

The efficacy and adverse effects of the Uniblocker and left-side double-lumen tube for one-lung ventilation under the guidance of chest CT

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Abstract. One-lung ventilation (OLV) is essential in numerous clinical procedures, in which the left-sided double-lumen tube (LDLT) is the most commonly used device. The application of bronchial blockers, including the Uniblocker or Arndt blocker, has increased in OLV. The present study aimed to compare the efficacy and adverse effects of the Uniblocker and LDLT for OLV under the guidance of chest CT. A total of 60 adult patients undergoing elective left-side thoracic surgery requiring OLV were included in the study. The patients were randomly assigned to the Uniblocker group (U group, n=30) or the LDLT group (D group, n=30). The time for initial tube placement, the number of optimal positions of the tube upon blind insertion, the number of attempts to adjust the tube to the optimal position, incidence of airway device displacement, injury to the bronchi and carina, the duration until lung collapse and the occurrence of sore throat and hoarseness over 24 h following surgery were recorded. The time for successful placement of the LDLT was 83.9 ± 19.4 sec and that for the Uniblocker was 84.3 ± 17.1 sec ($P > 0.05$). The degree of lung collapse 1 min following opening of the pleura was greater in the D group than that in the U group ($P < 0.01$) and the time required for the lung to completely collapse was shorter in the D group (3.3 ± 0.5 min) than that in the U group (8.4 ± 1.2 min; $P < 0.01$). On the contrary, the incidence of injury to the bronchi and carina was lower in the U group (2/30 cases) than in the D group (10/30 cases; $P = 0.02$); the incidence of sore throat was also lower in the U group (2/30 cases) compared with that in the D group (9/30 cases). The mean arterial pressure

of patients immediately following intubation was lower in the U group (122.0 ± 13.4 mmHg) than that in the D group (129.2 ± 12.1 mmHg; $P < 0.05$). The results of the present study indicated that the extraluminal use of the Uniblocker under guidance of chest CT is an efficient method with few adverse effects in left-side thoracic surgery. The study was registered at ClinicalTrials.gov on 16th December 2017 (no. NCT03392922).

Introduction

In numerous clinical situations, including cardiac, pulmonary and thoracic surgeries, one-lung ventilation (OLV) is required to facilitate visibility in surgical procedures; the management of OLV remains a challenge in the practice of thoracic anesthesia. Double-lumen tube (DLT) is the most commonly used device by the majority of anesthesiologists for OLV in thoracic surgeries (1,2); however, DLTs may be difficult to place in patients with restricted airways due to their larger diameter and distal curvature, and are more rigid than single-lumen tubes (SLTs) (3). Bronchial blockers (BBs) are an alternative to DLTs (4); however, BBs have numerous disadvantages, including increased duration of application (5) and collapse of the non-ventilated lung due to smaller lumen size (6).

A previous study by our group reported that chest CT images may be used to accurately predict the optimal insertion depth of left-sided DLT (LDLT) (7). Therefore, the present study aimed to compare the efficacy and adverse effects of extraluminal application of the Uniblocker (8) and LDLT under the guidance of chest CT for OLV.

Materials and methods

Patients. The present study was approved by the Ethics Committee of The First Hospital of Qinhuangdao (Qinhuangdao, China; ClinicalTrials.gov registration no. NCT03392922). A total of 60 adult patients undergoing elective left-side thoracic surgery requiring the Uniblocker or LDLT for OLV were included in the present study. The inclusion criteria were as follows: Age of 18-70 years, American Society of Anesthesiologists (ASA) classifications I-III and body mass index (BMI) ≤ 35 kg/m².

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The exclusion criteria were as follows: Pre-operative systolic blood pressure >140 mmHg and/or diastolic blood pressure >90 mmHg, neck deformity, ankylosing spondylitis, chronic bronchitis, bronchial asthma, history of airway hyperresponsiveness, thoracic surgery within the last month prior to enrolment, systemic infection or suspected tuberculosis, pre-operative hoarseness or combined visceral diseases of the heart, brain, liver or kidney. The patients were randomly allocated to the Uniblocker group (U group; n=30) or LDLT group (D group; n=30). Randomization (1:1) was based on codes generated by a computer and these codes were kept in sequentially numbered opaque envelopes until the end of the study.

