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Original Article

Video laryngoscope-guided double-lumen tube tracheal intubation in the left-lateral position for thoracoscopic surgery: an open-label randomized non-inferiority trial

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Abstract: Objective: To evaluate whether double-lumen tube (DLT) intubation guided by video laryngoscope in the left-lateral position is superior to that in the supine position. Methods: A prospective, single-center, open-label, randomized, non-inferiority trial included 94 patients (aged 18-75 years) undergoing thoracoscopic right lung surgery in the left position from July 2022 to September 2025. Patients were randomized to receive DLT intubation in the lateral or supine position. The primary outcome was total intubation time (TNI), with a non-inferiority margin (δ) of 10s. Secondary outcomes included first-attempt intubation success, Cormack-Lehane score, number of DLT adjustments, preparation time for patient positioning, number of medical staff required for positioning, and number of facilitating maneuvers. Safety outcomes were also recorded. Results: All patients were successfully intubated on the first attempt. TNI in the lateral position was 7 s (97.5% CI, 3 to 10) longer than that in the supine position. Compared with the supine group, the lateral group required fewer intubation adjustments, had a shorter preparation time for postural placement, had fewer medical staff personnel for postural placement, and intubation misplacement of the DLT was more common in the lateral group (P = 0.006). Furthermore, serial postoperative assessment revealed that airway discomfort (measured by NRS) peaked at 6 hours after extubation in both groups. Comprehensive clinical evaluation demonstrated that the lateral position significantly reduced the airway management difficulty score, while maintaining a comparable procedure smoothness index, confirming its clinical efficiency and feasibility. Conclusion: Video laryngoscope-guided DLT intubation in the left lateral position was non-inferior to the supine position in terms of operational feasibility.

Keywords: Double-lumen tube, endotracheal intubation, video-assisted thoracoscopic surgery, video laryngoscope

Introduction

Video-assisted thoracoscopic surgery (VATS) has become increasingly popular, as it allows for faster recovery and reduced postoperative pain, compared with thoracotomy [1]. Traditionally, VATS requires general anesthesia, muscle relaxation, and controlled ventilation with lung isolation, with the double-lumen tube (DLT) being the most widely used device for this purpose [2, 3]. However, mechanical ventilation with DLT intubation and the subsequent postoperative residual neuromuscular blockade are associated with an increased risk of postoperative pulmonary complications, including postoperative lung injury [4-6].

Non-intubated thoracoscopic surgery (NITS) is considered an alternative to VATS with intubation. Pompeo et al. [7] first reported on nodule resection through VATS without endotracheal intubation. Compared with VATS with intubation, NITS allows a significantly lower incidence of respiratory and intubation-related complications, shorter postoperative fasting time, shorter hospital stay, and lower mortality rate [8-11]. However, due to conditions such as severe mediastinal flutter [12], uncontrollable cough reflex, massive hemorrhage, severe hypercapnia, and hypoxemia [13-16], conversion to intubated VATS is required in 2%-11% of NITS cases [16-21]. Therefore, an abrupt, unplanned conversion requires DLT intubation in the lateral

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position. Additionally, lateral position DLT intubation may be optimal in certain clinical situations, such as cases in which patients have large mediastinal masses and sharp penetrating injuries to the posterior back [22, 23]. In conventional VATS, DLT intubation is usually performed after induction of general anesthesia in the supine position, and the position is changed after confirming that the bronchial catheter is in place. After general anesthesia, the patient is unable to cooperate, and the anesthesia, nursing, and surgical staff need to work together to move the patient to the lateral position, which consumes a lot of time and energy. Changes in position carry the risk of limb injury, dramatic hemodynamic changes, and catheter displacement or even dislocation [24-27]. Involving awake patients in the positioning process allows timely feedback, thereby improving perioperative positioning comfort and potentially reducing positioning-related complications.

This study aimed to assess the feasibility and safety of DLT intubation in the left-lateral position. While single-lumen tube (SLT) endotracheal intubation guided by video laryngoscopy in the lateral position is a safe and feasible approach [28, 29], DLT is characterized by a large external diameter, stiff material, and need to rotate the tube during intubation, which impedes tracheal intubation. To date, whether DLT intubation guided by video laryngoscopy in the lateral recumbent position is safe and feasible remains unclear. Due to the anatomical differences between the right and left bronchi, only patients with left DLT intubation for right-sided VATS were selected. Therefore, we aimed to evaluate whether DLT intubation guided by video laryngoscope in the left-lateral position is non-inferior to that in the supine position, with respect to Time Needed to Intubate (TNI), success rate, and adverse events.

Materials and methods

Ethical statement

The Ethics Committee of the China-Japan Union Hospital of Jilin University approved the original randomized controlled trial (No. 20220628011, June 28, 2022). The study protocol was prospectively registered in the Chinese Clinical Trial Registry on July 14, 2022 (http://www.chictr.org.cn, registration number: ChiCTR2200061969). All eligible patients were screened at least one day before surgery. Eligible patients received communication regarding the procedure and the potential benefits and complications of the trial. The participants provided informed consent and reserved the right to withdraw at any time point. This study was conducted according to the Declaration of Helsinki (2013). This report adheres to the Consolidated Standards of Reporting Trials guidelines 2010 [30].

