Effect of intubation in lateral position on placement of a double-lumen tube in patients undergoing unilateral video-assisted thoracic surgery: a randomied clinical trial

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Summary

Background Approximately one-third of patients who undergo double-lumen tube (DLT) intubation in the conventional supine position experience DLT malposition. No randomized study investigates the effect of DLT intubation in the lateral position. We therefore aimed to evaluate the effect of intubation in lateral position on placement of a DLT compared to supine intubation, and to test primary hypothesis that lateral DLT intubation could reduce the incidence of DLT malposition.

Methods We randomly allocated 108 patients undergoing video-assisted thoracic surgery to receive DLT intubation in the comfortable and surgically required lateral position (lateral group) or in the supine position (supine group) from October to December 2022. The primary outcome was the incidence of DLT malposition defined as movement >1.0 cm to correct the DLT position. The secondary outcomes included intubation time, the frequency and duration of fibreoptic bronchoscopy, the need for re-intubation, intra-operative vital signs, and post-operative recovery. This trial is registered with the Chinese Clinical Trial Registry (ChiCTR2200060794).

Findings The incidence of DLT malposition was significantly lower in the lateral group (1/53 [2%]) than that in the supine group (16/53 [30%]; RR [95% confidence interval] of 0.06 [0.01–0.46]; $P < 0.001$). Lateral DLT intubation decreased the intubation time, the frequency and duration of fibreoptic bronchoscopy. The incidence of hypotension, post-operative sore throat, and upper-arm discomfort was lower in the lateral group. Other secondary outcomes were similar between groups.

Interpretation Lateral DLT intubation reduced the incidence of DLT malposition for patients undergoing video-assisted thoracic surgery. These results support that lateral DLT intubation offers more benefits and may be a superior option compared to conventional supine intubation.

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Keywords: Double-lumen tube; Fibreoptic bronchoscopy; Lateral position; Malposition; Video-assisted thoracic surgery

Introduction

Accurate positioning of a double-lumen tube (DLT) is important for achieving lung isolation and facilitating one-lung ventilation during thoracic surgery.[1] With advances in DLTs and the routine use of fibreoptic bronchoscopy (FOB), the position of DLT placement has

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Research in context

Evidence before this study

Before conducting this trial, we searched PubMed until October 9, 2022, for publications in English evaluating the feasibility and clinical efficacy of double-lumen tube (DLT) intubation in lateral position. We used search terms such as "lateral double-lumen tube intubation", "double-lumen tube intubation in lateral position" and "lateral intubation". No randomized controlled trials of DLT intubation in the lateral position were found, with only a few case reports and reviews mentioned it. Ajimi et al. reported successful left-sided DLT intubation in the right lateral position for a patient with tracheal compression caused by a giant mediastinal tumour. Martinez et al. mentioned that an important and unique issue in non-intubated thoracic surgery was training for lateral DLT intubation in emergencies to cope with the potential need for intra-operative intubation. Single-lumen tube intubation in the lateral position has been widely used in clinical practice. However, no randomized controlled trials investigating the feasibility and superiority of lateral DLT intubation have been found.

Added value of this study

This single-center, parallel-group, randomized clinical trial validated the clinical application and efficacy of DLT intubation in the lateral position in thoracic surgery. The results of the trial showed that the incidence of DLT malposition, as the primary outcome, was significantly lower in the lateral DLT intubation group (1/53 [2%]) than that in the supine DLT intubation group (16/53 [30%]; relative risk [95% confidence interval] of 0.06 [0.01–0.46]; $P < 0.001$). Nowadays, thoracic surgery focuses on the concept of minimally invasive and Enhanced Recovery after Surgery. Lateral DLT intubation aligns with this concept, enhancing surgical safety, efficiency, and improving patient recovery and satisfaction. This study lays the foundation for lateral DLT intubation in patients undergoing thoracic surgery, and could inspire further research on the impact of this method.