Methods of anesthesia. A senior anesthesiologist trained by a senior radiologist pre-operatively screened all of the patients and performed the measurements of the distance from the vocal cord to the carina via the Picture Archiving and Communication System of the hospital. The measured distance was calculated based on the number of CT sections (5 mm) from the vocal cord to the carina where the left and right bronchus were able to be distinctly observed as a singular structure (Fig. 1A and B).

In the operating theatre, the patients were monitored via electrocardiogram; invasive arterial blood pressure, heart rate and peripheral oxygen saturation were also monitored after placing patients in the supine position. For the induction of anesthesia, the patients in the two groups were administered midazolam 0.05 mg/kg, 2–4 µg/kg fentanyl, 0.6 mg/kg rocuronium and 0.3 mg/kg etomidate. All patients were intubated by an experienced anesthesiologist 2 min following the administration of rocuronium using one of the two devices.

In the D group, an LDLT (Tuoren Medical Technology) of adequate size (35 Fr for female and 37 Fr for male) was used for intubation, which was performed as follows: The operator measured the aforementioned distance, between the vocal cords and carina according to the CT images of the patient's chest (Fig. 1C), on the LDLT from the black line on the endobronchial side of the tube to the side nearest to the mouth; a mark was made on the LDLT. Once the cuff of the endobronchial side of the tube had passed the vocal cords, the stylet was removed; the LDLT was rotated 90° toward the left main-stem bronchus and gently inserted further. The operator then identified the mark on the LDLT just above the vocal cords and further insertion was terminated (Fig. 2A). The correct position of the LDLT was determined by fiberoptic bronchoscope (FOB) (Fig. 2C). In addition, the insertion depth at the upper incisors was recorded and indicated on the LDLT with tape. The LDLT was firmly fixed at the patient's mouth with cloth tape.

In the U group, the Uniblocker (Changhua Medical Technology) was inserted by the same anesthesiologist. The intubation steps were as follows: The operator measured the distance, plus 10 mm, from the vocal cords to the carina according to the chest CT images (Fig. 1A and B) at the upper edge of the cuff to the side of the mouth and a mark was made on the Uniblocker (Fig. 1D). Once the tip of the Uniblocker had passed the glottis, it was inserted further toward the left main-stem bronchus. Insertion was stopped once the operator viewed the marker on the Uniblocker just above the vocal cords (Fig. 2B). The laryngoscope and Uniblocker were simultaneously held in the right hand of the operator; an SLT of

appropriate size (7.0 mm for females and 7.5 mm for males) was inserted via a video laryngoscope to the appropriate depth (Fig. 2B). The correct position of the Uniblocker was then determined by FOB (Fig. 2D); the insertion depth at the upper incisors was recorded and a mark was made on the Uniblocker, which was then separately fixed with the SLT at the patient's mouth with cloth tape.

The duration required for the initial insertion of the Uniblocker or LDLT, the number of optimal positions of the Uniblocker or LDLT upon blind insertion, the number of attempts to adjust the Uniblocker or LDLT to an optimal position, the incidence of tube displacement, the injuries of bronchi and carina assessed via FOB, the duration of lung collapse, the number of failed intubations, post-operative atelectasis or pneumonia diagnosis via X-ray, and the occurrence of hoarseness and sore throat within 24 h post-surgery were recorded.

The duration for initial intubation was defined as the time from when the operator inserted the video laryngoscope between the patient's teeth until the Uniblocker or LDLT was at the optimal position. The optimal position of the Uniblocker was achieved when the upper edge of the Uniblocker cuff was located 5–20 mm below the carina in the left main-stem bronchus; the optimal position of the LDLT was achieved when the upper edge of the cuff was located below the carina in the left main-stem bronchus. The patients were placed in the lateral decubitus position and the placement of the Uniblocker or LDLT was determined via FOB; failure of intubation was defined as the inability to insert the Uniblocker or LDLT into the left main bronchus after three attempts.

