Original Article

Comparison of early postoperative pulmonary complications between two-lung ventilation with artificial pneumothorax and one-lung ventilation with bronchial blockade in patients undergoing minimally invasive esophagectomy: a retrospective propensity score-matched cohort study

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Background: Two-lung ventilation (TLV) with artificial carbon dioxide (CO_2) pneumothorax is used during the thoracoscopic phase of minimally invasive esophagectomy (MIE). However, the impact of TLV with artificial pneumothorax on postoperative pulmonary complications (PPCs) after MIE is unclear. This study aimed to compare the incidence of early PPCs between TLV with CO_2 pneumothorax and one-lung ventilation (OLV) with bronchial blockade in patients undergoing MIE.

Methods: Five hundred ninety-three patients with esophageal cancer who underwent elective MIE with two-field lymph node dissection were analyzed. Patients in the TLV group were intubated using a single-lumen endotracheal tube and underwent surgery using TLV with artificial CO_2 pneumothorax. Patients in the OLV group underwent surgery using OLV with a bronchial blocker. Patient characteristics and intraoperative and PPC data were collected and analyzed. Propensity score matching (PSM) was performed to reduce confounding bias.

Results: The TLV and OLV group comprised 513 and 80 patients, respectively. PSM matched 197 TLV group and 73 OLV group patients. Incidence of pneumonia within the first 3 days of surgery was higher in the TLV group (11.7% *vs.* 4.1%) but the difference was not significant (P=0.06). The incidence of infiltrates on chest radiography was 36.0% in the TLV group and 28.8% in the OLV group (P=0.26). Incidence of other major PPCs requiring treatment and major non-pulmonary postoperative complications did not significantly differ between the groups. Length of hospital stay was significantly longer in the TLV group (13.0 *vs.* 11.0 days; P=0.03).

Conclusions: Compared with OLV with bronchial blockade, TLV with CO_2 pneumothorax did not reduce the incidence of early PPCs after MIE.

Keywords: Esophageal cancer; minimally invasive esophagectomy (MIE); one-lung ventilation (OLV); two-lung ventilation (TLV); postoperative pulmonary complications (PPCs)

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Introduction

Esophageal cancer is one of the most common cancers in China and the sixth most common cause of cancer-related death worldwide (1). Esophagectomy is the definitive treatment. Esophagectomy is associated with a high incidence of postoperative complications and high rates of procedure-related morbidity and mortality (2). Pulmonary complications are most frequent. Minimally invasive esophagectomy (MIE) is superior to open esophagectomy in terms of recovery time, incidence of perioperative complications, and short-term outcomes (3-5). Nevertheless, postoperative pulmonary complications (PPCs) remain a primary concern in patients undergoing MIE.

During most thoracic surgeries, one-lung ventilation (OLV) is typically used. With patients undergoing MIE in the prone position, two-lung ventilation (TLV) with artificial carbon dioxide (CO_2) pneumothorax is used during the thoracoscopic phase of the operation (6,7). TLV is associated with higher oxygenation during the thoracoscopic phase, shorter operating time, less blood loss, and shorter hospital stay than OLV (8-10). Additionally, because a single-lumen endotracheal tube (SLET) is employed with TLV, TLV is expected to be associated with fewer airway injuries, shorter intubation time, and reduced cost (8,11). Better lung protection is also expected with MIE performed in the prone position since OLV, a known risk factor for lung damage, can be avoided (12). However, research on the impact of TLV with artificial CO_2 pneumothorax on PPCs after MIE is limited and inconclusive (9,13).

OLV during MIE can be performed using either a double-lumen endotracheal tube (DLET) or a bronchial blocker (12,14,15). Use of a DLET has been associated with higher risk of airway injury and PPCs; moreover, it might increase the difficulty of lymph node dissection along the left recurrent laryngeal nerve (RLN) (8,11,16-18). Use of a bronchial blocker reduces the risk of those drawbacks (17-21). Accordingly, some institutions have begun to routinely use bronchial blockade for OLV during MIE (22). In previous studies comparing OLV and TLV for esophagectomy, however, nearly all OLV patients were intubated using a DLET (13,16,23). Only one previous study compared TLV and OLV with bronchial blockade in patients undergoing MIE, and pulmonary complications were not their main focus (9). Therefore, this study aimed to compare early PPCs between TLV with CO_2 pneumothorax and OLV with a bronchial blocker in patients who underwent MIE. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1667/rc).

Highlight box

Key findings

- Compared with one-lung ventilation (OLV) with bronchial blockade, two-lung ventilation (TLV) with CO_2 pneumothorax did not reduce the incidence of early postoperative pulmonary complications (PPCs) after minimally invasive esophagectomy (MIE).

What is known and what is new?

- TLV with artificial CO_2 pneumothorax is used in patients undergoing MIE in the prone position. TLV is associated with shorter operating time, less blood loss, and shorter hospital stay than OLV. Research on the impact of TLV with artificial CO_2 pneumothorax on PPCs after MIE is limited and inconclusive.
- This study aimed to compare early PPCs between TLV with CO_2 pneumothorax and OLV in patients who underwent MIE. In previous studies comparing TLV and OLV for esophagectomy, nearly all OLV patients were intubated using a DLET. In the present study, bronchial blocker was used in the OLV group, and we focused on PPCs.