Implications of all the available evidence

The conventional method of DLT intubation in supine position often poses challenges including DLT malposition, airway injury, lateral positioning, and positioning-related injuries in anaesthetised patients. In contrast, lateral DLT intubation has a lower DLT malposition rate, requires less use of fibreoptic bronchoscopy, not require changing the patient position, and has fewer complications, making it more advantageous in clinical practice. Lateral DLT intubation is a clinically efficient and easily mastered method. Further multicenter studies are required to evaluate whether lateral DLT intubation can be a viable alternative to conventional supine intubation.

become more stable and readily correctable.[1,2] However, the incidence of DLT malposition remains relatively high (approximately 26%–37%).[3–6] DLT malposition can occur due to various reasons, including shifting of the patient from the supine position to the lateral position, neck flexion or extension, and surgical manipulation.[7–9] Approximately 40% of DLT-related complications are caused by DLT malposition.[10] Failure to identify and correct DLT malposition promptly can lead to severe complications, including poor lung isolation, hypoxemia during one-lung ventilation, high airway pressure, atelectasis, and airway lacerations.[3,10,11]

The conventional method of DLT intubation in supine position requires moving the anaesthetised patient to the surgically required lateral position after intubation, which is labor-intensive and reduces work efficiency, especially in the case of overweight patients. It also requires a second examination of the DLT position using FOB after lateral positioning, since DLT movement is particularly common during changes in patient position.[7] Removing the headrest and wearing a neck brace can reduce the risk of DLT malposition during lateral positioning,[8,12] but they cannot completely eliminate this possibility. Furthermore, supine DLT intubation often poses challenges including airway injury, difficulty in rescuing airway hemorrhage, and positioning-related injuries in anaesthetised patients.

On the basis of the feasibility of single-lumen tube intubation in the lateral position,[13,14] we considered whether DLT intubation could be undertaken directly in the lateral position. A literature search revealed limited information on this topic, and no relevant randomized controlled trials. Ajimi and colleagues reported successful left-sided DLT intubation in the right lateral position for a patient with tracheal compression caused by a giant mediastinal tumour.[15] Martinez and coworkers mentioned that an important and unique issue in non-intubated thoracic surgery was training for lateral DLT intubation in emergencies to cope with the potential need for intra-operative intubation.[16]

Video-assisted thoracic surgery (VATS) has become the preferred method for the treatment of most thoracic disorders because it causes less damage and fewer complications while allowing faster post-operative recovery.[17] However, the effect of intubation in the lateral position on DLT placement during VATS has not been investigated previously.

Therefore, we conducted the randomized trial to investigate the clinical applicability and efficacy of lateral DLT intubation. We aimed to evaluate the effect of intubation in the lateral position on placement of a DLT, and to test primary hypothesis that lateral DLT intubation could reduce the incidence of DLT malposition in patients undergoing unilateral VATS compared with

supine intubation. We also explored the effect of lateral DLT intubation on the patient's vital signs and post-operative complications.

Methods

Study design and participants

This study was a single-center, parallel-group, randomized, clinical trial conducted in the Huzhou Central Hospital in China. The study protocol has been published previously and is presented in Supplement 1.[18] This trial was registered with Chinese Clinical Trial Registry (ChiCTR2200060794) before enrollment. This trial followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines.

Eligible patients were aged 18–80 years with American Society of Anesthesiologists physical status 1 to 3; and were scheduled for unilateral VATS with left-sided DLT intubation under general anesthesia. Patients were excluded if they were difficulty in achieving intubation at preoperative assessment (body mass index >30 kg/m^2, limited movement of the neck, mouth opening <3 cm or Mallampati grade 3 to 4); failure of multiple attempts to achieve DLT intubation; severe mental illness or communication difficulties; and history of pulmonary surgery.

Ethics statement

This study was approved by the Ethics Committee of Huzhou Central Hospital (number: 202205005-01). Written informed consent was obtained from all participants the day before surgery.

Randomization and masking

Investigators involved in statistical analyses used a computerized random-number generator to obtain random sequences on a 1:1 basis, and placed them into sealed, opaque, and sequentially numbered envelopes. After the participant had entered the operating room, the anesthesia investigator opened the envelope to obtain a random sequence. Participants with random sequences 1–54 received DLT intubation in the lateral position (lateral group), while 55–108 received DLT intubation in the supine position (supine group). To protect privacy, each patient was assigned a unique sequential number on the envelope cover in the order of his/her participation in this study denote his/her identity. We blinded only the investigators who undertook follow-up and statistical analyses.