Following completion of the intubation procedure, the indicators of bronchi and carina injury were assessed by another independent anesthesiologist using FOB. Injuries to the bronchi and carina were graded as follows: 1, clear; 2, few petechiae; 3, coalesced petechiae, hemorrhage or ecchymosis; and 4, erosion (8).

Pulmonary collapse (1 min following pleural opening) was ranked by the same independent thoracic surgeons as follows: 1, excellent (complete collapse of lung); 2, fair (total collapse of lung, but a certain amount of residual air remains) and 3, poor (no collapse or partial collapse of lung) (6,9). The incidence and subjective intensity of sore throat and hoarseness within 24 h post-surgery were recorded by an independent anesthesiologist in a blinded manner.

Statistical analysis. Continuous data were expressed as the mean ± standard deviation. A Student's t-test was used for comparisons between groups. The categorical data were presented as percentages; Fisher's exact test or a χ^2 test was used for comparisons between groups. Injuries to the bronchi and carina were analyzed by a Mann-Whitney U test. Statistical analysis was performed using SPSS 21 statistical software (IBM Corp.). $P < 0.05$ was considered to indicate a statistically significant difference.

Results

Patient characteristics. There were no significant differences between the two groups in patient demographics, including age, sex, body weight, body height, BMI, ASA grade, surgery time, OLV time and the type of thoracic surgery ($P > 0.05$; Table I).

Table I. Demographic characteristics of patients, one-lung ventilation time, surgery time and types of surgery in the two groups.

Patient characteristic	U group (n=30)	D group (n=30)	P-value
Age (years)	56.5±14.5	55.5±11.3	0.79
Sex (M/F)	14/16	17/13	0.44
ASA grade (I/II/III)	13/13/4	12/15/3	0.77
Body weight (kg)	61.6±11.8	66.4±11.5	0.13
Body height (cm)	167.6±8.9	167.9±7.1	0.85
BMI (kg/m ²)	21.8±2.9	23.6±4.2	0.14
Surgery time (min)	118.8±54.5	141.7±60.3	0.15
OLV time (min)	93.4±49.0	106.9±60.6	0.38
Type of surgery	30	30	
Lung surgery	24	21	0.37
Esophageal surgery	3	4	1.00
Mediastinal mass surgery	3	5	0.70

Values are expressed as the mean ± standard deviation or n. Groups: D, left-sided double-lumen tube; U, Uniblocker. ASA, American Society of Anesthesiologists; OLV, one-lung ventilation; BMI, body mass index; M, male; F, female.

Position of tube and intubation time. There were no significant differences in the number of optimal positions of the tube upon initial blind insertion (26/30 for LDLT vs. 24/30 for Uniblocker), the duration of reaching successful tube placement (83.9±19.4 vs. 84.3±17.1 sec for LDLT and Uniblocker, respectively) and the number of repositioning attempts and tube dislodgements following repositioning between the two groups ($P>0.05$).

Lung collapse. The degree of lung collapse 1 min following opening of the pleura was better in the D group than in the U group ($P<0.01$), while the time required for complete collapse of the lung was shorter in the D group (3.3±0.5 min) than that in the U group (8.4±1.2 min; $P<0.01$; Table II).

Incidence of complications. The incidence of injury to the carina and bronchi was significantly lower in the U group (2/30 cases) compared with that in the D group (10/30 cases; $P<0.05$); the incidence of sore throat was also lower in the U group (2/30 cases) than that in the D group (9/30 cases; $P<0.05$). The hoarseness of patients and the incidence of pneumonia or post-operative atelectasis were not significantly different between the two groups ($P>0.05$; Table III).

