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Novel Triple-Cuff versus Conventional Double-Cuff Double-Lumen Endobronchial Tube in Patients with Risk Factors for Tube Misdirection

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Purpose: Accurate positioning of the double-lumen endobronchial tube (DLT) is crucial for successful lung isolation during thoracic surgery. However, misdirection of the left-sided DLT into the right main bronchus frequently occurs in short, obese females with narrow airways. A novel triple-cuff DLT features an additional carinal cuff positioned on the right side of the tube, which differentiates it from conventional double-cuff DLTs. We hypothesized that inflating the carinal cuff would direct the bronchial tip of the triple-cuff DLT toward the left main bronchus, thereby reducing the likelihood of DLT misdirection when compared to the conventional double-cuff DLT.

Materials and Methods: In this single-center, unblinded randomized controlled trial, short, obese females with narrow airways were randomly assigned to either the triple-cuff or double-cuff group (n=77 each) and were intubated with the respective DLTs. The DLT misdirection rate, adjustment depth for optimal positioning, intubation time, and the incidence of hypoxia, airway injury, and postoperative airway complications were assessed.

Results: Data from 143 patients were analyzed. The triple-cuff group exhibited a lower DLT misdirection rate compared to the double-cuff group (15.3% vs. 46.5%, odds ratio 4.81, 95% confidence interval 2.18–10.64, $p<0.001$). Triple-cuff DLT was also associated with fewer adjustments, shorter intubation times, and lower incidences of hypoxia, airway injury, and sore throat than double-cuff DLT.

Conclusion: Triple-cuff DLT was superior to conventional DLT in reducing DLT misdirection in short, obese females with narrow airways. Furthermore, it facilitated a faster intubation process and reduced airway complications, thereby enhancing patient safety.

Clinical Trial Registration: NCT06061055 (ClinicalTrials.gov)

Key Words: Airway management, anatomy, bronchoscopy, intubation, one-lung ventilation, thoracic surgery

INTRODUCTION

Accurate positioning of the double-lumen endobronchial tube (DLT) is crucial for successful lung isolation during thoracic surgery.[1] Left-sided DLTs are preferred over right-sided DLTs due to the longer and more consistent anatomy of the left main bronchus (LMB) compared to the right main bronchus (RMB).[2] To place the left-sided DLT, the DLT is first advanced blindly towards the LMB and then adjusted to its optimal position using fiberoptic bronchoscopy (FOB). However, if the bronchial tip of the DLT is misdirected to the RMB during the blind insertion step, subsequent adjustment using FOB could often be challenging and threaten patient safety.[2,3] Evidence suggests that DLT misdirection occurs more frequently in patients who are short, obese, female, or have anatomically narrow airways,[3-6] and particular caution should be exercised to avoid RMB misdirection in this patient population.

The VentiBronc™ Anchor (Flexicare Medical Ltd., Moun-

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•Dr. Young Jun Oh holds the intellectual property rights to the design of the VentiBronc™ Anchor double-lumen endobronchial tube. None of the other authors have any conflicts of interest to disclose.

tain Ash, UK; VB) is a novel triple-cuff DLT equipped with an additional carinal cuff positioned between the tracheal and bronchial cuffs. During the blind insertion step, advancing the DLT with inflated carinal cuff anchors the DLT against the carina and prevents over-insertion into the distal main bronchus. Our previous study demonstrated that the VB DLT achieved more accurate depth placement compared to conventional double-cuff DLTs in thoracic surgery patients.[7]

Since the carinal cuff is positioned on the right side of the left-sided VB DLT, it is reasonable to assume that inflating the cuff would direct the bronchial tip toward the LMB, thereby reducing the likelihood of DLT misdirection (Fig. 1). This feature could be particularly beneficial for patients with known risk factors for DLT misdirection, yet no previous studies have specifically addressed this issue. Therefore, we aimed to compare the misdirection rates of the left-sided VB DLT with those of the conventional double-cuff DLT, and assessed whether the VB DLT facilitates safe and efficient intubation in this patient cohort.