Participants

This single-center randomized controlled clinical trial enrolled adult patients who underwent VATS at the China-Japan Union Hospital of Jilin University from July 2022 to September 2025. The inclusion criteria for patients were as follows: 1) Aged 18-75 years, 2) American Society of Anesthesiologists (ASA) physical status II or III, and 3) Scheduled elective thoracoscopic right lung surgery in the left position. The exclusion criteria for patients were as follows: 1) Difficulty with intubation and/or mask ventilation, as indicated by a thyromental distance of < 6 cm, mouth opening of < 2.5 cm, Mallampati grades III and IV, abnormal range of motion of the head and neck, or body mass index of > 30 kg/m^2; 2) History of airway difficulties; 3) Anatomical abnormality of the upper respiratory tract; and 4) History of tracheostomy.

Randomization and blinding

The patients were randomly allocated in a 1:1 ratio to either the lateral or supine groups using a computer-generated randomization table (http://www.randomization.com). The allocation sequence was concealed by enclosing assignments in sequentially numbered, sealed, and opaque envelopes. Each corresponding envelope was opened when the patient entered the operating room. None of the persons involved in this study, including patients, surgeons, anesthesiologists, intraoperative investigators, and members of the statistical team, were blinded to the group allocation of each participant.

Protocol

All patients were requested to fast for ≥ 8 h before surgery; further, no premedication was administered. Each patient was routinely moni-

tored using electrocardiography, non-invasive blood pressure, pulse oxygen saturation, airway pressure, end-tidal carbon dioxide, and bispectral index values. Invasive pressure was monitored, as appropriate.

For induction of and intubation after general anesthesia, the patients were placed in the left lateral or supine position based on their assigned groups. Patients in the lateral group placed themselves in a tolerable or comfortable left-lateral position. Subsequently, the surgeons changed the angles of the operating table to facilitate surgery. Proper thickness underneath the neck pillow and axillary rolls were set and adjusted to prevent unpleasant feelings, complaints, or numbness of the limbs. The sagittal axis of the head and neck was parallel to the operating table; further, the neck was extended. The proper position was maintained during induction and intubation. Patients in the supine group were intubated in the conventional supine position with a single pillow under each of their heads. Anesthetized participants were placed in the designated left-lateral position with pillows under the neck and axilla based on the medical staff's experience.

The size of each left-sided DLT was selected and prepared by an independent anesthetist. Generally, a 35 or 37 F DLT was used in each female patient, while a 37 or 39 F DLT was used in each male patient. Anesthesia induction was performed using intravenous propofol (2 mg/kg) or equivalent etomidate, sufentanil (0.5 μg/kg), and cisatracurium (0.15 mg/kg). Manual ventilation with pure oxygen was provided through a mask 3 min before intubation. Subsequently, a trained anesthetist performed the intubation with a lubricated plastic DLT (TUOREN Medical, Xinxiang, Henan, China) using a video laryngoscope (TD-C; UE Medical, Taizhou, Zhejiang, China) with a #3 single-use blade (UE Medical, Taizhou, Zhejiang, China). After the bronchial tip of the DLT passed beyond the vocal cords, the stylet that comes with the DLT was removed; additionally, the DLT was rotated 180° counterclockwise to facilitate sliding of the bronchial lumen tip into the glottis vocalis, which was then advanced until the bronchial cuff passed the vocal cords. Subsequently, the DLT was rotated clockwise to the intrinsic status to align the bronchial lumen with the left mainstem bronchus, followed by advancement until slight resistance was encountered [31]. After intubation, an independent unblinded researcher checked the appropriate DLT position within the left mainstem bronchus. First, the correct DLT position within the left main bronchus was checked by auscultation under manual one-lung ventilation using a stethoscope. Second, the assessor checked whether the fully inflated, blue-colored bronchial cuff was positioned just below the carina using the FOB.

An attempt at intubation was defined as any single laryngoscope insertion past the patient's lips. Intubation was considered a failure after two consecutive unsuccessful attempts.

For participant safety in the lateral group, a laryngeal mask airway was inserted before intubation to maintain airway patency for mask ventilation in cases of persistent hypoxia (SpO_2 < 90% lasting for 30 s). In the case of intubation failure in the lateral position, the operating table was rotated clockwise by 45° to improve the intubating conditions, followed by another attempt. In case this attempt was unsuccessful, the patient was placed in the supine position for intubation.

Measurement

Before randomization, we conducted preoperative interviews to confirm the risk factors for difficult intubation, if any, and recorded Mallampati scores. Data were recorded by an independent observer.

The primary outcomes were two metrics of TNI and the success rate of first-attempt intubation. The TNI was defined as the period between the laryngoscope passing the patient's lip and confirmation of intubation through capnography. In case of more than one intubation attempt, the TNI was considered as the time from initial laryngoscope insertion to the final confirmation of successful intubation by capnography. The first-attempt intubation success rate was defined as the ratio of patients with successful first intubation to the total number of participants in the group.

Secondary outcomes included the Cormack-Lehane score, number of DLT adjustments with the FOB, preparation time for postural placement, number of medical staff involved in pos-

tural placement, and number of facilitating maneuvers performed by an assistant for intubation. Cormack-Lehane scores were evaluated using the video laryngoscope images. The number of adjustments was recorded through the fully inflated, blue-colored bronchial cuff located just below the carina. We only counted adjustments that occurred during the period between anesthesia induction and the start of the operation since post-incision adjustments were considered unrelated to intubation. The preparation time was defined as the time from the patient lying on the operating table to postural placement for the operation. The number of facilitating maneuvers for DLT intubation included the Sellick maneuver on the cricoid cartilage or lifting the mandible to improve the Cormack-Lehane score.

Also, postoperative airway comfort was assessed using a standardized 0-10 Numeric Rating Scale (NRS) for sore throat and dysphagia at 2, 6, and 24 hours post-extubation. The NRS score is a tool used to quickly quantify pain intensity on a numerical scale, commonly ranging from 0 to 10. A score of 0 indicates no pain, while 10 represents the most severe pain, allowing patients to select a number that best describes their level of pain.