Vital signs at different time-points. The mean arterial pressure (MAP) immediately following intubation was lower in the U group (122.0±13.4 mmHg) than that in the D group (129.2±12.1 mmHg; $P<0.05$) and there were no significant differences between the two groups at before anesthesia, before intubation, 3 min after intubation ($P>0.05$). The heart rate and oxygen saturation were not significantly different between the two groups at any of the time-points ($P>0.05$; Table IV).

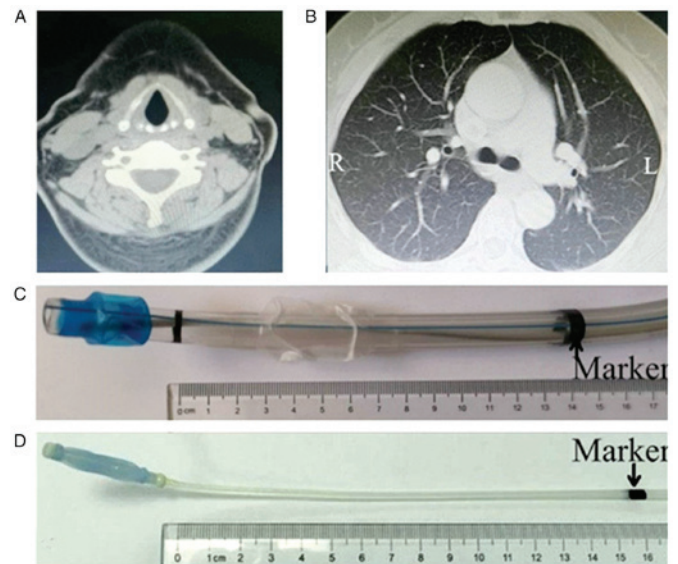


Figure 1. (A) Vocal cords and (B) carina on chest CT images. (C and D) A marker on (C) the left-sided double-lumen tube and (D) the Uniblocker.

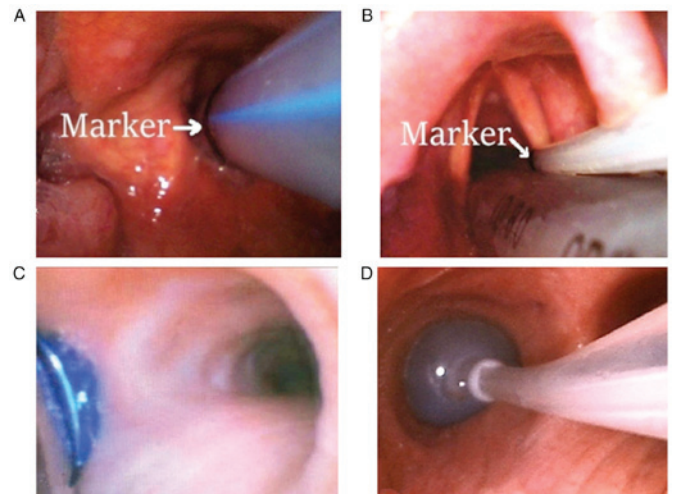


Figure 2. (A) Camera view during intubation by the video laryngoscope and the marker on the left-sided double-lumen tube. (B) Camera view during intubation via the video laryngoscope and the marker on the Uniblocker just above the vocal cords. (C) Cuff of the left-sided double-lumen tube located below the carina under the view of FOB. (D) Cuff of the Uniblocker located below the carina under the view of FOB. FOB, fiberoptic bronchoscope.

Discussion

The results of the present study demonstrated that LDLT had a shorter duration to lung collapse (3.3 vs. 8.4 min) and better lung collapse at 1 min following opening of the pleura, while the Uniblocker was associated with a reduced incidence of carinal and bronchial injuries and sore throat, and a lower MAP immediately following intubation. The duration of intubation did not significantly differ between the two devices.