MATERIALS AND METHODS

This single-center, unblinded randomized study was approved by the Institutional Review Board of the Yonsei University Health System (no. 1-2023-0043) in August 2023 and registered at ClinicalTrials.gov in October 2023 (NCT06061055). This study adhered to the applicable Consolidated Standards of Reporting Trials (CONSORT) guidelines and was conducted in accordance with the Ethical Principles for Medical Research Involving Human Subjects outlined in the Helsinki Declaration of 1975 (revised 2013). Patients scheduled for thoracic surgery at Severance Hospital (Seoul, Republic of Korea) were assessed for eligibility, and written informed consent was obtained from all participants. The inclusion criteria encompassed risk factors for RMB misdirection indicated by previous studies:[3-6] 1) female sex assigned at birth, 2) patients requiring left-sided DLT intubation, 3) height ≤160 cm, 4) body mass index (BMI) ≥25.0 kg/m^2,[8] and 5) inner diameter of the LMB ≤11 mm. The exclusion criteria were as follows: 1) American Society of Anesthesiologists (ASA) classification of IV or more, 2) presence of intraluminal lesions in the LMB or RMB, and 3) emergency surgery.

The inner diameter of the LMB was measured 1 cm below the carina where the bronchial cuff of the left-sided DLT was conventionally placed. Preoperative chest radiograph[3] and chest computed tomography[7] were used for anatomical measurements, and the values were averaged to reduce sampling error. The carina angle was measured, and after drawing a vertical line from the carina on the radiograph, the left and right tracheobronchial angles were measured (Fig. 2). The midline of the trachea was traced to identify the inflection point of the curved trachea, where the distance from the intratracheal midline to the vertical line of the carina was greatest. The tracheal deviation angle was defined as the angle formed by the carina, inflection point, and intratracheal midline at the level of the suprasternal notch. The horizontal distances between the carina vertical line and the left and right internal borders of the trachea (LC and RC distances, respectively) were measured (Fig. 2), and the tracheal diameter was calculated as the sum of the RC and LC distances.

Patients were randomly assigned to the triple-cuff group or double-cuff group according to a randomized sequence generated through a website (www.randomizer.org). The patients

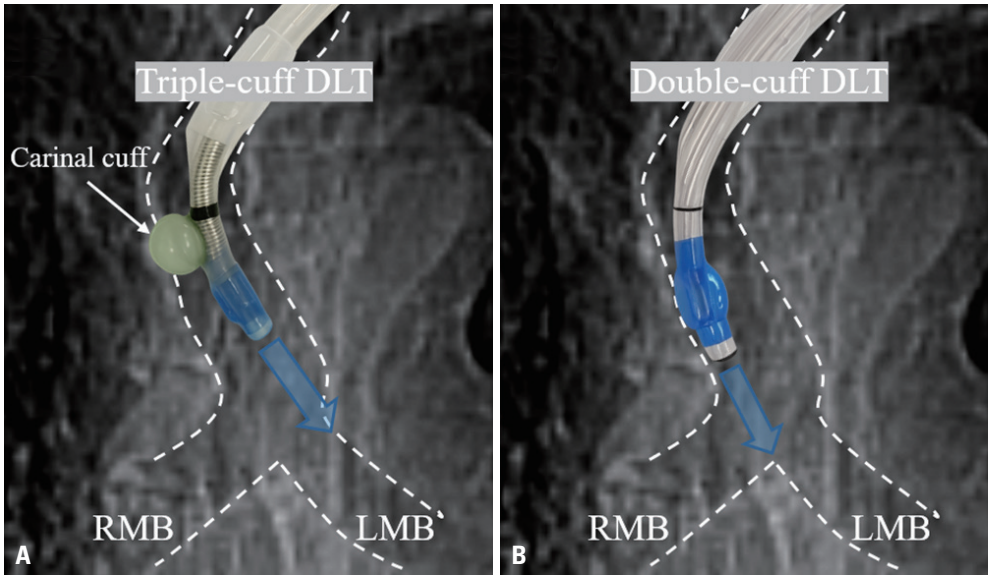

Fig. 1. DLT during intratracheal advancement. (A) Triple-cuff VentiBronc™ Anchor (VB) DLT with an additional carinal cuff. (B) Double-cuff Shiley® DLT. Note that the inflated carinal cuff (white arrow) of VB DLT directs the bronchial tip more towards the LMB (blue arrow). DLT, double-lumen endobronchial tube; RMB, right main bronchus; LMB, left main bronchus.