Furthermore, we recorded intubation-related adverse effects and complications, including carina injury (checked with the FOB), endotracheal and oral mucosal injury (blood found at the DLT surface or mouth secretions), dental injury (tooth movement or bleeding), misplacement (left DLT placed into the right principal bronchus), and hypoxia (SpO_2 < 90% during intubation).

Composite clinical assessment

To provide a comprehensive evaluation of the clinical implementation of lateral-position intubation, two composite scores were constructed based on objective intraoperative data: the Airway Management Difficulty Score (AMDS) and the Procedure Smoothness Index (PSI).

The AMDS was defined as the sum of points assigned to provider participated in positioning patients (1 person = 0, 2 persons = 1, ≥ 3 persons = 2), preoperative tube adjustments (0 = 0, 1-2 = 1, > 2 = 2), and total intubation time (TNI; < 30 s = 0, 30-60 s = 1, > 60 s = 2), reflecting the total clinical resource burden.

The PSI was calculated based on technical feasibility and complications: initial misplacement (no = 0, yes = 2), external assistance (no = 0, yes = 1), and Cormack-Lehane grade (I-IIa = 0, IIb-IV = 2). A higher PSI indicates lower procedural smoothness. Both scores were compared between groups to quantify the trade-off between procedural efficiency and clinical safety.

Power calculations

The sample size was calculated based on the primary outcomes. In a previous study [32], the standard deviation (SD) of TNI in the supine group was 14.8 s. The 10-second noninferiority selected based on a previous single-lumen intubation study was chosen to be 50% of the 20-second difference, which is considered to be the smallest clinically significant advantage time [28]. A total of 41 patients per group were required to assess non-inferiority of TNI, using a non-inferiority delta of 10 s longer, α of 0.025 (0.05/2 under one-sided test), and 85% power. The sample size was calculated based on the requirement for non-inferiority in the TNI, which requires more patients. Considering a 15% dropout rate, we enrolled 94 participants.

Statistical analyses

Descriptive statistics for demographics and baseline airway assessments are presented as means ± SDs and numbers (percentages). Comparisons between groups were performed using independent-sample t-tests (or Mann-Whitney U tests) for continuous variables and Chi-square tests (or Fisher's exact tests) for categorical variables. The between-group balance was compared using absolute standardized difference (ASD). An ASD of > 0.10 indicated an imbalance between the groups, with adjustment for these variables in the subsequent analyses.

Primary analyses: We performed between-group comparisons of the TNI and success rate of first-attempt intubation. Since the TNI was log-normally distributed, we performed between-group comparisons through linear regression models with a significance criterion of 0.025 (one-sided test). To provide additional

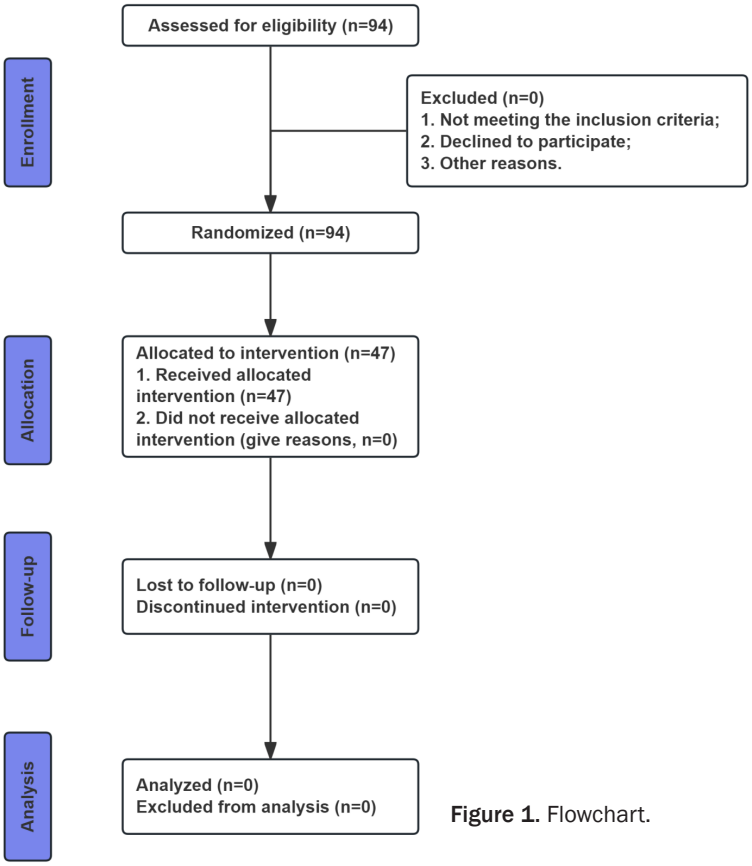


Figure 1. Flowchart.

information and allow sensitivity analysis, we used the Hodges-Lehmann method to estimate the median difference and 97.5% confidence interval (CI) of the TNI.

Secondary analyses: We evaluated secondary endpoints, including the success rate of first-attempt intubation (which is reported descriptively, as all patients were successfully intubated on the first attempt) and the Cormack-Lehane score. We performed between-group comparisons of the Cormack-Lehane score using a linear regression model, where Cormack-Lehane scores of 1, 2a, and 2b were assigned scores of 1-3, respectively, for easier comparisons. Moreover, we performed between-group comparisons of the number of adjustments (with FOB), preparation time for postural placement, and number of medical staff members participating in postural placement using a linear regression model. The number of facilitating maneuvers for DLT intubation was not compared owing to the small sample size. The significance criterion was 0.025, with adjustment through Bonferroni correction. Safety outcomes are summarized via standard summary statistics.

