Original Article

Video-assisted thoracoscopy with two-lung ventilation and CO_2 insufflation in primary spontaneous pneumothorax: propensity score matching comparison

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Background: Primary spontaneous pneumothorax (PSP) is commonly treated with video-assisted thoracoscopic surgery (VATS), which traditionally requires one-lung ventilation (OLV) with double-lumen endotracheal intubation to optimize the surgical field. However, OLV may be associated with complications such as airway trauma and postoperative sore throat. In contrast, two-lung ventilation (TLV) with CO_2 insufflation has been proposed as an alternative that may reduce airway-related complications while maintaining adequate visualization. This study assessed the feasibility of VATS with TLV and CO_2 insufflation for PSP compared to the conventional OLV approach.

Methods: We retrospectively analyzed 181 patients with PSP treated at our center between July 2020 and December 2023; of these, 134 underwent thoracoscopic bullectomy. Fifty-six patients received VATS with TLV and CO_2 insufflation. Seventy-eight patients underwent OLV via double-lumen endotracheal intubation. Patient data were categorized into groups based on the minimization of bias between those receiving TLV and those receiving OLV, following analysis matched by propensity scores. A comparative analysis across these groups was also conducted, focusing on demographic data and intraoperative and postoperative outcomes.

Results: The TLV group demonstrated several advantages, including shorter anesthesia induction time (13.45±5.25 min, P=0.01), shorter total anesthesia time (63.18±14.45 min, P=0.003), fewer days of chest tube drainage (1.41±1.22 days, P=0.04), shorter postoperative hospital stay (2.36±0.88 days, P=0.01), lower wedge resection specimen weight (3.21±2.5 g, P=0.03), fewer instances of postoperative ipsilateral and contralateral recurrence, and lower likelihood of short-term recurrence. No significant differences were found in surgical time (P=0.17), anesthesia recovery time (P=0.48), use of endostaplers (P=0.35), number of wedge resections (P=0.21), and pleurodesis (P=0.73).

Conclusions: In appropriately selected patients, TLV appears to be a viable option that does not increase recurrence risk compared to OLV while offering the benefit of a shorter anesthesia duration. Therefore, this method may be suitable for patients with PSP.

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Introduction

Primary spontaneous pneumothorax (PSP) occurs due to the rupture of subpleural blebs or bullae and primarily affects tall, lean young males. Its recurrence can significantly reduce quality of life; surgical treatment is preferred to lower the recurrence rate (1). Various minimally invasive surgeries are performed to treat PSP (2). Currently, PSP surgery is mostly performed with one-lung ventilation (OLV) using double-lumen endotracheal tubes. Despite improved surgical visibility under OLV, tracheal intubation using a double-lumen endotracheal tube is a more invasive procedure than intubation with a single-lumen endotracheal tube; it is associated with a relatively higher rate of intubation-related complications (3,4) and requires a longer induction time. Additionally, during OLV surgery, the contralateral lung is subjected to high airway pressure, potentially leading to complications. In contrast, surgeries performed under two-lung ventilation (TLV) using a single-lumen endotracheal tube require less time for induction, are less invasive, have fewer complications (5), and exert lower airway pressure on the contralateral lung; however, securing an adequate surgical field-of-view is challenging.

With advancements in thoracoscopic and robotic surgery, many mediastinal and esophageal surgeries is now secured the surgical field under TLV with CO_2 insufflation (6,7). In such surgeries, the target organ is not the lungs, and visibility is achieved through positioning and CO_2 insufflation; however, a few reports on lung surgery have been conducted. Lung surgery under TLV has limitations compared to mediastinal or esophageal surgery, requiring frequent lung manipulation for surgical resection and posing a risk of air embolism in cases of lung injury during surgery. However, PSP surgery, which mostly involves the resection of apical blebs or bullae, is relatively simple with minimal lung manipulation. Therefore, lung surgery under TLV is comparatively easier for patients with PSP.

In this study, we aimed to compare the outcomes of bullectomy performed under TLV with CO_2 insufflation after induction using a single-lumen endotracheal tube versus those of bullectomy conducted under OLV following induction with a double-lumen endotracheal tube, using propensity score matching. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1749/rc).

Highlight box

Key finding

- Our study demonstrates that compared to the conventional approach using one-lung ventilation (OLV) with double-lumen endotracheal intubation, video-assisted thoracoscopic surgery (VATS) for primary spontaneous pneumothorax (PSP) utilizing two-lung ventilation (TLV) and CO_2 insufflation does not increase the risk of recurrence, while offering the advantage of a shorter anesthesia duration.

