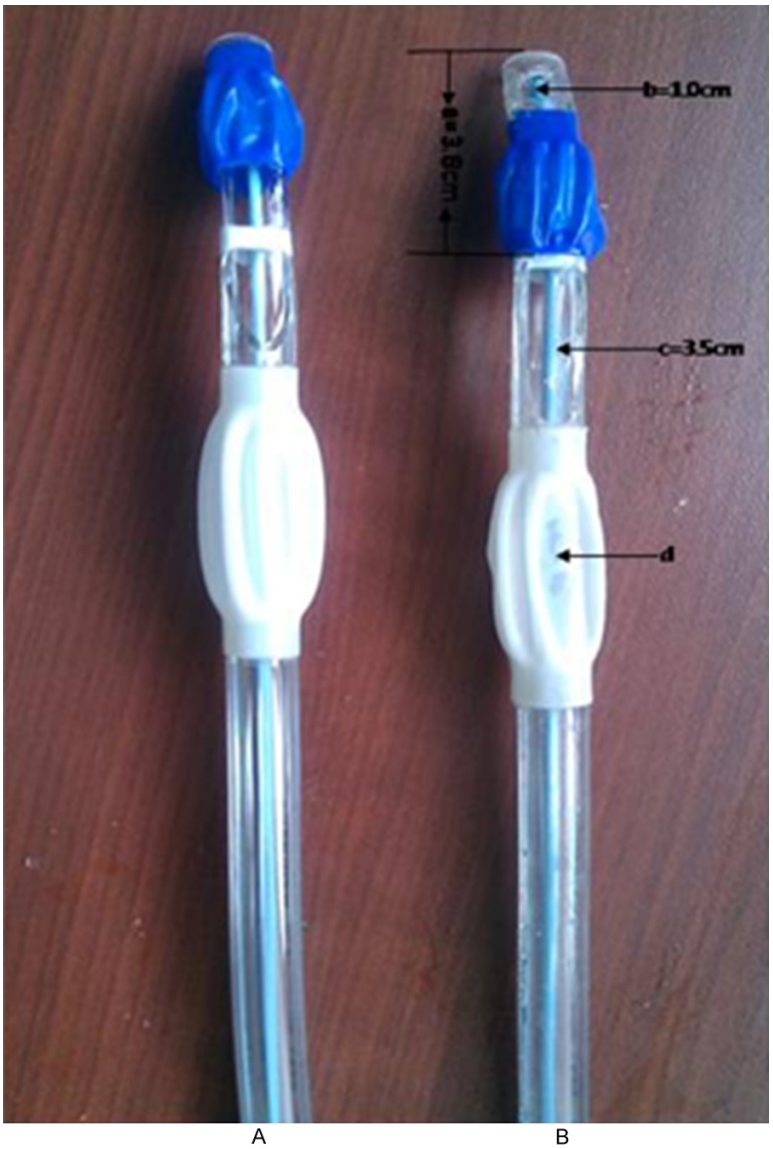

Figure 2. The modified left-sided double-lumen endotracheal tube (DLT). A. The left-sided Robertshaw DLT. B. The modified left-sided DLT: The extended main bronchus, 3.8 cm (a), added oval type side holes (diameter 1 cm) (b), extended right oblique opening diameter of DLT to 3.5 cm (c). The primary tracheal tube cuff was moved upwards 1.3 cm (d).

gists physical status classification (ASA grade) I-II who were undergoing thoracic surgery that required OLV, including esophageal surgery and lobectomy surgery, were randomly allocated by computer-coded envelopes into two groups n = 30 per group to receive either a left-sided Robertshaw DLT (Teleflex medical, Tecate, Mexico), or a modified left-sided DLT (Tuoren Medical Device Co., Ltd, Xinxiang, China). However, 4 patients abandoned therapy (1 in Group M; 3 in Group C) (**Figure 1**). Patients with known lesions along the path of the left-sided DLT, anticipated difficult airway (Mallampatti score ≥3), presence of tracheostomy, risk of regurgitation, previous lung resection, scheduled for bronchial sleeve resection or obstruction of the left main stem bronchus were excluded from the study.

Production of modified left-sided DLT

As shown in **Figure 2**, the modified DLT main bronchus was first extended to 3.8 cm, and two oval type side holes (1-cm lengthwise diameter) were added to the end of it. Next, the right oblique opening diameter of the DLT was increased to 3.5 cm. (This diameter of the left-sided Robertshaw DLT was 3 cm.) The primary tracheal tube cuff

Table 1. Demographic data and OLV time

	Group C (n = 27)	Group M (n = 29)	P
Age, y	56.88±13.08	51.83±13.76	0.165
Weight, kg	64.59±7.23	68.06±10.04	0.145
Height, cm	170.07±4.45	171.52±6.13	0.321
BMI	22.53±2.28	23.02±2.89	0.488
Sex, male, n	16 (59%)	20 (68%)	0.449
ASA I-II	14:13	18:11	0.440
Type of the operation, n			
Esophageal surgery	7	7	
Lobectomy surgery	20	22	0.877
OLV time, min	115.89±39.49	128.66±54.34	0.317

Group C: Lung isolation with the left-sided Robertshaw DLT method; Group M: Treated with modified left-sided double-lumen endotracheal tube (DLT) method. Data are expressed as mean ± standard deviation, unless otherwise indicated. OLV = one-lung ventilation.

was then moved upwards 1.3 cm, and the distance from the tip to the primary tracheal tube cuff was 12.3 cm.