Procedures

All patients were fasted routinely for 8 h before surgery and underwent standard intra-operative monitoring. Patients assigned to the lateral group were assisted to lie in a comfortable and surgically appropriate lateral position, which followed by induction of anesthesia and DLT intubation. For patients assigned to the supine group, induction of anesthesia and DLT intubation was performed in the conventional supine position. A total of four anesthesia investigators participated in the anesthesia and intervention process, and were randomly assigned in pairs to two designated thoracic surgery operating rooms. Anesthesia was induced with intravenous sufentanil 0.1–0.3 μg/kg, propofol 2.5–3.0 μg/mL by target-controlled infusion, and rocuronium 0.6 mg/kg. We used a disposable polyvinyl-chloride left-sided DLT (Broncho-Cath®; Mallinckrodt Medical, Hampshire, UK) for intubation in the left bronchial lumen of all patients. During surgery, we used propofol and remifentanil to maintain anesthesia, and all patients received total intravenous anesthesia with 100% oxygen. Systolic blood pressure was maintained within 20% of the basal value. The heart rate was maintained at 60–100 beats/minute during surgery. Phenylephrine (40 μg) was administered intermittently if systolic blood pressure was <80 mmHg. Atropine (0.5 mg) was administered if the heart rate was <50 beats/minute.

We performed lateral DLT intubation for a patient according to a flowchart. Before intubation, the DLT was shaped into an "S" conformation, checked for air leakage of two cuffs, and lubricated evenly. We helped the patient to lie on the operating table in the lateral position with a chest pillow placed under the armpit. The patient was adjusted slightly under the guidance of surgeon to achieve a comfortable and optimal lateral position for surgery. Standard monitoring, pre-oxygenation (100% oxygen for 3 min), and the induction of anesthesia were carried out, followed by mask-assisted ventilation. One anaesthesiologist held the patient's head with one hand to prevent excessive tilting of the neck, hooked the jaw with the index and middle fingers of the other hand, and kept the mask closed tightly with the remaining fingers. After the neuromuscular blocking drugs had taken effect, we placed a disposable laryngoscope blade into the middle of the patient's mouth, opened the video-laryngoscope, and linked the blade. Then, we advanced the video-laryngoscope slowly to lift the back of the tongue and expose the glottis, and inserted the DLT gently with a stylet through the larynx. After the tip of the DLT had passed through the glottis, an assistant straightened the end of the DLT and drew out the stylet. We continued to gently insert and rotate the DLT until some resistance was felt. Two cuffs were inflated and ventilation of the lungs was started, followed by assessment of appropriate placement of the bronchial cuff using FOB. The process for DLT intubation in the left or right lateral position (in general, similar) was demonstrated (Video 1 in Supplement 2). Conventional supine DLT intubation for a patient was undertaken according to a standard procedure. After DLT intubation and FOB adjustment in the supine position for DLT positioning, we fixed the DLT and shifted the patient to the lateral position in cooperation with the surgeons and nurses. Next, FOB was used again to reconfirm the DLT position.

Before the study, anesthesia investigators practiced lateral DLT intubation on the model. They strictly followed the process of intervention, including method of face mask ventilation, insertion of video laryngoscope, shaping and insertion of DLT. Then, under the guidance of the principal investigator, they performed 3–5 cases of lateral DLT intubation in patients. The following needed to be noted for trainers: when placing the patient in a lateral position before induction, use a headrest to ensure that the head, neck and trunk axis are at the same horizontal line; stand on one side of the patient's head with hands extended in line with their mouth opening direction for better intubation operation.

The classical criteria for correct DLT position was defined as clear visibility into the left-upper and lower-lobe bronchus through the bronchial lumen, with the bronchial cuff directly beneath the carina and the main left bronchus just visible through the tracheal lumen according to FOB.[19] If the intraoperative oxygen saturation was less than 92%, plateau pressure greater than 30 cm H_2O, poor lung collapse in the video, or as determined by the anesthesiologist based on experience, then FOB examination should be performed again to determine if adjustment of DLT position was necessary. After completing the DLT positioning, all adjustments for DLT positions in both groups were recorded, including the reason for adjustment, time, distance, and direction. Any adjustments exceeding 1.0 cm in distance for DLT positions were recorded as DLT malposition. The intubation time we defined as the time from use of a video-laryngoscope to confirmation of correct position of the DLT using FOB. If the patient underwent re-intubation, the intubation time was the sum of the durations for each intubation.