Results

Baseline

This study included 94 participants from July 2022 to September 2022 (**Figure 1**). Patient demographics and baseline characteristics are summarized in **Table 1**. Most variables showed a between-group balance, with the lateral group having a slightly greater number of patients with ASA grade 3 and 35 F tubes than the supine group. Accordingly, the ASA grades and tube sizes were adjusted in all analyses (**Table 1**).

Clinical efficiency and intubation time

Compared with that of the supine group, the preparation time in the lateral group was 0.85 (97.5% CI, 0.80 to 0.89; $P < 0.001$) times shorter. Additionally, the lateral group required 2.18 (97.5% CI, -2.38 to -1.99; $P < 0.001$) times fewer medical staff members for postural placement (**Table 2**). As illustrated by the individual data distribution in **Figure 2A**, there was minimal overlap in preparation time between the two groups.

Regarding the subsequent airway management, the median interquartile times to intubation were 36 (30 to 41) and 41 (37 to 47) in the supine and lateral groups, respectively (**Table 3**). Although the lateral group required a slightly longer time to intubate (**Figure 2B**), the observed difference remained within the predefined non-inferiority margin. The TNI was longer by 7 s (97.5% CI 3 to 10) in the lateral group, compared with that of the supine group, with the upper CI (10 s) not exceeding the non-inferiority delta of 10 s (**Figure 3**).

Postoperative recovery and airway comfort

Postoperative airway discomfort was evaluated using Numeric Rating Scale at 2, 6, and 24

Table 1. Patient characteristics

	Lateral group (n = 47)	Supine group (n = 47)	ASD	χ^2/t	P
Age, years	57 ± 9	56 ± 13	0.004	0.018	0.986
Female, number	25 (53)	24 (51)	0.04	0.043	0.836
Height, cm	166 ± 8	165 ± 7	0.06	0.296	0.768
Weight, kg	65 ± 9	65 ± 10	0.05	0.240	0.811
BMI, kg/m^2	24 ± 2	24 ± 3	< 0.001	0.012	0.991
ASA class, number			0.13	0.382	0.537
2	40 (85)	42 (89)			
3	7 (15)	5 (11)			
Mallampati Score, number			0.09	0.177	0.674
1	18 (38)	20 (42)			
2	29 (62)	27 (58)			
Tube Type, number			0.18	0.681	0.409
35	25 (53)	21 (45)			
37 or 39	22 (47)	26 (55)			

Variables are summarized as mean ± standard deviation or N (%). ASD: Absolute standardized difference; BMI, body mass index; ASA, American Society of Anesthesiologists. ASD > 0.10 indicates a potential imbalance between the groups.

Table 2. Preparation for patient positioning

	Lateral group (n = 47)	Supine group (n = 47)	Difference (97.5% CI)	U	*P*-value
Preparation time for postural placement, min	7.9 (7.4, 9.6)	9.3 (8.7, 10.2)	0.85 (0.80, 0.89)*	274.5	< 0.001
Provider participated in positioning patients, number	1.1 ± 0.3	3.3 ± 0.5	-2.18 (-2.38, -1.99)	2.500	< 0.001

Data are summarized as mean ± standard deviation, or median [Q1, Q3]. *Difference measured in the ratio of geometric means.

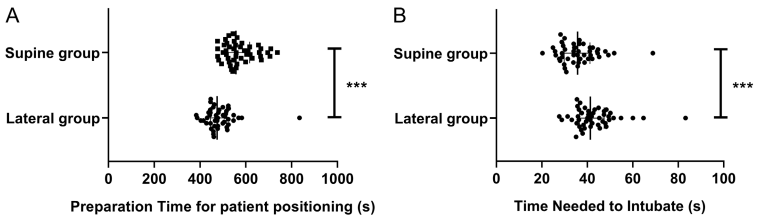


Figure 2. Distribution of intubation time and positioning preparation time. A. Preparation time for patient positioning. B. Time needed to intubate. Data are presented as column scatter plots with median and interquartile range. ***P < 0.001.

hours post-extubation. Both groups exhibited a consistent recovery trajectory, with NRS scores peaking at 6 hours, which aligns with the expected inflammatory response following airway instrumentation. Notably, the lateral group showed comparable, and numerically lower (P < 0.05), NRS scores at all measured time points compared with the supine group. These findings suggest that the specific technical interventions required for the lateral position did not lead to increased subjective postoperative morbidity. As shown in **Figure 4**.

Airway visualization and technical feasibility

No significant between-group difference was identified in the Cormack-Lehane score (lateral group, 0.9 ± 0.6 vs. supine group, 1.6 ± 0.6; *P* = 0.64). Under these glottic visualization conditions, the first-attempt intubation success rate reached 100% in both groups (**Table 4**). Furthermore, one patient (2%) in each group required assistance to facilitate intubation.

Airway safety and complications

Compared with the supine group, the lateral group required 0.72 (97.5% CI, 0.45 to 1.00; P < 0.001) times fewer tube adjustments (**Table 5**). However, the DLT was misplaced into the right main bronchus in seven patients in the lateral position group, but not in the supine position group (*P* = 0.006) (**Table 6**).

Table 3. Time needed to intubate

	Lateral group (n = 47)	Supine group (n = 47)	Difference (97.5% CI)	U	*P*-value
Time Needed to Intubate, s	41 (37, 47)	36 (30, 41)	7 (3, 10)	595.5	< 0.001

Data are summarized as median [Q1, Q3].