What is known and what is new?

- VATS with TLV and CO_2 insufflation has been introduced as an alternative approach in thoracic surgery. Traditionally, OLV with double-lumen endotracheal intubation has been the standard method for surgical management of PSP. Despite advancements in thoracic surgery, OLV still faces several challenges, including airway trauma and postoperative discomfort. However, there is limited evidence directly comparing the clinical outcomes of TLV with CO_2 insufflation versus conventional OLV.
- Given the absence of robust evidence on the relative benefits and risks of these techniques, further comparative analysis is warranted to guide clinical decision-making. We performed a propensity score matching analysis to minimize baseline differences and achieve a more accurate comparison between the two surgical methods. The results demonstrate that TLV with CO_2 insufflation is a feasible alternative that may preserve more normal lung parenchyma while maintaining comparable surgical outcomes.

What is the implication, and what should change now?

- Compared to the OLV approach, the TLV technique with CO_2 insufflation does not increase the risk of recurrence and also offers the benefit of reducing anesthesia time.

Methods

The study was conducted in accordance with the

Table 1 Baseline preoperative characteristics

Variables	Unadjusted analysis			Propensity score-matched analysis		
	TLV (n=56)	Unadjusted OLV (n=78)	P value	TLV (n=56)	Matched OLV (n=56)	P value (matched)
Age (years)	21.82±8.6	27.97±14.77	0.006	21.82±8.64	21.51±7.48	0.30
Gender			0.45			0.09
Male	48 (85.7)	70 (89.7)		48 (85.7)	54 (96.4)	
Female	8 (14.3)	8 (10.3)		8 (14.3)	2 (3.6)	
BMI (kg/m^2)	19.6±3.84	19.45±2.88	0.80	19.59±3.84	18.77±2.68	0.09
Smoking			0.71			0.27
Yes	6 (10.7)	10 (12.8)		6 (10.7)	2 (3.6)	
No	50 (89.3)	68 (87.2)		50 (89.3)	54 (96.4)	
Reoperation			0.90			0.82
Yes	11 (19.6)	14 (17.9)		11 (19.6)	12 (21.4)	
No	45 (80.4)	64 (82.1)		45 (80.4)	44 (78.6)	
Laterality			0.96			>0.99
Left	27 (48.2)	39 (50.0)		27 (48.2)	27 (48.2)	
Right	28 (50.0)	38 (48.7)		28 (50.0)	28 (50.0)	
Bilateral	1 (1.8)	1 (1.3)		1 (1.8)	1 (1.8)	
Bullae/blebs on HRCT			0.51			>0.99
Single	18 (32.1)	21 (26.9)		18 (32.1)	18 (32.1)	
Multiple	38 (67.9)	57 (73.1)		38 (67.9)	38 (67.9)	

Data are presented as mean ± SD or N (%). BMI, body mass index; HRCT, high-resolution computed tomography; OLV, one-lung ventilation; SD, standard deviation; TLV, two-lung ventilation.

Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Chungnam National University Sejong Hospital (CNUSH IRB No. 2022-03-016-003) and individual consent for this retrospective analysis was waived.

Patients

Our study focused on patients with PSP, including those with subpleural bullae or blebs visible on chest computed tomography (CT), as well as those with recurrent and/or complicated pneumothorax, such as bilateral pneumothorax, persistent air leak, unexpanded lung, or tension pneumothorax. Patients with secondary or traumatic pneumothorax and those who refused surgical intervention were excluded from this study. Overall, 181 patients with PSP were treated. Of these, 47 patients did not undergo surgical intervention. Fifty-six patients received video-assisted thoracoscopic surgery (VATS) with TLV and CO_2 insufflation. In total, 78 patients underwent OLV via double-lumen endotracheal intubation. To obtain more precise clinical data analysis results, the study participants were matched to their nearest neighbors in a 1:1 ratio using propensity score matching, with 56 patients in each of the TLV and OLV groups without substitution. The covariates included in the propensity score model were age, sex, body mass index (BMI), smoking history and the number of bullae/blebs on CT scans. Fifty-six patients were included in each group for propensity score matching, and their demographic data are presented in *Table 1*. By comparing the demographic data and preoperative, intraoperative, and postoperative outcomes between the TLV and OLV patient groups, this approach minimized the potential bias linked to the selection of specific patients for surgery. Thus, it is more accurate to determine the surgical treatment approach that is most likely to benefit patients.