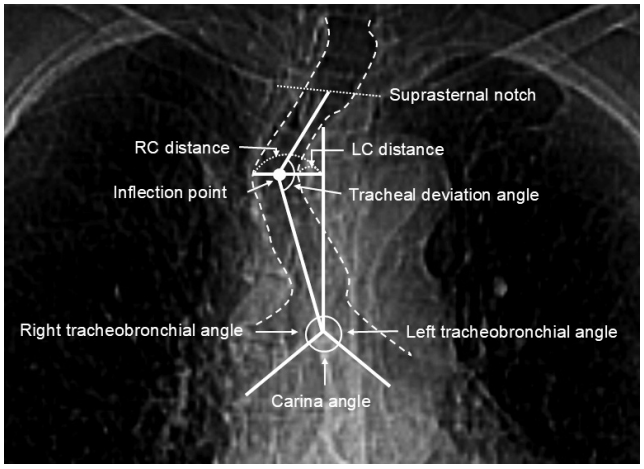

Fig. 2. Anatomical measurement. LC, the horizontal distance between the carina vertical line and left internal border of the trachea; RC, the horizontal distance between the carina vertical line and right internal border of the trachea.

were blinded to group allocation. All intubation procedures were performed by anesthesiologists with experience of more than 5000 cases of thoracic anesthesia. Standard monitoring, including electrocardiography, pulse oximetry, and noninvasive blood pressure measurement, was initiated upon arrival at the operating room. Anesthesia was standardized with intravenous propofol 1.0–1.5 mg/kg, rocuronium 0.8 mg/kg, remifentanil 0.5–1.0 μg/kg, and sevoflurane inhalation 2.0–4.0 vol%, according to our departmental protocol.

In the triple-cuff group, a 33 Fr VB DLT made of silicone, with a bronchial external diameter of 8.5 mm and an internal diameter of 6 mm, was inserted through the glottis using a video laryngoscope. After the carinal cuff passed the vocal cords, the stylet was removed, and the DLT was rotated 90° counterclockwise. The carinal cuff was inflated with 8 mL of air, and the DLT was gently advanced until moderate resistance was encountered. The initial depth was assessed at the level of the incisors. The carinal cuff was then deflated, and ventilation was resumed after the tracheal and bronchial cuffs were inflated. In the double-cuff group, a Shiley® DLT (Covidien, Mansfield, MA, USA), made of polyvinyl chloride with a bronchial external diameter of 7.5 mm and an internal diameter of 6 mm, was used to achieve lung isolation. The DLT was introduced into the glottis using a videolaryngoscope, and the stylet was removed after the bronchial cuff passed through the vocal cords. The DLT was rotated 90° counterclockwise and advanced to the estimated depth calculated using a height-based formula: 12.5+0.1× height (cm).[9]

In both groups, the initial position of the DLT was assessed by observing chest wall movement and auscultating both lungs during alternate clamping of the bronchial and tracheal lumens.[10] An FOB (IS3-F2, Shenzhen Insighters Medical Technology Co., Ltd; outer diameter 2.8 mm) was then used to confirm DLT positioning and evaluate airway injuries, which were graded as clear, a few petechiae, coalesced petechiae, or erosion.[1] Failure to achieve optimal DLT placement despite FOB guidance was regarded as intubation failure. In such cases, a single-lumen endotracheal tube was inserted, and a bronchial blocker was placed. These cases were excluded from the analysis.