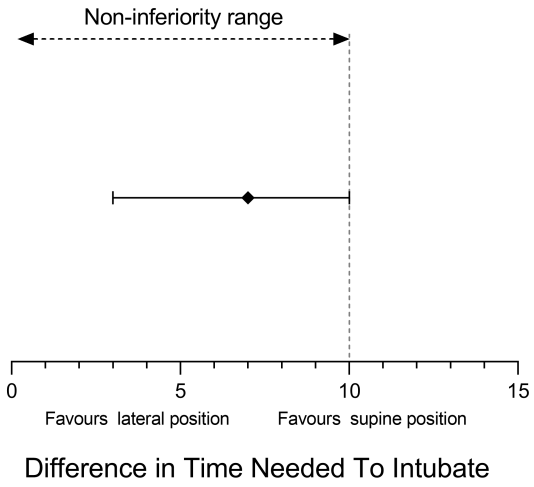


Figure 3. Differences in TNI between lateral and supine positions. The confidence interval does not cross the non-inferiority margin, which was set at 10 s, indicating that the lateral position is non-inferior to the supine position in terms of TNI. Mean and 97.5% confidence interval.

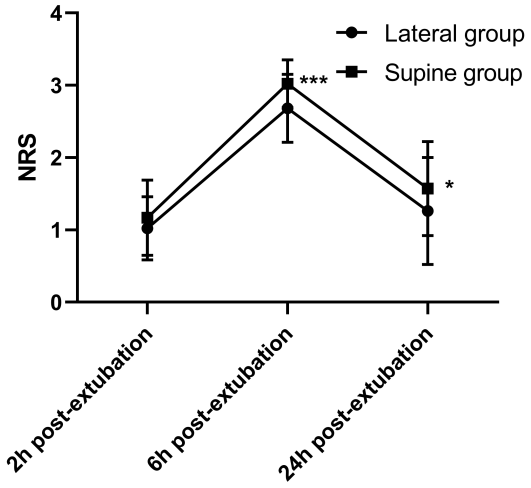


Figure 4. Postoperative airway discomfort recovery trajectory. *P < 0.05, ***P < 0.001.

No between-group differences were identified in the occurrences of the two complications of carina injury and oral mucosal injury, and we did not observe any dental injuries or hypoxia (**Table 6**). To further evaluate the strength of these associations, relative risks (RRs) and their corresponding 95% confidence intervals (CIs) were analyzed. The RR for initial DLT misplacement in the lateral group compared with the supine group was 15.00 (95% CI: 0.88 to 255.45). Meanwhile, no significant increased risks were observed for carina injury (RR = 1.50, 95% CI: 0.45 to 4.97) or oral mucosal injury (RR = 1.00, 95% CI: 0.40 to 2.49). The comprehensive forest plot displaying these relative risks is presented in **Figure 5**.

Clinical comprehensive evaluation

To provide a holistic assessment of the clinical performance and workload associated with different positioning strategies, we developed two composite indices: the Airway Management Difficulty Score (AMDS) and the Procedure Smoothness Index (PSI). As shown in **Table 7**, the lateral group demonstrated a significantly lower AMDS compared with the supine group (1.89 ± 0.70 vs. 3.72 ± 0.65, P < 0.001), indicating a substantial reduction in the overall clinical resource and management burden. In contrast, no significant difference was observed in the PSI between the two groups (0.62 ± 1.01 vs. 0.32 ± 0.78, P = 0.114), suggesting that the lateral approach achieved superior clinical efficiency without compromising the procedural smoothness.

Discussion

We compared the supine and lateral positions for DLT placement in patients intubated using a video laryngoscope. The first-attempt intubation success rate was 100% in both groups and therefore, no further attempts were needed. The difference in intubation time between the two groups was 7 s (97.5% CI, 3 to 10), which was within the corresponding non-inferiority margin δ. Both indicators satisfy the non-inferiority test conditions, so we determined that video laryngoscope-guided DLT intubation in the left-lateral position is not inferior to that in the supine position in terms of feasibility. We found that, compared with the supine group,

Table 4. Success rate of first-attempt intubation

	Lateral group (n = 47)	Supine group (n = 47)	Difference (97.5% CI)	*P*-value
Success rate of first-attempt intubation, number	47 (100)	47 (100)	NA	NA

Data are summarized as N (%).

Table 5. Intubation-related conditions and management

	Lateral group (n = 47)	Supine group (n = 47)	Difference (97.5% CI)	χ^2	*P*-value
Cormack-Lehane score, number			-0.07 (-0.25, 0.38)	0.474	0.64
1	14 (30)	17 (36)			
2a	26 (55)	23 (49)			
2b	7 (15)	7 (15)			
Preoperative tube adjustment, number			-0.72 (-1.00, -0.45)	28.893	< 0.001
0	11 (23)	2 (4)			
1	32 (68)	17 (36)			
2	4 (9)	27 (57)			
3	0	1 (2)			

Data are summarized as N (%).

Table 6. Safety outcomes

	Lateral group (n = 47)	Supine group (n = 47)	χ^2	*P*-value
Carina injury	6 (13)	4 (9)	0.448	0.504
Oral mucosal injury	8 (17)	8 (17)	0.000	1
Misplacement	7 (15)	0	7.563	0.006
Dental injury	0	0		
Hypoxia	0	0		

Data are summarized as N (%).