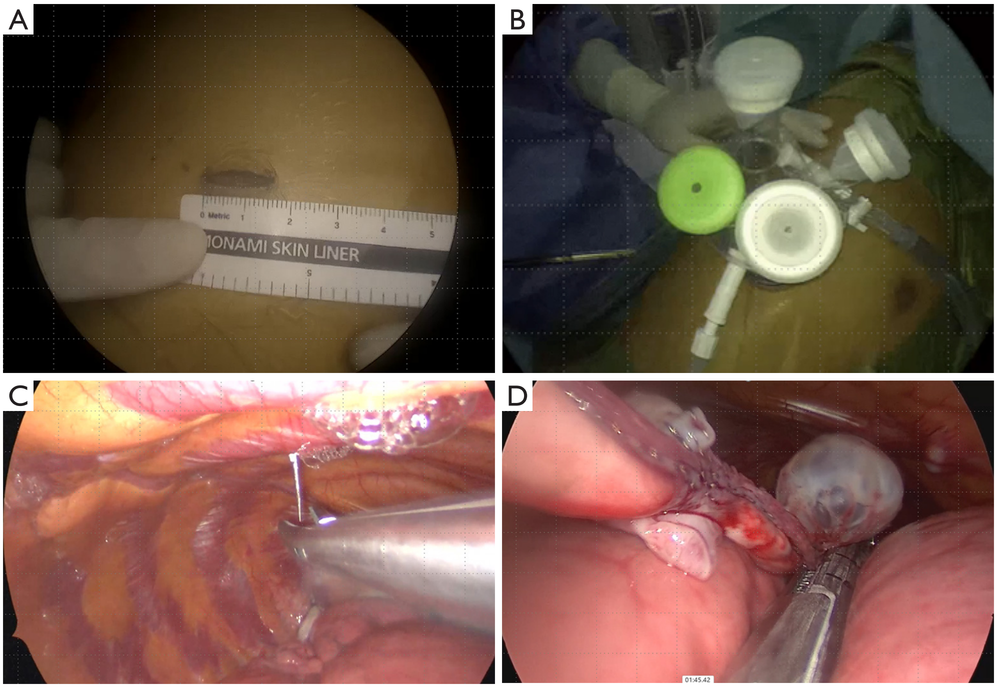

Figure 1 15-mm incision (A) and ONEPORT (4 branched wound protector) (B) and intraoperative field of view and procedures (C,D).

Procedures

All patients in this study were treated by four experienced surgeons, with one performing TLV combined with CO_2 insufflation. Among the surgeons included in this study, only one performed TLV surgeries, and this surgeon also conducted conventional OLV surgeries. TLV procedures were performed only on highly selected patients. The selection criteria included healthy individuals with no underlying lung or systemic disease, no evident adhesion bands on CT, no obesity (based on BMI), no history of redo surgery on the ipsilateral thorax, and no bullae in the lower lobe basal segments on CT. Patients who did not meet these criteria underwent elective OLV surgery. All surgeries were performed under general anesthesia with standard patient monitoring.

A dedicated anesthesiologist was involved in all cases to ensure optimal anesthesia management. Induction time was defined as the period from the initiation of anesthesia, marked by the administration of anesthetic agents, to the establishment of stable surgical anesthesia and successful endotracheal intubation. Total anesthesia time referred to the duration from the start of induction to the discontinuation of anesthetic agents at the conclusion of the surgical procedure. Anesthesia recovery time was defined as the interval from the cessation of anesthetic agents to the patient's ability to follow verbal commands and maintain spontaneous breathing without assistance.

All patients were fully informed about the surgical procedure, including the use of TLV, its potential advantages and challenges. Written informed consent was obtained from all patients prior to surgery after a detailed discussion of the risks, benefits, and alternative options.