OLV is fundamental in thoracic anesthesia as the majority of thoracic surgeries require lung isolation to facilitate visibility in surgical procedures and protect the healthy lung from cross-contamination. DLT is the preferred device for OLV; however, DLT is associated with numerous disadvantages, including difficulty in intubation in patients with restricted

Table II. The number of optimal positions of the tube upon initial blind insertion, the number of repositioning attempts, times for intubation and lung collapse, dislodgement and the degree of lung collapse.

Factor	U group (n=30)	D group (n=30)	P-value
Optimal positions upon initial blind insertion	24 (80)	26 (87)	0.73
Repositioning attempts			0.42
1	5 (17)	2 (7)	
2	1 (3)	2 (7)	
3	0 (0)	0 (0)	
Time for intubation (sec)	84.3±17.1	83.9±19.4	0.95
Time to lung collapse (sec)	8.4±1.2	3.3±0.5	<0.01
Degree of lung collapse			<0.01
Excellent	0 (0)	7 (23)	
Fair	12 (40)	18 (60)	
Poor	18 (60)	5 (17)	
Dislodgement	1 (3)	3 (10)	0.60

Values are expressed as the mean ± standard deviation or n (%). Groups: D, left-sided double-lumen tube; U, Uniblocker. Degree of pulmonary collapse: Excellent, complete collapse with perfect surgical exposure; fair, total collapse, but had residual air; poor, no collapse or partial collapse with interference of surgical exposure.

Table III. Degree of bronchial and carina injuries, and postoperative adverse events in the two groups.

Factor	U group (n=30)	D group (n=30)	P-value
Injury to bronchi and carina	2 (7)	10 (33)	0.02
1	1 (3)	5 (17)	0.20
2	1 (3)	3 (10)	0.61
3	0 (0)	2 (7)	0.47
4	0 (0)	0 (0)	
Sore throat	2 (7)	9 (30)	0.04
Hoarseness	0 (0)	3 (10)	0.24
Post-operative pneumonia or atelectasis	7 (23)	4 (13)	0.51

Values are expressed as n (%). Groups: D, left-sided double-lumen tube; U, Uniblocker. Degree of bronchi and carina injury: 1, clear; 2, few petechiae; 3, coalesced petechiae, hemorrhage or ecchymosis; 4, erosion.

airways (10) and increased incidence of airway injury due to its large diameter (11,12). Furthermore, in patients requiring post-operative ventilation support, the DLT may be replaced with an SLT. The first application of the BB was reported by Magill (13) in 1936. The first modern BB, known as the 'Univent tube', was presented by Inoue *et al* (14) in 1982. To date, the use of BBs, including the Univent blocker, Uniblocker, Cohen blocker (15), Coopdech blocker (16), Arndt blocker (17) and the

Table IV. Hemodynamic alterations in patients during intubation.

Factor	U group (n=30)	D group (n=30)	P-value
MAP (mmHg)			
T0	96.4±8.6	100.0±9.1	0.14
T1	73.9±8.1	76.2±9.1	0.10
T2	122.0±13.4	129.2±12.1	0.04
T3	109.2±16.8	112.2±14.4	0.50
HR (bpm)			
T0	74.8±9.4	76.2±9.1	0.60
T1	72.0±10.4	76.2±12.5	0.19
T2	90.9±9.9	93.7±13.3	0.39
T3	83.6±11.8	86.9±14.1	0.37
SpO ₂ (%)			
T0	98.9±1.2	98.6±1.6	0.89
T1	99.7±0.5	99.6±0.7	0.51
T2	99.8±0.4	99.7±0.5	0.76
T3	99.0±1.4	99.7±0.6	0.31

Values are expressed as the mean ± standard deviation. Groups: D, left-sided double-lumen tube; U, Uniblocker. MAP, mean arterial pressure; HR, heart rate; SpO₂, oxygen saturation. T0, before anesthesia; T1, before intubation; T2, immediate after intubation; T3, 3 min after intubation.