The demographic data, OLV time and type of the operation are listed in **Table 1** (the raw data can be found in the Supplementary Table). Standard monitors and radial arterial catheters were placed before anesthesia. Tube size was determined by measuring the width of the tracheal diameter in millimeters based on the preoperative chest radiograph, as described by Brodsky et al. [8]. After preoxygenation, anesthesia was induced with intravenous fentanyl (4 μg/kg), propofol (2 mg/kg), and vecuronium (0.1 mg/kg).

DLTs with a stylet were introduced into the glottis by direct laryngoscopy with distal curved concavely in advance. After the bronchial cuff had passed the vocal cords, the stylet was removed and the tube was rotated 90° toward the left then advanced (typically 27-30 cm). Anesthesia was maintained with propofol at 3-5 μg/ml TCI, remifentanil at 2-5 ng/ml TCI, and vecuronium. We administered vecuronium based on the changes in the TOF ratio. When the TOF ratio was 10%, we added vecuronium. Both groups had one-time tube placement of the DLT. Accuracy of the DLT placement was assessed by auscultation after selective clamping of the bronchial and tracheal limbs, and DLT position was subsequently assessed via a flexible fiber-optic bronchoscopy (FOB, OLYMPUS BF-3C40, 4.0 mm) by another anesthesiologist, unaware of the first anesthesiologist's assessment. Once proper position was achieved, patients were turned to the lateral decubitus position, and tube placement was reassessed by FOB. During one-lung ventilation, we adjusted the tidal volume 6-8 ml/kg, respiratory rate 12-14 times per minute and respiratory/expiratory ratio 1:2. A positive end-expiratory pressure was not used in all patients. The used limited peak pressure was 40 cm H_2O. Where possible, arterial carbon dioxide tension was kept between 35 and 45 mmHg. When the peak pressure was more than 30 cm H_2O, tube placement was reassessed by a FOB. The correct position of the DLT was defined as follows: unobstructed view into the left upper and lower lobe bronchus through the endobronchial lumen, with the bronchial cuff immediately below the carina and just visible in the main left bronchus through the tracheal lumen [9]. Unsatisfactory placement of the tube was corrected by using a flexible FOB. Airway pressure and end-tidal carbon dioxide partial pressure were monitored during surgery. The initial intubation and the fiberoptic management of all 56 DLTs were performed by three anesthesiologists who were equally experienced with both tubes. Surgeons were absent from the operating room during tube placement and were blinded to the device used.

Variables recorded in each patient

The primary variable to be measured was the first intubation success rate.

The second variable was frequency of tube displacement. Several factors, such as body position or surgery, may result in tube malposition. Malpositioning was diagnosed when the tube had to be moved (in or out) by more than 0.5 cm to correct its position [5]. We marked the tube at the incisors level before and after tube moving and then we measured the distance between the two markers.

The third variable to be measured was intraoperative airway pressure. After DLT intubation, changes in airway pressure were recorded when two lungs and one lung were ventilated at 0, 15, and 30 min.

Table 2. Variables recorded

	Group C (n = 27)	Group M (n = 29)	*P*
No. of the first intubation success rate, n (%)	16 (59%)	27 (93%)	0.003
The frequency of tube displacement			
The supine to the lateral decubitus position, n (%)	10 (37%)	4 (14%)	0.045
One-lung ventilation, n (%)	9 (33%)	2 (7%)	0.013
Intraoperative airway pressure, cm H_2O (mean ± SD)			
Two-lung ventilation			
0 min	19.19±1.95	19.96±2.32	0.046
15 min	18.87±1.85	19.48±2.36	0.037
30 min	19.50±2.33	19.76±2.68	0.030
One-lung ventilation			
0 min	24.41±2.44	25.40±2.35	0.045
15 min	25.94±2.54	26.76±2.28	0.035
30 min	25.52±2.43	26.68±2.37	0.040

Table 3. Lung collapse and tracheal and bronchial mucosal injury for each group

	Group C (n = 27)	Group M (n = 29)	P
Lung collapse, n			
Excellent	18	26	
Fair	6	3	0.030
Poor	3	0	
Tracheal and bronchial mucosal injury, n			
Excellent	14	23	
Fair	8	4	0.032
Poor	5	2	

After the pleura were opened and the lung could be seen, assessment of lung collapse began. Ranking of surgical exposure was done according to the following definitions, as described by Campos et al. [10]: 1) excellent-complete collapse with perfect surgical exposure; 2) fair-total collapse, but the lung still had residual air; and 3) poor-no collapse was achieved, or there was partial collapse that interfered with surgical exposure. If lung collapse was not satisfactory, a flexible FOB was used to diagnose and to correct it. During and after surgery, the surgeon was asked to comment on the surgical exposure.