In the TLV group, induction was performed using a single-lumen endotracheal tube. During anesthesia and surgery, the tidal volume was maintained at 5–6 mL/kg with an average airway pressure of 12 cmH_2O. Single-incision VATS was performed using ONEPORT (Tebah, Anyang-si, Korea) with four channels under a 15-mm skin incision at the 5th intercostal space in the full lateral position (*Figure 1A,1B*). To minimize tension on the staple line, CO_2 insufflation pressure was set to 5–8 cm H_2O at a flow of 8–10 L/min. In the reverse Trendelenburg position of an operating bed, a 30° endoscope with a diameter of 5 mm and a 5-mm lung grasper were used to inspect the whole lung to locate any blebs or bullae. For stapling and lung manipulation, 0-0 vicryl was passed through an intercostal space two spaces above the 15 mm port to perform anchoring sutures at the proximal point of the blebs or bullae. Lung mobilization was achieved using an

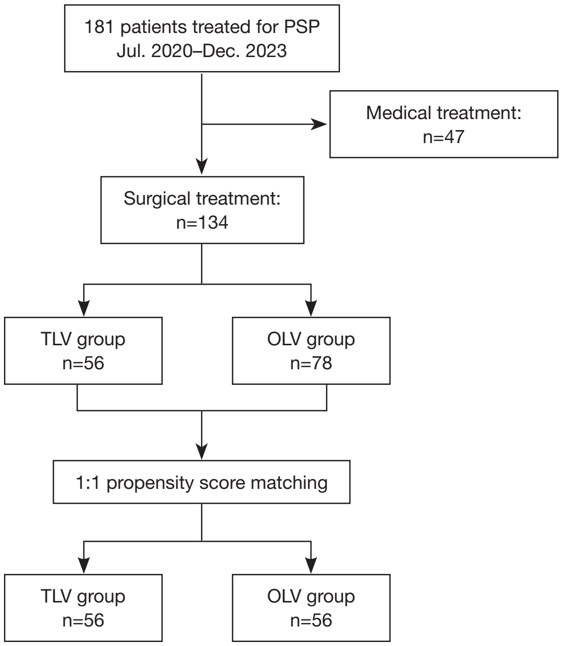

Figure 2 Summary of 181 patients with PSP. PSP, primary spontaneous pneumothorax; TLV, two-lung ventilation; OLV, one-lung ventilation.

anchoring suture while performing bullectomy with staples (*Figure 1C,1D*). During TLV surgery, ventilation was maintained with partial lung deflation and low tidal volume to minimize the risk of lung parenchyma laceration during stapling. In cases where lung manipulation was challenging, an additional 5-mm instrument port was installed. After excising the lung bullae with a staple, an air leak test was performed under ONEPORT uncapping. The stapled line was covered with Neoveil (Gunze Limited, Ayabe, Japan) and fibrin glue. No intraoperative pleural procedures were performed, and the operation was concluded after placing a 20-Fr chest tube.

In the OLV group, the non-ventilated lung was fully collapsed, and the ventilated lung operated at a similar tidal volume as in the TLV group. Although peak airway pressure was not directly measured in the OLV group, it is expected to be slightly higher than in the TLV group due to the increased ventilation demand on a single lung. A 10-mm incision was typically made along the mid-axillary line between the 6^{th} or 7^{th} rib for thoracoscope insertion. A second 5-mm incision was made along the anterior axillary line between the 5^{th} or 6^{th} rib for a similarly sized grasper incision. If necessary, an additional small incision was made. The specific locations of these incisions may vary depending on the thoracic condition being addressed. A thorough inspection of the chest cavity was performed using a thoracoscope to locate blebs or bullae. After excising the lung bullae with a staple, an air leak test was performed, followed by covering with neo-veil and fibrin glue. Before concluding the surgery, the lung was fully inflated, and a 20-Fr chest drain was placed to remove air and fluid from the chest cavity.

Statistical analysis

We used the R version 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria) to perform a propensity score 1:1 matching method to reduce confounding variables and selection bias. Descriptive statistics are presented as mean ± standard deviation. Continuous data were compared using the Student's *t*-test, while categorical data were assessed using the chi-square test. The survival analysis involved the log-rank (Mantel-Cox) test to contrast the recurrence-free survival curves across different groups. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 29.0 (IBM Corp, Armonk, NY, USA).

Results

Overall, 181 patients received PSP treatment (*Figure 2*). Of these, 47 patients did not undergo surgical intervention, of whom 15 whose chest CT scans revealed no bullae or blebs and had minimal pneumothorax volume were managed conservatively with observation and oxygen therapy. The remaining 32 patients underwent closed thoracic drainage. The remaining 134 patients successfully underwent thoracoscopic bullectomy without any cases necessitating conversion to open thoracotomy or switching from TLV to OLV. *Table 1* summarizes the demographic and baseline clinical characteristics of patients in the two groups before and after propensity score matching. After propensity score matching, the difference in age was successfully minimized (P=0.30), and all baseline characteristics, including age, became balanced between the two groups.