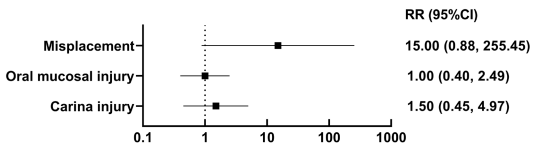


Figure 5. Forest plot of relative risks (RRs) for intubation-related complications. CI, confidence interval; RR, relative risk.

the lateral group required fewer perioperative tube adjustments, shorter preparation times for postural placement, and fewer human resources to set positions. Moreover, the DLT tended to slide into the right principal bronchus in the lateral group; however, no between-group difference was observed in the incidences of other complications.

SLT endotracheal intubation in the lateral position is more difficult than that in the supine position [33, 34]. Video laryngoscopy reduces the restriction on patient posture and improves the conditions for SLT intubation in the lateral position [31, 35]. Jin et al. [29] reported first-attempt SLT intubation success rates of 95% and 97% for the supine and left-lateral positions, respectively, which is consistent with our findings. In contrast, Komatsu et al. [28] reported a relatively low single intubation success rate of 70% for SLT in the left lateral position. This difference could be attributed to the fact that our study excluded patients with Mallampati grades III and IV because NITS cannot be used in patients with expected difficult airway management [12, 15].

SLT intubation in the left-lateral position has not been shown to prolong TNI under video laryngoscopic guidance [28, 29]. However, we found that the lateral group had a significantly longer TNI than the supine group, even though the Cormack-Lehane scores were comparable. This could be attributed to differences in the characteristics and intubation procedures between the SLT and DLT. Compared with SLT, DLT is characterized by a larger external diameter and stiffer material; additionally, DLT intu-

Table 7. Comparison of clinical comprehensive evaluation indices between groups

	Lateral group (n = 47)	Supine group (n = 47)	t	*P*-value
The Airway Management Difficulty Score	1.89 ± 0.70	3.72 ± 0.65	13.13	< 0.001
The Procedure Smoothness Index	0.62 ± 1.01	0.32 ± 0.78	1.612	0.114

bation requires counterclockwise tube rotation, followed by clockwise re-rotation. However, in the left-lateral position, the operating space is limited due to pillow compression under the left mandible and gravitational drooping of the right oral commissure, which restricts intubation.

In our study, the same trained investigator (KL) performed all intubations, which eliminated variability attributed to skill level and provider differences. The TNI in the lateral position was 7 s (97.5% CI, 3 to 10) longer than that in the supine position, and differences within 3-10 s are clinically negligible and do not indicate the clinical inferiority of DLT intubation in the left-lateral position. No cases of hypoxemia were observed.

In contrast, DLT intubation in the lateral position could effectively reduce the number of preoperative tube adjustments, which shortens the preparation time and reduces the number of participating staff. No between-group difference was present in the incidence of carina and tracheal wall injury, as well as oral mucosal injury; further, no cases of dental injury or hypoxia were identified. Moreover, a risk of drastic hemodynamic changes and catheter displacement or even dislodgement must be considered when switching from the supine position to the lateral position under general anesthesia [29, 36, 37]. Thus, inclusion of lateral intubation may be beneficial in routine thoracic surgery. Moreover, future large-scale studies are warranted to elucidate the advantages and disadvantages of lateral intubation of DLT, compared with those of routine supine intubation of DLT.

In our study, the incidence rates of misplacements in the lateral and supine groups were 15% and 0%, respectively. However, Seo et al. [38] reported that the incidence rate of misplacements in the lateral position was 4.2%. We believe that the misplacements in our study could be attributed to the increased angle between the left principal bronchus and trachea, as well as the smaller diameter of the left principal bronchus, which makes the left DLT prone to sliding into the right principal bronchus. These changes can result from a certain degree of anatomical displacement of the left principal bronchus caused by the muscle relaxant and lateral position, gravitational prolapse of the mediastinum and right lung, and compression of the left chest wall by the pillows underneath the axilla. Other risk factors for misplacement of the left DLT into the right mainstem bronchus include female sex, shorter height, smaller DLT size, and finer tracheal and bronchial diameter [38]. In our study, five (71%) patients with misplaced DLT were female; further, no significant between-group difference was observed in height. Nevertheless, the incidence of misplacements could be further reduced by improvements in lateral DLT intubation techniques, including the use of fiber bronchoscope guidance shortly after entry of the DLT into the trachea cannula, or the use of visualized DLT, which has become increasingly popular.

This study has several limitations. First, this was an open-label trial in which neither the patients, anesthesiologists, outcome assessors, nor statisticians were blinded. Since several endpoints involved semi-objective or subjective measures, the lack of blinding may have led to measurement bias, thereby reducing the overall quality of the evidence. Second, because this study employed a single-center design with strict inclusion criteria enrolling only elective right thoracic surgery patients with ASA physical status II-III, normal airways, and a BMI < 30 kg/m^2; our findings have limited external generalizability and cannot be directly applied to patients with high airway risk or those undergoing emergency thoracic surgery. Future large-scale, multicenter trials are warranted that incorporate a more heterogeneous patient population. Third, this was a small-scale, single-center study. We only had 85% power for detecting an approximately 10 s increase in the TNI, which was insufficient to achieve a significant clinical difference. Therefore, high-quality, large-sample, randomized controlled trials are warranted to confirm our findings. Fourth, all intubations were performed

by an experienced anesthetist using the simulation model in the lateral position. However, insufficient experience with DLT intubation in the lateral position remains, compared with that in the supine position. Therefore, our findings may not apply to anesthetists who have clinically practiced or are at least skilled in SLT intubation in the lateral position. Fifth, although we found no between-group differences in the incidences of vertebral artery and tracheal wall injuries and oral mucosal injuries, the study was not designed to detect differences in morbidity; therefore, the lack of a reported measure in our study does not indicate the absence of morbidity. Finally, our main study objective was to evaluate whether video laryngoscope-guided DLT intubation in the left-lateral position was feasible, with the advantages of lateral position intubation being only a secondary outcome. Thus, our conclusions cannot be broadly generalized to all thoracic surgical positions or configurations. Future investigations involving various surgical sides and tube types are warranted.