EZ blocker (18) has increased in OLV. It has been reported that BBs are more advantageous than DLTs due to easier insertion, particularly in patients with restricted airways (19). In addition, the tube does not have to be replaced when post-operative mechanical ventilation is required; however, it was reported that the placement of BBs was more time-consuming and additional intra-operative attempts in repositioning may be required compared with the LDLT (5). DLTs and BBs have been used for more than seven decades; however, which device is the most effective and has fewer adverse effects in patients has remained controversial (20-22).

In a previous study by our group, chest CT images were used to accurately predict the optimal insertion depth of an LDLT (7), and the extraluminal use of the Uniblocker was determined to be faster and more accurate than the conventional intraluminal use of the Uniblocker for left-side thoracic surgery (8). Therefore, in the present study, the efficacy and adverse effects of the Uniblocker and LDLT for OLV were investigated under the guidance of chest CT images. The results revealed that the number of optimal positions of the tube upon initial blind insertion and repositioning attempts were similar in the two groups. The duration of successful LDLT placement was 83.9 sec and that for the Uniblocker was 84.3 sec; the time was recorded from when the laryngoscope was inserted between the teeth of patients until the optimal position was obtained as determined via FOB. Campos and Kernstine (6) reported that the duration for successful LDLT placement was 128 sec and that for the Univent BB was 158 sec (as recorded from when the tube passed the vocal cords until satisfactory placement of the tube was achieved). Ruetzler *et al* (23) reported that the time recorded for initial LDLT placement was 85 sec, while that for the EZ blocker was 192 sec (the duration

from the tube passing the vocal cords to satisfactory placement). In a study by Narayanaswamy *et al* (5), the intubation time (from the beginning of laryngoscopy to lung isolation) for the LDLT was 93 sec and that for the Uniblocker was 203 sec. The present study reported a comparatively shorter time for LDLT placement (83.9 sec), while that for the Uniblocker was 84.3 sec. The shorter placement time of the LDLT compared with that in previous studies (5,6,23) may be associated with the use of chest CT images, which is more accurate and effective. A reduced placement time of the Uniblocker may be due to the extraluminal insertion of the SLT, in which the operator is able to rotate the Uniblocker an additional 20° counterclockwise to the left main-stem bronchus for posterior access to the trachea branches (24). In addition, the extraluminal use of Uniblocker allowed the tube to be inserted with ease. Furthermore, the operator was able to accurately measure the insertion depth based on the chest CT images. The operator viewed the marker on the Uniblocker just above the vocal cords during intubation to identify the optimal depth in the left main-stem bronchus. Therefore, the extraluminal use of the Uniblocker under the guidance of chest CT images may allow for rapid and easy insertion compared with the conventional intubation method.

Displacement of BBs or DLTs is a common event during intubation, particularly when the patient is moved from a supine to a lateral position, or from surgical manipulation of the operated lung, which may result in insufficient lung collapse and increases the risk of hypoxia during OLV (5). Narayanaswamy *et al* (5) revealed that repositioning of the DLT was required for 2/26 patients, while repositioning of the Uniblocker was performed in 11/26 patients. In the present study, displacement was recorded for 3/30 patients for the LDLT and 1/30 patients for Uniblocker intubation. The reasons for this may be as follows: The present study only selected patients undergoing left-side thoracic surgery and the left main-stem bronchus is longer than the right one. In addition, the insertion depth of the Uniblocker was 10 mm below the carina (the distance between the vocal cords and carina plus 10 mm) and the Uniblocker was inserted extraluminally to the trachea; thus, there was a greater space for the Uniblocker to move. Furthermore, whilst moving patients into the lateral decubitus position, the LDLT or Uniblocker was securely held near the incisors and the patient's head was kept in a neutral position. Therefore, displacement of the BB or LDLT was reduced in the present study.