Finally, the degree of tracheal and bronchial mucosa injury after extubation was assessed via FOB in all patients by the anesthesiologist who was unaware of the type of intubation. At the end of surgery, the tubes were removed and 30 mg topical lidocaine spray, 2%, was administered nasally, and patients were sedated with low-dose propofol and tracheal and bronchial mucosa injury was assessed by a FOB. After assessing mucosal injury, a laryngeal mask was inserted. The condition of the tissues were considered to be excellent if there was no mucous membrane damage; good, with mild mucosal injury, swelling, or both, but no bleeding; or poor, with severe mucosal damage, bleeding, or both.

Statistical analysis

Statistical analysis was performed using SPSS 17.0 for Windows (SPSS, Inc.). Values were expressed as the mean ± standard deviation (SD). Patient's age, weight, height and type of the operation were analyzed by *t*-test. One-lung ventilation time, and the changes of airway pressure during surgery were analyzed by one-way ANOVA test. The number of the first intubation success rate and tube displacement was analyzed by Pearson's χ^2 test. Lung collapse and tracheal and bronchial mucosal injury were analyzed using the Mann-Whitney rank sum test. Results were considered statistically significant for values of $P<0.05$.

Results

Demographic data, OLV time and type of the operation were comparable between two gro-

ups (**Table 1**, Supplementary Table). There were no patients who refused to participate in the trial or who were excluded from participating.

The number of the first intubation success rate was significantly better in group M compared with group C (27 (93%) vs. 16 (59%), respectively; $P = 0.003$). The frequency of tube displacement was significantly better in group M compared with group C after turning the patients to the lateral decubitus position (4 (14%) vs. 10 (37%), respectively; $P = 0.045$) and during OLV (2 (7%) vs. 9 (31%), respectively; $P = 0.013$). Significant differences were observed in intraoperative airway pressure changes during the two-lung and one-lung ventilation between two groups (all $P<0.05$) (**Table 2**, Supplementary Table).

Changes in lung collapse and tracheal and bronchial mucosal injury are summarized in **Table 3** (the raw data can be found in the Supplementary Table). Group M got better lung collapse compared with Group C ($P<0.05$) and there were less tracheal and bronchial mucosal injuries in Group M ($P = 0.032$).

Discussion

The left-sided DLTs have high incidence of malpositions, which lead to poor lung isolation and inadequate ventilation and oxygenation in surgery. These effects may possibly result from the main bronchus of the left-sided DLT being too short and having no bypass ventilation design, and the right obligue opening being too small.

The modified left-sided DLT used in the study is based on left-sided Robertshaw DLT technology. The rationale for this design is: even if DLTs were inserted too deep, patients whose left bronchus is too long also can get good ventilation. In these patients, the DLT oblique opening can be embedded in the left bronchus and the right bronchus can be blocked, leading to poor lung ventilation. The purpose of the modified DLT is to reduce the rate of malpositions. Its main bronchus is extended, and two long oval-shaped side holes of 1-cm diameter have been added. When the main bronchus is extended, the contact area of the tube and left bronchial increased and the tube can be fixed better. Although the tube might have been inserted too deeply, the left lung ventilation could be effectively guaranteed via oval-shaped side holes in the main bronchus extension segment. The right oblique opening diameter of the DLT is increased, and the main bronchus cuff is shifted up. This design can guarantee the right lung ventilation via the increased right obligue opening diameter of the DLT when the tube is too deep.

In this study, the first intubation success rate and tube displacement were significantly better in group M compared with group C. Disadvantages of left-sided Robertshaw DLT were high malpositions after intubation and after positioning. During changes of the body position, tube displacement occurred in 46% of the patients, as described by Klein et al. [5]. Most malpositions with DLTs are attributable to positioning that is too deep [1, 7]. Although the modified tube might have been inserted too deeply, the left lung ventilation could be effectively guaranteed via oval-shaped side holes in the main bronchus extension segment.

Maintaining airway pressure within an appropriate range is important to protect lung function in thoracic surgery. The finding that ventilator pressures play a role in the development of ARDS is supported by existing literature, which emphasizes the adverse effects of high airway and transpulmonary pressures [11-15]. Our study revealed that intraoperative airway pressure did not differ between the two groups during one-lung ventilation or two-lung ventilation.

We also found that group M got better lung collapse compared with group C and there were less tracheal and bronchial mucosal injuries in group M. The left-sided Robertshaw DLTs are associated with more airway injury. Other authors [1] observed a high number (28 of 48) of tracheas with large hematomas in the DLT group. These results may be related with the higher first intubation success rate and lower tube displacement, which make the less tube moving.

In conclusion, a modified left-sided DLT is a feasible device to get higher first intubation success rate, lower tube displacement and causes less injury to the tracheal and bronchial mucosa. The use of bronchoscopic control of the position of the modified left-sided DLT after initial placement and after repositioning the

patient is recommended, although the higher first intubation success rate and lower malpositions after intubation and after positioning.

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Disclosure of conflict of interest

None.

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