Conclusion

We observed that video laryngoscope-guided DLT intubation in the left lateral position was superior to that in the supine position in terms of operational feasibility. Left position DLT intubation more easily mislead the DLT into the right main bronchus; however, no significant difference was identified in other safety indexes.

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Disclosure of conflict of interest

None.

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References

[1] Feray S, Lubach J, Joshi GP, Bonnet F and Van de Velde M; PROSPECT Working Group *of the European Society of Regional Anaesthesia and Pain Therapy. PROSPECT guidelines for video-assisted thoracoscopic surgery: a systematic review and procedure-specific postoperative pain management recommendations. Anaesthesia 2022; 77: 311-325.

[2] Campos JH. Current techniques for perioperative lung isolation in adults. Anesthesiology 2002; 97: 1295-1301.

[3] Campos JH. Progress in lung separation. Thorac Surg Clin 2005; 15: 71-83.

[4] Liu S, Mao Y, Qiu P, Faridovich KA and Dong Y. Airway rupture caused by double-lumen tubes: a review of 187 cases. Anesth Analg 2020; 131: 1485-1490.

[5] Serpa Neto A, Hemmes SN, Barbas CS, Beiderlinden M, Fernandez-Bustamante A, Futier E, Hollmann MW, Jaber S, Kozian A, Licker M, Lin WQ, Moine P, Scavonetto F, Schilling T, Selmo G, Severgnini P, Sprung J, Treschan T, Unzueta C, Weingarten TN, Wolthuis EK, Wrigge H, Gama de Abreu M, Pelosi P and Schultz MJ; PROVE Network investigators. Incidence of mortality and morbidity related to postoperative lung injury in patients who have undergone abdominal or thoracic surgery: a systematic review and meta-analysis. Lancet Respir Med 2014; 2: 1007-1015.

[6] Murphy GS, Szokol JW, Avram MJ, Greenberg SB, Shear T, Vender JS, Gray J and Landry E. Postoperative residual neuromuscular blockade is associated with impaired clinical recovery. Anesth Analg 2013; 117: 133-141.

[7] Pompeo E, Mineo D, Rogliani P, Sabato AF and Mineo TC. Feasibility and results of awake thoracoscopic resection of solitary pulmonary nodules. Ann Thorac Surg 2004; 78: 1761-1768.

[8] Wen Y, Liang H, Qiu G, Liu Z, Liu J, Ying W, Liang W and He J. Non-intubated spontaneous ventilation in video-assisted thoracoscopic surgery: a meta-analysis. Eur J Cardiothorac Surg 2020; 57: 428-437.

[9] Yu MG, Jing R, Mo YJ, Lin F, Du XK, Ge WY, Dai HJ, Hu ZK, Zhang SS and Pan LH. Non-intubated anesthesia in patients undergoing video-assisted thoracoscopic surgery: a systematic review and meta-analysis. PLoS One 2019; 14: e0224737.

[10] Zhang XX, Song CT, Gao Z, Zhou B, Wang HB, Gong Q, Li B, Guo Q and Li HF. A comparison of non-intubated video-assisted thoracic surgery