After extubation of the DLT in the operating room, all patients were transferred to the post-anesthesia care unit (PACU) for monitoring. We assessed whether patients experienced sore throat, hoarseness, and discomfort in the upper arm 30 min later. Patients with an Aldrete score ≥9 were transferred to the ward.[20] On the first day after surgery, we conducted the Quality of Recovery-15 (QoR-15) questionnaire to patients and recorded any additional postoperative complications until discharge. We collected satisfaction scores from surgeons, nurses, and patients after surgery (from 0 to 10, with 10 being very satisfied). For surgeon, the criteria of satisfaction score were the convenience of the procedure and clarity of surgical field in video. For nurse, the criteria were the difficulty of patient positioning management and convenience of procedure. For patient, the criteria were comfort level and occurrence of complications.

Outcomes

The primary outcome was the incidence of DLT malposition observed by FOB in two groups. Malposition was defined as movement >1.0 cm to correct the DLT position.[3] The secondary outcomes were intubation time; the frequency and duration of FOB usage; the need to re-intubate; intra-operative vital signs (blood pressure, heart rate, and partial pressure of oxygen); post-operative recovery (sore throat, hoarseness, upper-arm discomfort and the QoR-15 score at 24 h after surgery); the surgeon/nurse/patient satisfaction scores.

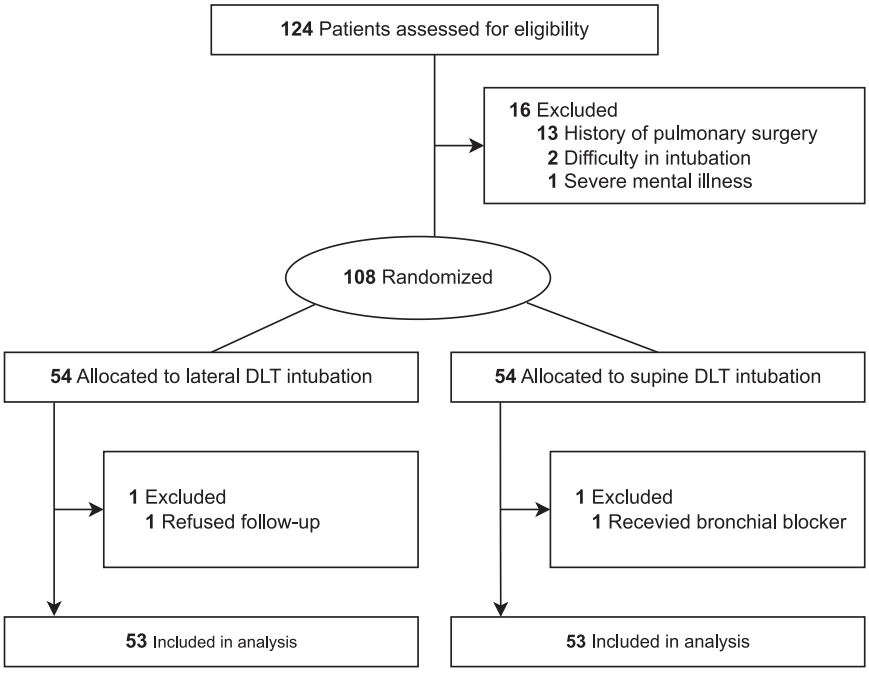

Fig. 1: Trial profile. DLT: double-lumen tube.

Statistical analysis

Sample size was calculated on the basis of the incidence of DLT malposition of approximately 30% in previous studies.[5,21] Expecting a 50% reduction in the incidence of DLT malposition to be considered an effective intervention, with a level of significance α of 0.05 and a power of 80%, we calculated that 48 patients per group were required. Accounting for a 10% dropout rate, we aimed to recruit a total of 108 patients.

Continuous variables with a normal distribution were reported as mean (standard deviation [SD]) and were compared between groups using the independent *t*-test, whereas non-normally distributed variables were reported as median (interquartile range [IQR]) and were compared using the Mann–Whitney *U*-test. Categorical variables were presented with frequencies and percentages and were analysed with the chi-squared test. Mean group differences and relative risk (RR) were reported with 95% confidence interval (95% CI), and a two-sided *P*-value <0.05 considered significant. Statistical analyses were performed using SPSS 26.0 (IBM, Armonk, NY, USA) and OriginPro 2021 (OriginLab, Northampton, MA, USA).

Role of the funding source

The funders had no role in the study design, data collection, data analysis, data interpretation, manuscript writing or publication decisions. HL and SPH had access to dataset and had final responsibility for the decision to submit for publication.