The optimal depth was defined as the depth at which the proximal margin of the inflated bronchial cuff was positioned just below the carina, with the left secondary carina clearly visible along with unobstructed views of the left upper and lower bronchi, as confirmed by FOB.[11] DLT depths were measured at the level of the incisors, and adjustment depth, defined as the absolute difference between initial and optimal depth, was calculated by subtracting the initial depth from the optimal depth confirmed by FOB.

After extubation, the presence of stained blood on the extubated DLT was assessed. The incidence of postoperative sore throat (none, mild; pain with deglutition, severe; constant pain increasing with deglutition) and hoarseness (none, mild; noticed by the patient, severe; noticed by the observer) were assessed in the post-anesthesia care unit (PACU).

Data collected included age, height, weight, BMI, ASA classification, preoperative spirometry, anatomical measurements (e.g., bronchial diameters, tracheobronchial angles, carina angle, tracheal deviation angle, LC and RC distances, and aorta diameter), DLT misdirection rate, initial and final DLT depths, intubation time, airway injury, sore throat, and hoarseness.

The primary endpoint of this study was the DLT misdirection rate, defined as inadvertent advancement of the DLT into the RMB. Secondary outcomes included adjustment depth, intubation time (time from oral insertion of the videolaryngoscope to completion of FOB inspection), hypoxia (defined as peripheral oxygen saturation of <94%[12]) during intubation, airway injury, sore throat, and hoarseness in the PACU.

The sample size was calculated using G*Power software (version 3.1.9.7; Heinrich Heine University, Düsseldorf, Germany). Since the DLT misdirection rate had not been previously assessed in high-risk patients, assumptions were made based on our clinical experience, referencing data reported in the general population. The DLT misdirection rate in the general population using conventional double-cuff DLTs has been reported to be as high as 16.7%,[2] and this rate was expected to be higher in patients meeting our inclusion criteria. Based on our clinical experience, we anticipated a misdirection rate of 30% for the double-cuff group in this high-risk population. In contrast, the misdirection rate of VB DLTs has been reported as 8.4% in the general population.[7] Accordingly, we assumed a misdirection rate of 10% in the triple-cuff group and calculated the required sample size based on this estimate. In the G*Power software, the test family was set to "Exact," and the statistical test selected was "Proportions: Inequality, two independent groups (Fisher's exact test)." A two-tailed test was used with an alpha error probability of 0.05, power of 0.80, and an allocation ratio

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of 1. The type of power analysis was set to "A priori: Compute required sample size–given α, power, and effect size." Assuming 10% dropout rate, the required sample size was calculated as 154 patients (77 per group).

Statistical analyses were performed using SPSS 28.0 (IBM Corp., Armonk, NY, USA). The results are expressed as mean±standard deviation, median [interquartile range], or number (%). Continuous variables were first assessed for normality using the Kolmogorov–Smirnov test. Intergroup comparisons were performed using the t-test, Mann–Whitney U test, or χ^2/Fisher's exact test, as appropriate. The effect size was calculated as follows: odds ratio for dichotomous categorical data, Cramér's V for multi-category contingency tables, and Cliff's delta for variables not meeting normality assumptions. Statistical significance was set at $p<0.05$.

RESULTS

Between October 2023 and November 2024, 180 patients were assessed for eligibility. After exclusion, 154 patients were enrolled and randomly assigned to either the triple-cuff or double-cuff group (n=77 each). However, 11 patients were excluded from the analysis (6 in the double-cuff group and 5 in the triple-cuff group) due to preoperatively unidentified intrabronchial lesions, incomplete data, or failed DLT intubation. Data from the remaining 143 patients were analyzed (Fig. 3).

The patient characteristics are presented in Table 1. Age, height, weight, BMI, ASA classification, and preoperative spirometry results were comparable between the two groups. Bronchial anatomy measurements are presented in Table 2. Variables including main bronchial diameters, LC diameter, RC diameter, LC/RC ratio, tracheal diameter, tracheobronchial angles, carina angle, tracheal deviation angle, and aorta diameter were comparable between the groups.