To reduce and control selection bias between groups, we used R for 1:1 propensity score matching, aiming to make the groups similar across various baseline covariates and minimize potential outcome differences caused by covariates. Finally, the data from 56 patients in each group were extracted. No intraoperative adverse events related to the conversion from single-port to two or three-port VATS or CO_2-related intraoperative adverse events occurred in

Table 2 Intraoperative data for two groups

Variables	Unadjusted analysis			Propensity score-matched analysis		
	TLV (n=56)	OLV (n=78)	P value	TLV (n=56)	OLV (n=56)	P value
Induction time of anesthesia (min)	13.45±5.25	16.26±6.46	0.008	13.45±5.25	15.86±6.86	0.01
Total anesthesia time (min)	63.18±14.45	74.49±16.3	<0.001	63.18±14.45	71.82±15.9	0.003
Operation time (min)	38.63±14.07	45.83±16.78	0.009	38.63±14.07	41.50±15.31	0.17
Anesthesia recovery time (min)	10.70±3.10	10.27±3.18	0.44	10.70±3.1	10.73±3.39	0.48
SBP (mmHg)	105.46±10.43	116±13.4	<0.001	105.46±10.43	116.09±12.7	<0.001
DBP (mmHg)	61.38±11.94	72.32±14.87	<0.001	61.38±11.94	69.95±13.11	<0.001
$ETCO_2$ (mmHg)	41.7±4.19	38.06±3.16	<0.001	41.7±4.19	37.84±3.35	<0.001
Adhesion			0.71			0.08
Yes	13 (23.2)	16 (20.5)		13 (23.2)	6 (10.7)	
No	43 (76.8)	62 (79.5)		43 (76.8)	50 (89.3)	
Wedge count (n)	2.07±1.23	2.19±1.21	0.78	2.07±1.23	1.91±0.92	0.21
Endostapler used (n)	3.29±1.86	3.45±1.69	0.61	3.29±1.86	3.16±1.41	0.35
Specimen weight (g)	3.21±2.5 (n=50)	4.78±4.79 (n=69)	0.03	3.21±2.5 (n=50)	4.8±5.34 (n=50)	0.03

Data are presented as mean ± SD or N (%). Six patients were excluded because their weight could not be measured. DBP, diastolic blood pressure; $ETCO_2$, end-tidal carbon dioxide; OLV, one-lung ventilation; SBP, systolic blood pressure; SD, standard deviation; TLV, two-lung ventilation.

any group. No surgical deaths occurred.

This study included 102 male and 10 female patients. Eight (7.1%) patients had a history of smoking, and 23 (20.5%) had previously undergone surgery for pneumothorax. The most common indications for PSP were visible bullae or blebs on chest CT or recurrent pneumothorax. Fifty-four (48.2%) patients had left lung involvement, 56 (50%) had right lung involvement, and two (1.8%) had bilateral involvement and underwent unilateral surgery (*Table 1*).

The TLV group had shorter mean anesthesia induction (TLV: 13.45±5.25 *vs.* OLV: 15.86±6.86 min, P=0.01) and total anesthesia times (TLV: 63.18±14.45 *vs.* OLV: 71.82±15.9 min, P=0.003) than the OLV group. No significant differences were observed between the two groups regarding surgery (P=0.17) and anesthesia recovery times (P=0.48). However, mean end-tidal carbon dioxide ($ETCO_2$) levels showed significant variation between the two groups (TLV: 41.7±4.19 *vs.* OLV: 37.84±3.35, P<0.001). No statistically significant differences were observed in the mean number of wedge resections (P=0.21), mean usage of endostaplers (P=0.35), the presence of adhesions (P=0.08) between the two groups. A statistically significant difference was found in the mean weight of the wedge resection specimens between the two groups (TLV: 3.21±2.5 *vs.* OLV: 4.8±5.34 g, n=50, P=0.03). Six patients were excluded owing to missing data on the specimen weight. Although significant differences were observed in systolic blood pressure (SBP) and diastolic blood pressure (DBP) (P<0.001 and P<0.001, respectively), no adverse events related to these changes were occurred. In the TLV and OLV groups, *Table 2* displays the intraoperative outcomes of the two groups.