Results

Participant characteristics

From October to December 2022, a total of 124 patients were screened, of whom 108 (87.1%) were randomly assigned to the study. One patient in the lateral group was removed from analyses for refusing to follow-up and one patient in the supine group was removed due to conversion to a bronchial blocker after failed DLT intubation, leaving a total of 106 patients (53 per group) were included in the analyses (Fig. 1). Baseline characteristics were similar between groups (Table 1). Patients in the lateral group received lateral DLT intubation according to a flowchart (Fig. 2).

Characteristic	Lateral group (n = 53)	Supine group (n = 53)
Age (years), mean (SD)	54.5 (12.8)	56.9 (13.0)
Sex, No. (%)		
Male	22 (42)	26 (49)
Female	31 (58)	27 (51)
BMI, mean (SD)	22.9 (2.4)	23.2 (3.3)
ASA physical status, No. (%)		
1	8 (15)	5 (10)
2	40 (75)	41 (77)
3	5 (10)	7 (13)
Mallampati score, No. (%)		
1	37 (70)	36 (68)
2	16 (30)	17 (32)
Hypertension, No. (%)	14 (26)	13 (25)
Diabetes mellitus, No. (%)	4 (8)	1 (2)
Coronary artery disease, No. (%)	3 (6)	4 (8)
History of tobacco smoking, No. (%)	16 (32)	14 (36)
Surgical lung, No. (%)		
Left	32 (60)	23 (43)
Right	21 (40)	30 (57)
DLT size, No. (%)		
35 Fr	31 (58)	28 (53)
37 Fr	22 (42)	25 (47)
Depth of intubation[a] (cm), median (IQR)	29.1 (28.0–30.0)	29.2 (28.0–30.0)
Duration of surgery (hours), median (IQR)	1.3 (0.9–1.9)	1.1 (0.8–1.8)
Duration of anaesthesia (hours), median (IQR)	1.5 (1.2–2.2)	1.5 (1.2–2.0)
Closed suction drainage, No. (%)	37 (70)	27 (51)
Length of hospital stay (days), median (IQR)	5 (4)	5 (4, 6)
Hospitalization costs (¥), mean (SD)	29,368.5 (5698.6)	28,102.1 (4838.8)

SD, standard deviation; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); ASA, American Society of Anesthesiologists; IQR, interquartile range; DLT, double-lumen tube.
[a]Optimal depth of DLT placement for the first positioning.

Table 1: **Participant characteristics.**

Primary outcome

DLT malposition occurred in 1 of 53 patients (2%) in the lateral group and 16 of 53 patients (30%) in the supine group (Table 2), and RR (95% CI) of 0.06 (0.01–0.46; $P < 0.001$).

Secondary outcomes

With respect to intra-operative variables (Table 3), the median (IQR) intubation time was 78 (65–94) s in the lateral group and 86 (68–133) s in the supine group ($P = 0.042$). Two (4%) and 12 (23%) patients underwent FOB exams more than twice ($P = 0.004$), and the median (IQR) FOB duration was 75 (47–97) seconds and 106 (64–158) seconds, respectively ($P = 0.001$). The median (IQR) time interval between the start of anesthesia and the start of surgery was 15 (11–18) minutes and 20 (20–25) minutes, respectively ($P < 0.001$). The mean (SD) time in PACU was 47.3 (5.2) minutes and 51.0 (9.6) minutes, respectively ($P = 0.014$).

With respect to intra-operative vital signs and post-operative complications (Table 3), intra-operative hypotension occurred in 28 patients (53%) in the lateral group and 39 (74%) in the supine group ($P = 0.027$). Seventeen patients (32%) and 28 (53%) had post-operative sore throat, respectively ($P = 0.031$). None (0%) of the patients experienced upper-arm discomfort in the lateral group while 5 (9%) experienced it in the supine group ($P = 0.022$). The two groups showed no significant difference in re-intubation rates, the incidence of bradycardia and hypoxemia, the occurrence of hoarseness, and the 24 h QoR-15 score.