Table 1. Baseline Demographics and Clinical Characteristics

	Double-cuff group (n=71)	Triple-cuff group (n=72)	*p*
Age (yr)	64.1±8.6	62.6±12.7	0.423
Height (cm)	153.2±4.3	154.0±4.9	0.326
Weight (kg)	64.6±8.6	66.3±8.3	0.238
BMI (kg/m^2)	27.5±2.0	27.9±2.8	0.370
ASA classification			0.420
I	20 (28.2)	27 (37.5)	
II	41 (57.7)	34 (47.2)	
III	10 (14.1)	11 (15.3)	
Preoperative spirometry			
FEV_1 (% predicted)	91.86±13.48	91.26±17.24	0.818
FEV_1/FVC (%)	77.04±5.44	77.46±6.26	0.675
DLCO (% predicted)	98.68±17.86	96.78±14.28	0.638

BMI, body mass index; ASA, American Society of Anesthesiologists; FEV_1, forced expiratory volume in 1 s; FEV_1/FVC, forced expiratory volume in 1 s to forced vital capacity ratio; DLCO, diffusing capacity of the lung for carbon monoxide.
Data are presented as mean±standard deviation or number (%).

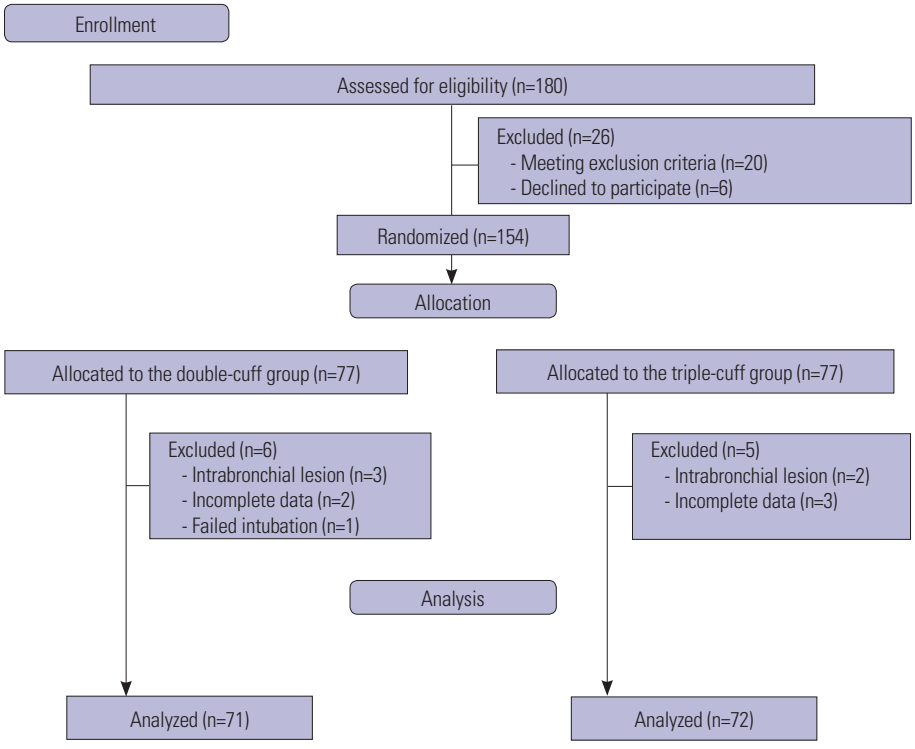

Fig. 3. CONSORT flow diagram of patient enrollment and allocation.

The intubation-related variables are summarized in Table 3. The DLT misdirection rate was significantly lower in the triple-cuff group than in the double-cuff group. The initial DLT depth was greater in the double-cuff group than in the triple-cuff group; however, the optimal depths confirmed by FOB were comparable between the groups. The incidence of initial depth exceeding the optimal depth of >10 mm was significantly higher in the double-cuff group than in the triple-cuff group. The absolute adjustment depth required to optimally position the DLT was significantly lower in the triple-cuff group than in the double-cuff group. The intubation time was shorter in the triple-cuff group.