with spontaneous ventilation and intubated video-assisted thoracic surgery: a meta-analysis based on 14 randomized controlled trials. J Thorac Dis 2021; 13: 1624-1640.
[11] Deng HY, Zhu ZJ, Wang YC, Wang WP, Ni PZ and Chen LQ. Non-intubated video-assisted thoracoscopic surgery under loco-regional anaesthesia for thoracic surgery: a meta-analysis. Interact Cardiovasc Thorac Surg 2016; 23: 31-40.
[12] Fabo C, Oszlanyi A, Lantos J, Rarosi F, Horvath T, Barta Z, Nemeth T and Szabo Z. Non-intubated thoracoscopic surgery-tips and tricks from anesthesiological aspects: a mini review. Front Surg 2022; 8: 818456.
[13] Chen JS, Cheng YJ, Hung MH, Tseng YD, Chen KC and Lee YC. Nonintubated thoracoscopic lobectomy for lung cancer. Ann Surg 2011; 254: 1038-1043.
[14] Hung MH, Hsu HH, Chan KC, Chen KC, Yie JC, Cheng YJ and Chen JS. Non-intubated thoracoscopic surgery using internal intercostal nerve block, vagal block and targeted sedation. Eur J Cardiothorac Surg 2014; 46: 620-625.
[15] Gonzalez-Rivas D, Bonome C, Fieira E, Aymerich H, Fernandez R, Delgado M, Mendez L and de la Torre M. Non-intubated video-assisted thoracoscopic lung resections: the future of thoracic surgery? Eur J Cardiothorac Surg 2016; 49: 721-731.
[16] Hung WT, Hung MH, Wang ML, Cheng YJ, Hsu HH and Chen JS. Nonintubated thoracoscopic surgery for lung tumor: seven years' experience with 1,025 patients. Ann Thorac Surg 2019; 107: 1607-1612.
[17] Furák J, Szabó Z, Tánczos T, Paszt A, Rieth A, Németh T, Pécsy B, Ottlakán A, Rárosi F, Lázár G and Molnár Z. Conversion method to manage surgical difficulties in non-intubated uniportal video-assisted thoracic surgery for major lung resection: simple thoracotomy without intubation. J Thorac Dis 2020; 12: 2061-2069.
[18] Li H, Huang D, Qiao K, Wang Z and Xu S. Feasibility of non-intubated anesthesia and regional block for thoracoscopic surgery under spontaneous respiration: a prospective cohort study. Braz J Med Biol Res 2019; 53: e8645.
[19] Moon Y, AlGhamdi ZM, Jeon J, Hwang W, Kim Y and Sung SW. Non-intubated thoracoscopic surgery: initial experience at a single center. J Thorac Dis 2018; 10: 3490-3498.
[20] Liu J, Cui F, Pompeo E, Gonzalez-Rivas D, Chen H, Yin W, Shao W, Li S, Pan H, Shen J, Hamblin L and He J. The impact of non-intubated versus intubated anaesthesia on early outcomes of video-assisted thoracoscopic anatomical resection in non-small-cell lung cancer: a propensity score matching analysis. Eur J Cardiothorac Surg 2016; 50: 920-925.
[21] Al-Abdullatief M, Wahood A, Al-Shirawi N, Arabi Y, Wahba M, Al-Jumah M, Al-Sheha S and Yamani N. Awake anaesthesia for major thoracic surgical procedures: an observational study. Eur J Cardiothorac Surg 2007; 32: 346-350.
[22] Blank RS and de Souza DG. Anesthetic management of patients with an anterior mediastinal mass: continuing professional development. Can J Anaesth 2011; 58: 853-859, 860-867.
[23] Subedi A, Tripathi M, Pathak L, Bhattarai B, Ghimire A and Koirala R. Curved knife "Khukuri" injury in the back and anaesthesia induction in lateral position for thoracotomy. JNMA J Nepal Med Assoc 2010; 50: 303-305.
[24] Desiderio DP, Burt M, Kolker AC, Fischer ME, Reinsel R and Wilson RS. The effects of endobronchial cuff inflation on double-lumen endobronchial tube movement after lateral decubitus positioning. J Cardiothorac Vasc Anesth 1997; 11: 595-598.
[25] Cheng KS, Wu RS and Tan PP. Displacement of double-lumen tubes after patient positioning. Anesthesiology 1998; 89: 1282-1283.
[26] Klein U, Karzai W, Bloos F, Wohlfarth M, Gottschall R, Fritz H, Gugel M and Seifert A. Role of fiberoptic bronchoscopy in conjunction with the use of double-lumen tubes for thoracic anesthesia: a prospective study. Anesthesiology 1998; 88: 346-350.
[27] Hurford WE and Alfille PH. A quality improvement study of the placement and complications of double-lumen endobronchial tubes. J Cardiothorac Vasc Anesth 1993; 7: 517-520.
[28] Komatsu R, Kamata K, You J, Sessler DI and Kasuya Y. Airway scope for tracheal intubation in the lateral position. Anesth Analg 2011; 112: 868-874.
[29] Jin Y, Ying J, Zhang K and Fang X. Endotracheal intubation under video laryngoscopic guidance during upper gastrointestinal endoscopic surgery in the left lateral position: a randomized controlled trial. Medicine (Baltimore) 2017; 96: e9461.
[30] Piaggio G, Elbourne DR, Pocock SJ, Evans SJ and Altman DG; CONSORT Group. Reporting of noninferiority and equivalence randomized trials: extension of the CONSORT 2010 statement. JAMA 2012; 308: 2594-2604.
[31] Bhat R, Sanickop CS, Patil MC, Umrani VS and Dhorigol MG. Comparison of Macintosh laryngoscope and C-MAC video laryngoscope for intubation in lateral position. J Anaesthesiol Clin Pharmacol 2015; 31: 226-229.
[32] Mathew A, Chandy J, Punnoose J, Gnanamuthu BR, Jeyseelan L and Sahajanandan R. A randomized control led study comparing CMAC video laryngoscope and Macintosh laryngoscope for insertion of double lumen tube in

patients undergoing elective thoracotomy. J Anaesthesiol Clin Pharmacol 2021; 37: 266-271.
[33] Dimitriou V and Voyagis GS. Use of the intubating laryngeal mask for airway management and light-guided tracheal intubation in the lateral position. Eur J Anaesthesiol 2000; 17: 395-397.
[34] McCaul CL, Harney D, Ryan M, Moran C, Kavanagh BP and Boylan JF. Airway management in the lateral position: a randomized controlled trial. Anesth Analg 2005; 101: 1221-1225.
[35] Takenaka I, Aoyama K, Iwagaki T and Kadoya T. Efficacy of the Airway Scope on tracheal intubation in the lateral position: comparison with the Macintosh laryngoscope. Eur J Anaesthesiol 2011; 28: 164-168.
[36] Sudheer PS, Logan SW, Ateleanu B and Hall JE. Haemodynamic effects of the prone position: a comparison of propofol total intravenous and inhalation anaesthesia. Anaesthesia 2006; 61: 138-141.
[37] Seo JH, Hong DM, Lee JM, Chung EJ and Bahk JH. Double-lumen tube placement with the patient in the supine position without a headrest minimizes displacement during lateral positioning. Can J Anaesth 2012; 59: 437-441.
[38] Seo JH, Bae JY, Kim HJ, Hong DM, Jeon Y and Bahk JH. Misplacement of left-sided double-lumen tubes into the right mainstem bronchus: incidence, risk factors and blind repositioning techniques. BMC Anesthesiol 2015; 15: 157.