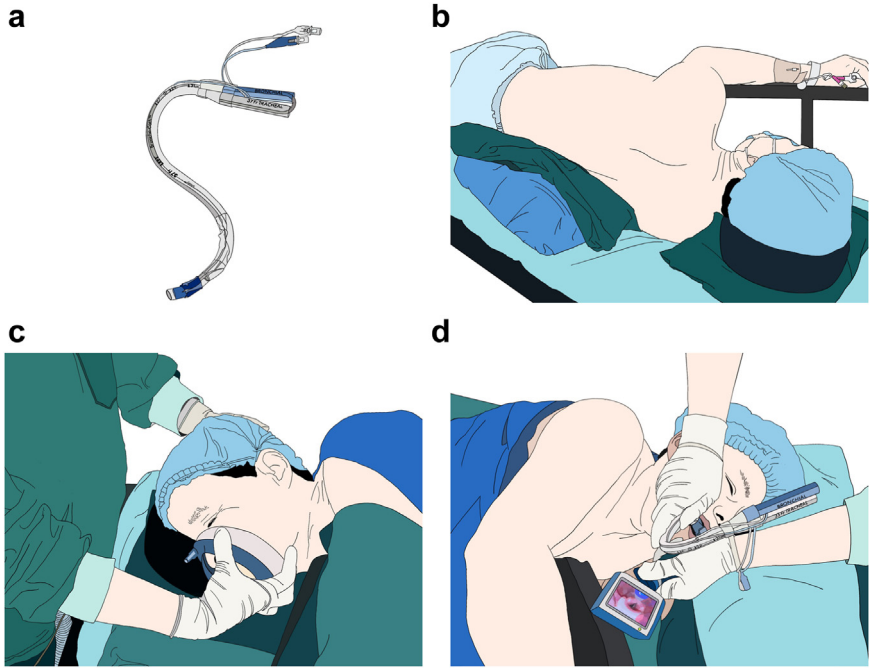

Fig. 2: Flowchart of lateral DLT intubation. (a) Shaping of the DLT into an "S" model. (b) Patients lay on the operating table with a chest pillow placed under the armpit before induction of anesthesia. (c) The anesthesiologist held the patient's head with one hand and hooked the jaw with the other hand to perform manual-assisted ventilation. (d) We gently inserted the DLT with a stylet through the larynx to the epiglottis under the guidance of the video-laryngoscope. DLT: double-lumen tube.

Postoperatively, the median (IQR) satisfaction scores reported by surgeons (9 [8–9] vs 7 [6–8]; $P < 0.001$) and nurses (9 [9–10] vs 6 [6–7]; $P < 0.001$) were higher in the lateral group, and there was no significant difference in patient satisfaction scores (9 ([8–9]) vs 9 ([7–9]); $P = 0.113$) between groups (Fig. 3).

Discussion

We showed that, in comparison with conventional DLT intubation in the supine position, DLT intubation in the lateral position was associated with a lower incidence of DLT malposition in patients undergoing elective unilateral VATS under general anesthesia.

	Lateral group (n = 53)	Supine group (n = 53)	Relative risk (95% CI)	*P*-value
DLT malposition, No. (%)	1 (2)	16 (30)	0.06 (0.01–0.46)	<0.001
During lateral positioning	0	16/16 (100)		<0.001
During surgery	1 (2)	2 (4)		<0.001
In the upward direction	1 (2)	11 (21)		0.506

DLT malposition was defined as movement >1.0 cm to correct the DLT position. DLT, double-lumen tube; CI, confidence interval.

Table 2: **Incidence of double-lumen tube malposition of the patients.**

Avoiding DLT malposition is an important task in thoracic surgery. However, shifting the patient to the lateral position for surgery after conventional supine DLT intubation is likely to result in DLT malposition.[7] The unavoidable flexion or tilting of the patient's head and neck during lateral positioning, coupled with the dynamics of carinal shift downward due to gravity, makes the movement of the DLT from a mechanical point of view. In a recent study, the pressure of the bronchial cuff increased during lateral positioning, which can damage the mucous membranes of bronchi.[22] Notably, lateral DLT intubation without changing the patient position can avert DLT malposition and other adverse effects caused by lateral positioning. There is no standardized definition of DLT malposition. Given the shorter stature of Chinese individuals, even slight deviations in DLT placement may pose a significant risk. Additionally, in order to measure quantitatively the effect of lateral DLT intubation on DLT position, we defined DLT malposition as movement >1.0 cm to correct the position, which was in reference to previous studies.[3,12,23] In the present study, one patient in the lateral group developed intra-operative DLT malposition that was likely caused by surgical manipulation. In contrast, 16 (30%) patients in the supine group developed DLT malposition during lateral positioning, data which are consistent with findings from previous