Intubation-related complications are shown in Table 4. The incidences of hypoxia during intubation and airway injury were higher in the double-cuff group than in the triple-cuff group. Blood-stained DLTs after extubation were observed more frequently in the double-cuff group than in the triple-cuff group. Postoperative sore throat assessed in the PACU was more frequent in the double-cuff group than in the triple-cuff group, whereas the incidence of hoarseness was similar between the groups.

Table 2. Airway and Bronchial Anatomical Measurements

	Double-cuff group (n=71)	Triple-cuff group (n=72)	*p*
LMB diameter (mm)	9.76±1.00	9.82±1.05	0.709
RMB diameter (mm)	12.46±2.16	12.06±1.80	0.235
LC diameter (mm)	6.0 [4.4–8.0]	6.0 [4.0–8.0]	0.401
RC diameter (mm)	7.0 [6.0–10.0]	7.0 [6.0–10.0]	0.995
LC/RC ratio	0.8 [0.5–1.2]	0.9 [0.4–1.2]	0.547
Tracheal diameter (mm)	14.0 [13.0–15.0]	13.1 [12.6–14.4]	0.165
Left tracheobronchial angle (°)	126.94±7.04	128.81±8.04	0.141
Right tracheobronchial angle (°)	138.79±8.65	138.73±7.61	0.967
Carina angle (°)	94.27±12.01	92.46±12.61	0.380
Tracheal deviation angle (°)	171.4 [166.0–175.8]	171.1 [164.8–175.1]	0.408
Aorta diameter (mm)	30.0 [28.0–32.0]	30.0 [28.0–33.0]	0.696

LMB, left main bronchus; RMB, right main bronchus; LC, horizontal distance between the carina vertical line and left internal border of the trachea; RC, horizontal distance between the carina vertical line and right internal border of the trachea.
Data are presented as mean±standard deviation or median [interquartile range].

DISCUSSION

In this study, we demonstrated that the VB DLT significantly reduced the DLT misdirection rate in short, obese, female patients with narrow airways. Additionally, the use of the VB DLT was associated with fewer adjustments, shorter intubation times, and lower incidences of hypoxia during intubation, airway injury, and postoperative sore throat than conventional DLT.

Evidence indicates that risk factors for DLT misdirection include female sex, short stature, obesity, narrow airways, and the use of small-sized DLTs.[3-6] Hence, it is reasonable to assume that patients with all these risk factors are likely to have the highest DLT misdirection rates. Regarding the DLT size selection, although the traditional method is based on the patient's gender and height, evidence suggests that this approach is not always accurate in Asian females and individuals of smaller stature.[13-15] At our institution, the inner LMB diameter is considered the primary determinant for an appropriate DLT size. For patients with an inner LMB diameter ≤11 mm we routinely use 32 Shiley® DLT or 33 Fr VentiBronc™ Anchor DLT, considering the external diameters of the bronchial lumens (7.5 mm and 8.5 mm, respectively) and the required margin for bronchial cuff inflation. A major strength of our study was the selective inclusion of patients with these high-risk characteristics. This targeted approach underscores clinical strategies aimed at improving intubation success rates in this particularly challenging patient population.

The VB DLT demonstrated a significantly lower misdirection

Table 3. Comparative Intubation Outcomes between Study Groups

	Double-cuff group (n=71)	Triple-cuff group (n=72)	Effect size (95% CI)	*p*
Direction of DLT				
DLT misdirection (%)	33 (46.5)	11 (15.3)	0.21 (0.09–0.46)	<0.001*
Depth of DLT				
Initial depth (cm)	27.4 [27.0–27.7]	25.8 [25.0–26.1]	0.42 (0.40–0.43)	<0.001*
Optimal depth (cm)	26.0 [25.0–27.0]	25.8 [25.0–26.0]	0.14 (0.13–0.14)	0.159
Too deep (>10 mm)	32 (45.1)	10 (13.9)	0.20 (0.09–0.44)	<0.001*
Too shallow (>10 mm)	15 (21.1)	14 (19.4)	0.90 (0.40–2.04)	0.802
Adjustment depth (mm)	17.0 [8.0–25.0]	3.0 [0.0–10.0]	0.59 (0.58–0.60)	<0.001*
Intubation time (sec)	345 [230–450]	270 [168–360]	0.31 (0.30–0.32)	0.001*