The study showed that the TLV group had significantly shorter mean times for chest tube removal (TLV: 1.41±1.22 *vs.* OLV: 1.84±1.28 days, P=0.04) and postoperative hospital stays (TLV: 2.36±0.88 *vs.* OLV: 2.88±1.32 days, P=0.01) than the OLV group. No postoperative complications, including infections, bleeding, or pleural effusion were observed.

In this study, nine (8%) patients underwent bedside pleurodesis, with no statistically significant difference found between the groups (P=0.73), and chest tubes were successfully removed in all cases.

During the follow-up period, the median duration was 16 months (range, 1–40 months), the recurrence rates were as follows: *Table 3* shows that, in the TLV group, there

Table 3 Postoperative data for two groups

Variables	Unadjusted analysis			Propensity score-matched analysis		
	TLV (n=56)	OLV (n=78)	P value	TLV (n=56)	OLV (n=56)	P value
Chest drainage (days)	1.41±1.22	2.04±1.36	0.006	1.41±1.22	1.84±1.28	0.04
Hospital stay (days)	2.36±0.88	3.27±1.97	0.007	2.36±0.88	2.88±1.32	0.01
Recurrences			0.38			0.16
Ipsilateral	3 (5.4)	7 (9.0)	0.65	3 (5.4)	7 (12.5)	0.32
Contralateral	4 (7.1)	10 (12.8)	0.44	4 (7.1)	8 (14.3)	0.36
No	49 (87.5)	61 (78.2)		49 (87.5)	41 (73.2)	
Pleurodesis			0.21			0.73
Yes	4 (7.1)	11 (14.1)		4 (7.1)	5 (8.9)	
No	52 (92.9)	67 (85.9)		52 (92.9)	51 (91.1)	

Data are presented as mean ± SD or N (%). OLV, one-lung ventilation; SD, standard deviation; TLV, two-lung ventilation.

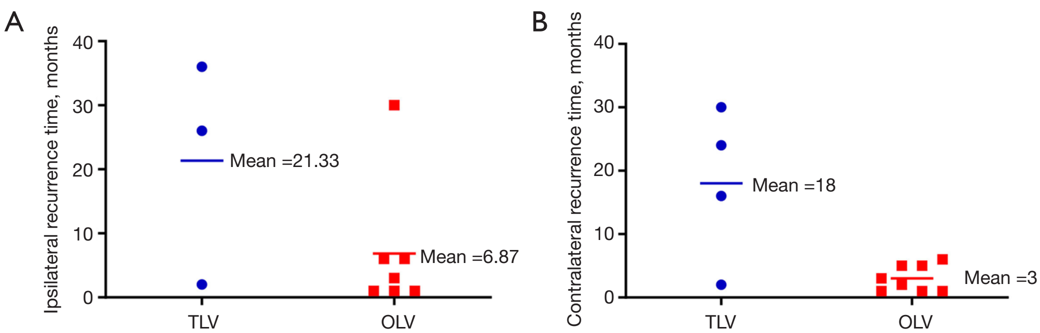

Figure 3 The number of cases and timing of ipsilateral (A) and contralateral (B) recurrences between the two groups. OLV, one-lung ventilation; TLV, two-lung ventilation.

were three (5.4%) and four (7.1%) cases of ipsilateral and contralateral recurrence, respectively. In the OLV group, ipsilateral and contralateral recurrence was observed in seven (12.5%) and eight (14.3%) patients, respectively. No statistically significant difference was found in recurrence rates between the two groups (P=0.16). *Figure 3* shows that the mean time to the ipsilateral (6.87 *vs.* 21.33 months) and contralateral (3 *vs.* 18 months) recurrences were shorter in the OLV group than in the TLV group. In cases of contralateral recurrence, the OLV group showed quicker recurrence, with all patients experiencing recurrence within 10 months and a mean time to recurrence of 3 months. *Figure 4* presents the Kaplan-Meier curves for freedom from recurrence, which showed no significant differences between groups for either ipsilateral (P=0.12) or contralateral (P=0.15) recurrence.

Discussion

Pneumothorax frequently recurs, and surgical treatment is the primary method for reducing its recurrence. With the development of thoracoscopic techniques, the treatment has gradually become minimally invasive. Recently, lung surgeries using a single port (15–20 mm) have been reported (8,9). This study aimed to analyze the results of applying thoracic surgery with TLV, which is already used for mediastinal or esophageal surgeries, to lung surgery.