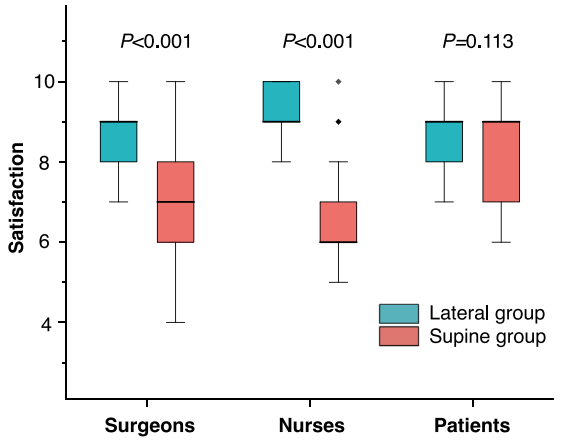

Fig. 3: Satisfaction scores reported by surgeons, nurses, and patients. The bold line in the center indicates the median, the size of the box indicates interquartile ranges, and the whiskers indicate the minimum and maximum.

studies.[5,21] Two of these 16 patients experienced intra-operative hypoxemia due to secondary DLT malposition. This finding supports the viewpoint of Inoue and colleagues, who reported that patients with DLT malposition after lateral positioning were more likely to develop hypoxemia during one-lung ventilation.[3] We found that DLT malposition was predominantly in the upward direction (12 of 17 patients), in line with previous study.[7]

DLT intubation in the lateral position may seem awkward and difficult for anaesthesiologists who have never tried or even heard of this method. In our experience, lateral DLT intubation can be undertaken readily and rapidly under appropriate DLT shaping and intubation methods in patients without potentially difficult airways. Martinez and colleagues also indicated that DLT intubation in the lateral position was not difficult.[16] The duration of intubation in the lateral group was shorter when undertaken by two anesthesia investigators who were proficient in DLT intubation in both types of patient positioning. This could be attributed to the ease of DLT intubation in the lateral position reported by anesthesia investigators, and the fact that fewer patients in the lateral position group underwent re-intubation. All patients underwent at least two FOB examinations to confirm appropriate placement of the DLT. However, more patients in the supine group received more than two FOB examinations and longer duration of FOB usage, which increased the risks of desaturation episodes or infection due to FOB use.[24,25] Considering the rigor of a randomized controlled trial, we added the second FOB examination for patients in the lateral group before surgery commencement, as a control for the second FOB examination after lateral positioning in the supine group. However, we did not find DLT malposition at the second examination in the lateral group. Thus, greater adoption of lateral DLT intubation may require a minimum of single use of FOB in patients without special circumstances. Given that the video-laryngoscope and FOB are not available in some developing countries, we do not recommend lateral DLT intubation in this situation.

Furthermore, lateral DLT intubation was associated with more stable intra-operative vital signs and fewer post-operative complications compared with supine intubation. Patients in the lateral group without passive position changes experienced fewer episodes of intra-

	Lateral group (n = 53)	Supine group (n = 53)	Differences (95% CI)/Relative risk [95% CI]	*P*-value
Intubation time (s), median (IQR)	78 (6594)	86 (68–133)	−20.6 (−36.2 to −5.0)	0.042
Re-intubation, No. (%)	3 (6)	8 (15)	0.38 [0.16–1.34]	0.111
FOB usage >2, No. (%)	2 (4)	12 (23)	0.17 [0.04–0.71]	0.004
Duration of FOB usage (s), median (IQR)	75 (47–97)	106 (64–158)	−36.7 (−55.6 to −17.7)	0.001
Interval before surgery[a] (min), median (IQR)	15 (11–18)	20 (20–25)	−6.59 (−8.11 to −5.06)	<0.001
Hypotension, No. (%)	28 (53)	39 (74)	0.72 [0.53–0.97]	0.027
Bradycardia, No. (%)	14 (26)	22 (42)	0.64 [0.37–1.11]	0.101
Hypoxemia, No. (%)	0	2 (4)		0.153
Sore throat, No. (%)	17 (32)	28 (53)	0.61 [0.38–0.97]	0.031
Hoarseness, No. (%)	17 (32)	18 (34)	0.94 [0.55–1.62]	0.836
Upper-arm discomfort[b], No. (%)	0	5 (9)		0.022
Time in PACU (min), mean (SD)	47.3 (5.2)	51.0 (9.6)	−3.77 (−6.76 to −0.79)	0.014
24 h QoR-15 score, median (IQR)	136 (132–140)	136 (133–141)	−1.40 (−4.28 to 1.49)	0.494