DLT, double-lumen endobronchial tube; CI, confidence interval.
Data are presented as number (%) or median [interquartile range]. The numbers in the effect size column represent the following: odds ratios for dichotomous categorical data and Cliff's delta for variables not meeting normality assumptions.
*p<0.05, compared with the double-cuff group.

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Table 4. Complications Associated with DLT Intubation

	Double-cuff group (n=71)	Triple-cuff group (n=72)	Effect size (95% CI)	*p*
Hypoxia	13 (18.3)	5 (6.9)	0.33 (0.11–0.99)	0.041*
Airway injury			0.35 (0.23–0.47)	<0.001*
Clear	17 (23.9)	37 (51.4)		
A few petechiae	29 (40.8)	29 (40.3)		
Coalesced petechiae	23 (32.4)	6 (8.3)		
Erosion	2 (3.9)	0 (0)		
Blood-stained DLTs after extubation	30 (42.3)	15 (20.8)	0.36 (0.17–0.75)	0.006*
Sore throat in PACU			0.28 (0.18–0.39)	0.003*
None	38 (53.5)	55 (76.4)		
Mild	27 (38.0)	17 (23.6)		
Severe	6 (8.5)	0 (0)		
Hoarseness in PACU			0.15 (0.02–0.23)	0.218
None	20 (28.2)	28 (38.9)		
Mild	41 (57.7)	39 (54.2)		
Severe	10 (14.1)	5 (6.9)		

DLT, double-lumen endobronchial tube; PACU, post-anesthesia care unit; CI, confidence interval.
Data are presented as numbers (%). The numbers in the effect size column represent the following: odds ratios for dichotomous categorical data and Cramér's V for multi-category contingency tables. For "Sore throat in PACU," "mild" refers to pain with deglutition, and "severe" refers to constant pain increasing with deglutition. For "Hoarseness in PACU," "mild" refers to hoarseness noticed by the patient, and "severe" refers to hoarseness noticed by the observer.
*$p<0.05$, compared with the double-cuff group.

rate compared to the conventional double-cuff DLT, suggesting that the carinal cuff aids in directing the DLT toward the LMB in patients at high risk of misdirection. Notably, the misdirection rate in the double-cuff group approached 50%, significantly exceeding the 11.6% reported in our previous study conducted in a general patient population.[7] These findings underscore the impact of unfavorable airway anatomy on successful DLT placement and highlight the importance of selecting an appropriate DLT type to minimize misdirection in high-risk patients.

A larger diameter and straighter angle of the RMB compared to LMB have been identified as inherent causes of DLT misdirection.[2] In addition, the bronchial anatomy of our patients exhibited features that made DLT insertion into the LMB more challenging, including a narrower LMB, a more vertical left tracheobronchial angle, and a widened carinal angle compared to normal anatomy.[13,16] Distinct leftward deviation of the trachea was also observed, as indicated by an LC/RC ratio <1.0 and a tracheal deviation angle <180°. We presume that such structural changes in the airway may have been further affected by obesity for the following reasons: first, adipose tissue may accumulate within the walls of the airway in obese individuals,[5] which can contribute to a smaller airway compared to non-obese patients.[17] Second, increased abdominal pressure associated with obesity and reduced caudal traction on the trachea may also contribute to structural airway alterations.[18] Additionally, the normal aortic diameters in our patients suggest that the possibility of airway distortion caused by a dilated or tortuous aorta[19] can be ruled out in our patients, which also indicates the significant impact of obesity on airway structure.