The study comprised 56 and 78 patients in the TLV and OLV groups, respectively. A significant difference in demographic data, specifically age, was found between the two groups. Consequently, propensity score matching was employed to match the patient groups in a 1:1 ratio. After matching, demographic differences were eliminated, and

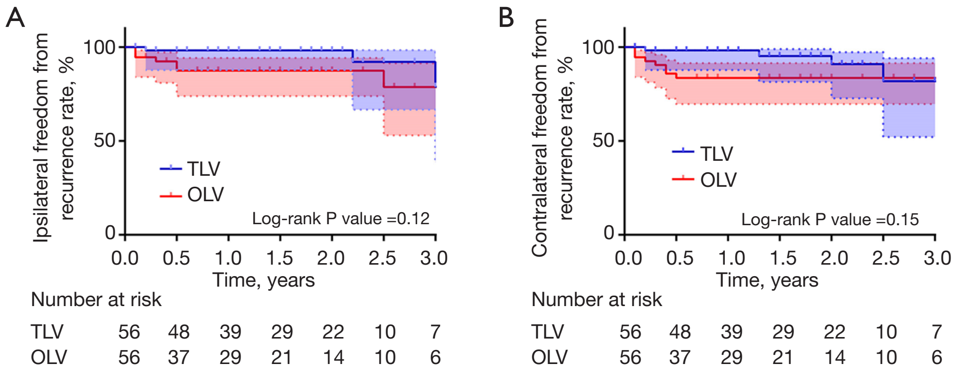

Figure 4 Kaplan-Meier curves for ipsilateral (A) and contralateral (B) freedom from recurrence between the two groups. OLV, one-lung ventilation; TLV, two-lung ventilation.

analysis was conducted on the matched groups.

The TLV group had shorter induction and total anesthesia times, suggesting that single-lumen endotracheal tube is easier and more convenient to use than double-lumen tube, as they eliminate the need for bronchoscopy based position-verification. Additionally, there is no possibility of OLV failure due to endotracheal tube migration after positioning the patient in the lateral position for surgery, thereby preventing delays in surgical time due to anesthesia. However, during anesthesia for TLV, CO_2 is required to ensure visibility in the surgical field. Although this study did not conduct a quantitative analysis of visibility, some research (10,11) has reported that adequate visibility is achieved in pneumothorax surgeries using CO_2 under TLV. In the cases included in this study, there were no instances where it was necessary to convert to OLV owing to the difficulty in maintaining the surgical field, nor did the limitation in visibility result in longer surgical times. This study used CO_2 insufflation (pressure, 5–8 cmH_2O; flow, 8–10 L/min) and a low tidal volume (6 mL/kg) to maintain visibility. With an average airway pressure of 12 cmH_2O and a CO_2 insufflation pressure of 5–8 cmH_2O, the actual transpleural pressure is calculated to be 4–7 cmH_2O. Consequently, CO_2 insufflation does not significantly increase the tension on the staple line caused by lung inflation during ventilation.

In our study, significant differences were observed in SBP and DBP ($P<0.001$ and $P<0.001$, respectively) between two groups. It is difficult to determine whether the observed hypotension during TLV with CO_2 insufflation was due to decreased venous return caused by positive pleural pressure or the direct absorption of CO_2. However, the blood pressure range in the TLV group did not reach a dangerous level, and no patients experienced abrupt blood pressure drops or blood pressure-related adverse events. $ETCO_2$ levels in the TLV group were significantly higher than that in the OLV group; however, the mean value of $ETCO_2$ was 41.7±4.19 mmHg, which was sufficiently tolerable. Moreover, the surgeries were relatively simple lung procedures, therefore, no complications, such as CO_2 embolism, were found.

The surgical field in TLV with CO_2 pneumothorax surgery has been evaluated in previous study (12). In our study, we focused on postoperative results. In the TLV group, both the duration of chest drainage and hospital stay were significantly shorter, and complications, such as prolonged air leaks, were not higher than those in the OLV group. Additionally, no significant differences were found in the number of wedge resections performed, or endostaplers used intraoperatively, indicating that limitations in the surgical field did not result in additional resections or the use of additional instruments.