The degree of lung collapse may affect visibility in surgical procedures. In the present study, the results revealed that the LDLT had a shorter time for lung collapse (3.3 vs. 8.4 min) and better lung collapse 1 min following pleura opening compared with the Uniblocker. This may be due to the larger lumen of the LDLT than the Uniblocker catheter (internal diameter, 1.6 mm), which may be associated with increased gas flow (25). On the contrary, deflating the cuff of the Uniblocker prior to pleura opening may induce a period of apnea (30 sec); however, with adequate suctioning via SLT, it is possible to insert a suction catheter into the SLT for the extraluminal application of the Uniblocker. Thus, the non-ventilated lung may also collapse well (26). Upon complete deflation, no differences between the two devices were observed (6).

Hoarseness and sore throat are common post-operative symptoms following tracheal intubation. Christensen *et al* (27)

reported that the incidence of hoarseness following tracheal intubation was ~50%. In a study by Zhong *et al* (28), the incidence of sore throat from Coopdech was 13%, that from Arndt was 20% and that from Univent was 30%. Knoll *et al* (9) observed the notable frequency of post-operative hoarseness in the DLT group (44%) compared with that in the BB group (17%). In the present study, sore throat was reported in 2/30 cases in the U group and in 9/30 cases in the D group; hoarseness occurred in 1/30 cases in the U group and in 4/30 cases in the D group. An explanation for this may be that the LDLT with a larger diameter and distal curvature is more rigid than the SLT (3). Furthermore, during intubation, the LDLT must be rotated 90° toward the left main-stem bronchus after the cuff of the tube passes the vocal cords; this process may cause injury to the glottis. Thus, the incidence of post-operative hoarseness was higher in the LDLT group than in the Uniblocker group. The results demonstrated that the size of the tracheal tube is a common risk factor associated with higher incidences of hoarseness and sore throat.

Injuries to the bronchi and carina were reported in 2/30 patients in the U group and 10/30 patients in the D group. This may have resulted from the larger outer diameter of the LDLT compared with the SLT, and as the endobronchial tube has a distal curvature, the endobronchial tube was required to be rotated 90° during intubation to pass the vocal cords, trachea and carina and enter the left main-stem bronchus. Therefore, this process may cause injury to the tracheal mucosa; however, the Uniblocker and SLT are thinner than the LDLT. Thus, the injuries to the bronchi and carina were more severe in the D group than in the U group. The MAP following intubation was higher in the D group than in the U group. This may be associated with the size of the DLT applied in the D group, which may induce injuries, particularly when passing the carina.

In numerous clinical situations, including the intubation of patients with restricted airways or tracheostomy, intubation with DLT tends to be difficult and at times impossible (29,30). In other situations, including empyema, hemothorax or blood and secretion in the trachea, the healthy lung may be exposed to cross-contamination with the use of the Uniblocker. Under these conditions, an alternative device for guaranteeing patient safety must be selected (31), and regardless of whether DLTs or BBs are employed, it is important that the operator is familiar with the devices (32).

There are also numerous limitations to the present study. The patient cohort was small and those patients with an undetectable glottis during intubation were excluded from the analysis. In addition, pre-operative chest CT scans must contain slices of vocal cord and carina, from which the distance between vocal cord and carina may be determined. Furthermore, there may be a bias in the procedure performed, as it was not performed in a blinded manner.

In conclusion, the duration until lung collapse was longer with Uniblocker intubation compared with the LDLT; providing a period of apnea is induced (30 sec) and adequate suctioning is performed via an SLT, the non-ventilated lung may also collapse well. Therefore, the extraluminal use of the Uniblocker under the guidance of chest CT images may be an easy and efficient method for OLV in left-side thoracic surgery with few adverse effects.

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Availability of data and materials

The datasets used and/or analyzed generated during the study are available from the corresponding author on reasonable request.

Authors' contributions

ZL contributed to the conception and design. LZ, YZ and QQJ collected the data. XCY, LB and SJL performed the analysis of data and interpretation of results. LZ and YZ wrote the manuscript and were involved in its critical revision. All authors reviewed and approved the final manuscript.

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of The First Hospital of Qinhuangdao (Qinhuangdao, China) and informed written consent was obtained from all patients.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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