The adjustment depth required to achieve optimal position from the initial depth was significantly smaller in the triple-cuff group. The greater adjustment depth observed in the double-cuff group appeared to be associated with the dependence on the height-based formula. Among the various height-based formulas,[9,20-23] we used the one proposed by Takita, et al.,[9] which was derived from an Asian population and was relatively straightforward to apply in clinical settings. However, advancing the DLT to the calculated depth often led to excessive DLT insertion in our patients, suggesting that such formulas may not always provide accurate guidance. Given that adjustment depths exceeding 10 mm may be critical in short Asian patients,[24] our results suggest that the VB DLT offered a significant advantage in achieving safe and optimal DLT placement.

The incidence of hypoxia during intubation was significantly lower in the triple-cuff group. Obese patients are predisposed to a rapid decline in oxygen saturation,[25] and given that the preoperative spirometry values were comparable between the two groups, we presume that the shorter intubation time, and consequently the shorter apnea time, likely contributed to this difference. The higher misdirection rate observed in the double-cuff group necessitated additional DLT manipulations under FOB guidance, which may have prolonged apnea time and increased the risk of hypoxia.

The incidence and severity of airway injury, as assessed using FOB, were significantly lower in the triple-cuff group than in the double-cuff group. There are two possible explanations for this finding. First, the double-cuff group had a higher occurrence of DLTs being advanced deeper than the optimal position, and forceful DLT insertion into the narrower distal bron-

chus likely resulted in more severe injury. Second, differences in the DLT material may have influenced the degree of airway injury. The VB DLT is made of silicone, whereas the Shiley® DLT used in the double-cuff group is made of polyvinyl chloride. Consistent with our results, a previous study demonstrated that silicone DLTs are associated with reduced mucosal damage compared to polyvinyl chloride DLTs, presumably because of their pliability.[26] It also seems reasonable to assume that the lower incidence of postoperative sore throat in the triple-cuff group was likely attributable to the reduced occurrence of airway injuries in this group.[27] In contrast, the occurrence of hoarseness was similar between the two groups, which aligns with previous study findings indicating that sore throat and vocal cord injuries are not directly associated with hoarseness.[28]

The limitations of this study were as follows. First, owing to the unavailability of identical DLT sizes, a 32 Fr Shiley® DLT was used in the double-cuff group, while a 33 Fr VB DLT was used in the triple-cuff group. Although the difference in the external diameters of the bronchial lumens between the two DLTs was 1 mm, this could still serve as a potential confounding factor affecting the study outcomes. Nonetheless, while larger DLTs are generally associated with a higher risk of airway injury,[29] our results showed that patients in the double-cuff group experienced more severe injuries. This suggests that the minimal discrepancy in DLT size between the two groups likely had little impact on the study outcomes. Second, our definition of obesity according to the Asia-Pacific BMI classification[8] limits the generalizability of our findings for other ethnic groups. Lastly, the outcome assessors could not be blinded because of the visibly different appearances of the two DLTs, which leaves a potential risk of bias in the outcome assessment.

In conclusion, triple-cuff VB DLT was superior to conventional double-cuff DLT in reducing DLT misdirection in high-risk patients. Furthermore, it facilitated a faster intubation process and reduced airway complications, thereby enhancing patient safety.

DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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AUTHOR CONTRIBUTIONS

Conceptualization: Young Jun Oh. Data curation: Hye Jin Kim. Formal analysis: Kyuho Lee. Funding acquisition: Hye Jin Kim. Investigation: Namo Kim. Methodology: Kyuho Lee. Project administration: Young Jun Oh. Resources: Young Jun Oh. Software: Kyuho Lee and Hye Jin Kim. Supervision: Young Jun Oh. Validation: Kyuho Lee and Hye Jin Kim. Visualization: Kyuho Lee. Writing—original draft: Namo Kim. Writing—review & editing: Young Jun Oh and Kyuho Lee. Approval of final manuscript: all authors.

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