Intubation time was defined as the time from the use of the video-laryngoscope to confirmation of correct positioning of the DLT by using FOB. Hypotension was defined as a decrease in systolic blood pressure greater than 20% of baseline value for at least 1 min. Bradycardia was defined as a heart rate of <60 beats/minute for at least 1 min. Hypoxemia was defined as the decrease in arterial blood oxygen saturation as measured by pulse oximetry to a threshold value of 92% or lower. DLT, double-lumen tube; FOB, fibreoptic bronchoscopy; IQR, interquartile range; SD, standard deviation; PACU, post-anaesthesia care unit; QoR-15, Quality of Recovery-15 scale; CI, confidence interval. [a]Time interval between the start of anaesthesia and the start of surgery. [b]One upper arm of the patient was compressed by the lateral position.

Table 3: **Intra-operative and post-operative variables of the patients.**

operative hypotension. Post-operative sore throat and hoarseness are common events following tracheal intubation.[26] We found a lower incidence of sore throat in the lateral group, which suggested that lateral DLT intubation may cause less damage to the patient's throat. None of the patients in the lateral group experienced discomfort in the compressed upper arm with self-adjustment to a comfortable lateral position before anesthesia. In contrast, 5 patients in the supine group experienced numbness or distension in the compressed upper arm, which may have been related to compression of the shoulder or brachial plexus after passive lateral positioning.[27] Moreover, surgery could begin immediately after DLT positioning in the lateral group, thereby reducing the interval between the induction of anesthesia and the start of the surgical procedure. Patients in the two groups showed similar 24-h QoR-15 scores.[28] Surgeons and nurses involved in the surgical procedure reported greater satisfaction with lateral DLT intubation than supine intubation. They did not have to shift the anaesthetised patient to the surgically required lateral position, which was a labor-intensive process.

This is the first randomized controlled trial investigating the clinical application and efficacy of DLT intubation in the lateral position in thoracic surgery. Our study lays the foundation for lateral DLT intubation in patients undergoing thoracic surgery, and could inspire further research on the impact of this method. We hope that lateral DLT intubation can be mastered by more anesthesiologists and be implemented widely to benefit more patients.

Our study had the following limitations. First, blinding patients and anesthesia investigators to the study protocol was not possible. Patients were informed of the method of DLT intubation after entering the operating theater and accordingly laid in the lateral position or supine position. The anesthesia investigators were also aware of the patient grouping and undertook lateral or supine DLT intubation. To ensure the accuracy of the data, an independent research nurse who was not involved in the study supervised the collection of intraoperative data, and the investigators involved in follow-up and data analyses were unaware of the patient grouping. Second, lateral DLT intubation is not appropriate for patients with known or predicted to have difficult intubation. As indicated by McCaul and colleagues, single-lumen tube intubation in the lateral position is considered inappropriate for patients with difficult intubation.[29] Third, all patients received only total intravenous anesthesia. High doses of propofol may have side effects such as hypotension.[30] Fourth, this is a single-center, small sample size clinical study. Multicenter investigations are required to evaluate whether lateral DLT intubation can be a viable alternative to conventional supine intubation. Fifth, in our next clinical trial of predicting the depth of lateral DLT intubation by preoperative patient CT, we will include flexible video laryngoscopic examination to evaluate vocal fold pathology.

In conclusion, our study provided evidence that performing DLT intubation in the lateral position reduced the incidence of DLT malposition compared with conventional supine intubation for patients undergoing unilateral VATS. Our findings validate the feasibility and superiority of DLT intubation in the lateral position, which may be a superior option for DLT intubation in thoracic surgery.

Contributors

Xi Zhang: conceptualisation, investigation, methodology, writing-original draft; Dongxu Wang: conceptualisation, investigation, methodology, writing-original draft; Zhenduo Zhang: conceptualisation, investigation, visualisation; Yawen Tang: conceptualisation, investigation, visualisation; Qin Zhang: data curation, formal analysis, software; Fei Tong: investigation, visualisation; Yonghe Hu: investigation, visualisation; Xian Lu: data curation, formal analysis; He Liu: conceptualisation, funding acquisition, methodology, supervision, writing-review & editing; Siping Hu: conceptualisation, funding acquisition, investigation, methodology, supervision, writing-review & editing.

Data sharing statement

The datasets generated and analyzed during the current study are not publicly available because of patient privacy but are available from the corresponding author upon reasonable request.

Declaration of interests

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2023.102402.

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