Wedge resection is a type of non-anatomical resection; if the resected volume increases, lung distortion can occur after lung inflation and significant tension can be applied to the stapled line, potentially becoming a risk factor for recurrence postoperatively (13). However, when stapling for the wedge resection of a deflated lung, unexpectedly large amounts of normal parenchyma can be resected, making it difficult to predict the shape of the lungs after inflation. In contrast, performing wedge resection on an inflated lung can include less normal lung parenchyma because the alveolar spaces are open, and it is easier to anticipate the shape of the lung after full inflation. In this study, we analyzed the size of the resected lungs. Even when cut to the same size, the resected lung volume differed between the inflated and deflated lungs. Our rationale for proposing weight measurement as the basis for assessing limited resection is that, in the TLV group, specimens were resected in an inflated state and immediately fixed in formalin, allowing for the measurement of relatively larger volumes compared to the OLV group. For the same reason, H&E-stained slides from the TLV group often exhibited a larger area of normal lung tissue. We believe that measuring the gross specimen weight is a reasonable alternative method for evaluating the amount of resected tissue. Therefore, we analyzed the weight of the resected lung and found that the weight of the resected lung in the TLV group was significantly smaller, indicating that performing wedge resection on an inflated lung can include less normal parenchyma, potentially reducing lung distortion and tension at the staple line of the resection site, which could have a relatively positive impact on long-term recurrence.

Moreover, we compared the pneumothorax recurrence rates between the ipsilateral and contralateral groups. Ipsilateral recurrence occurred in three (5.4%) and seven (12.5%) patients in the TLV and OLV groups, respectively, showing no significant between-group difference. This indicated that there was no significant difference in the precision of lesion resection between surgeries performed under TLV and OLV. Similarly, no significant difference was found in contralateral recurrence between the two groups. There have been reports on factors affecting the occurrence of contralateral pneumothorax in patients undergoing pneumothorax surgery, indicating that the number or size of bullae found on high-resolution computed tomography (HRCT) scans is a major cause of pneumothorax (14,15). However, these studies analyzed the risk factors in the entire patient group undergoing pneumothorax surgery and did not compare TLV. The OLV groups showed differences in airway pressure and did not consider the timing of contralateral pneumothorax occurrence. Although no difference was found between the two groups in the occurrence of postoperative contralateral pneumothorax in our study, when considering the timing, in the TLV group, one case of contralateral pneumothorax occurred within 8 months postoperatively, whereas in the OLV group, all cases occurred within 6 months postoperatively, and there was no difference in the number of bullae or blebs detected on the contralateral lung in HRCT scans between both groups. Therefore, various factors should be considered when interpreting these results. We believe that the high airway pressure applied to the contralateral lung intraoperatively under OLV may be one of these factors, although there is a lack of evidence regarding the mechanisms underlying the quicker timing of contralateral pneumothorax recurrence.

This study had some limitations. First, this was a retrospective study with a small sample size. Despite employing propensity score matching, there may have been incomplete matching between the comparison groups due to patient selection, as the TLV group tended to involve patients who appeared to have simpler cases. Second, the pathology department's approach to slide preparation introduced another limitation. Slides were prepared from selected areas of the gross specimen where bullae were confirmed or suspected, rather than representing the entire specimen. Pathological evaluations at our center primarily focused on the presence or absence of bullae, without providing quantitative data on their size or number. To address this limitation, we conducted an analysis using preoperative CT scans to compare the bullae characteristics. However, the accuracy of this approach may be limited by the retrospective nature of the study and variability in CT scan interpretations. Third, the follow-up duration for recurrence monitoring was relatively short. Finally, only one surgeon among the surgeons who performed PSP surgery used TLV and CO_2 insufflation. The postoperative management strategy between the surgeons may be different, and it cannot be ruled out that the non-identical placement of the surgeon between the two groups may affect the postoperative results. Despite these limitations, the aim of our study was not to demonstrate the superiority of TLV over OLV but rather to show that TLV, when performed in well-selected patients, can achieve outcomes comparable to those of OLV. Future studies should focus on collecting more comprehensive data on airway pressures, bullae characteristics, and pathological findings, as well as evaluating outcomes in a wider range of surgical complexities.

Conclusions

In appropriately selected patients, the TLV surgical approach with CO_2 insufflation appears to be a viable option that does not increase the risk of recurrence compared to the OLV approach, simultaneously offering the benefit of a shorter anesthesia duration. Therefore, this method may be suitable for patients with PSP.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1749/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Chungnam National University Sejong Hospital (CNUSH IRB No. 2022-03-016-003) and individual consent for this retrospective analysis was waived.

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