What is the implication, and what should change now?

- Additional research is warranted to better comprehend the impact of TLV on PPCs after MIE, particularly large-scale randomized controlled trials.

Methods

Study population

This study was performed at the Peking University Cancer Hospital and registered in the Chinese Clinical Trial Registry (No. ChiCTR2300071571). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Ethics committee approval was obtained from the Institutional Review Board at Peking University

Cancer Hospital (No. 2023YJZ36). The requirement for written informed consent was waived because of the study's retrospective design. Patients diagnosed with esophageal cancer and scheduled for elective MIE with two-field lymph node dissection via thoracoscopy and laparoscopy between August 2018 and February 2023 were reviewed. Those with cervical esophageal carcinoma were excluded from the study because of their distinct oncological characteristics and therapeutic regimens. We also excluded patients with the following characteristics: recurrent esophageal carcinoma, American Society of Anesthesiologists class IV or higher, DLET intubation, coronavirus disease 2019 diagnosis within 1 month prior to surgery or during hospitalization, change in operation method during surgery (e.g., conversion to open procedure or unplanned additional excision of other organs), and incomplete data. Each operation was performed by one of three experienced thoracic surgeons. Postoperative care was provided in the general ward or intensive care unit (ICU) as appropriate. Patient characteristics and surgical and postoperative data were retrieved from the electronic medical records. Chronic obstructive pulmonary disease, asthma, bronchiectasis, pulmonary bulla, lung infection within 1 month, and pulmonary tuberculosis were considered preoperative pulmonary comorbidities.

Anesthesia and surgical procedures

General anesthesia was managed by the same group of thoracic anesthesiologists. Standard monitoring was employed using electrocardiography, pulse oximetry, arterial pressure transduction, and a bispectral index monitor. Arterial blood gases were routinely measured before induction and after extubation; intraoperative measurements were determined by the attending anesthesiologist. Intravenous sufentanil/oxycodone, propofol/etomidate, and cisatracurium/rocuronium were used for induction. Patients in the TLV group were intubated using a SLET. The thoracic procedure was completed under TLV with artificial pneumothorax (CO_2 was insufflated to a pressure of 8 to 10 mmHg to facilitate partial collapse of the right lung). Patients in the OLV group were first intubated using a SLET; then a bronchial blocker was placed in the right bronchus under fiberoptic guidance. Use of a bronchial blocker is at the attending anesthesiologists' discretion. Tidal volume during the thoracic phase of surgery was set at 4 to 6 mL/kg (calculated based on predicted body weight) in both groups; it was set at 6 mL/kg throughout the remainder of the procedure. Respiratory rate was set at 14 to 20 breaths per minute and modified to maintain an end-tidal CO_2 of 35 to 45 mmHg. General anesthesia was maintained using inhaled sevoflurane and continuous infusions of propofol and remifentanil; muscle relaxation was achieved using intermittent cisatracurium/rocuronium. Postoperative analgesia was administered using patient-controlled intravenous analgesia.

The surgical procedure comprised a right transthoracic subtotal esophagectomy, mediastinal and abdominal lymph node dissection, and anastomosis in the neck. The thoracic procedures were performed in the left lateral-prone position using a thoracoscope (four trocars were placed in the fourth and seventh intercostal spaces in the mid-axillary line and the sixth and ninth intercostal spaces in the subscapular line). The abdominal procedures were carried out laparoscopically. Gastric tube reconstruction was performed with a cervical anastomosis. After surgery, patients were transported to the post-anesthesia care unit. Neostigmine was routinely used for the reversal of neuromuscular blockade, and the recovery of neuromuscular blockade was monitored before extubation. Patients were then transferred to the ward after recovery from anesthesia. Patients who required continued mechanical ventilation or had significant comorbidities were transferred to the ICU.

Measurements

PPC data were gathered while the patient was in the hospital. Given the assumption that PPCs associated with intraoperative ventilation would appear early, the primary outcome was incidence of pneumonia in the first 3 days after surgery (24). Pneumonia was defined as a new or progressive radiological infiltrate and at least two of the following: body temperature >38 ℃, leukocytosis or leukopenia, and purulent secretions (25). The secondary outcome was incidence of other major PPCs in the first 3 days, including pleural effusion requiring drainage, pneumothorax requiring treatment, atelectasis mucous plugging requiring bronchoscopy, respiratory failure requiring invasive or noninvasive ventilation, acute respiratory distress syndrome, acute aspiration, and tracheobronchial injury (adapted from a proposal by the Esophagectomy Complications Consensus Group) (26). The number of re-intubations and tracheotomies in the first 3 days, occurrence of major non-pulmonary postoperative complications including RLN injury, anastomotic leak, wound infection, and chylothorax, and length of hospital and ICU stays were also recorded.

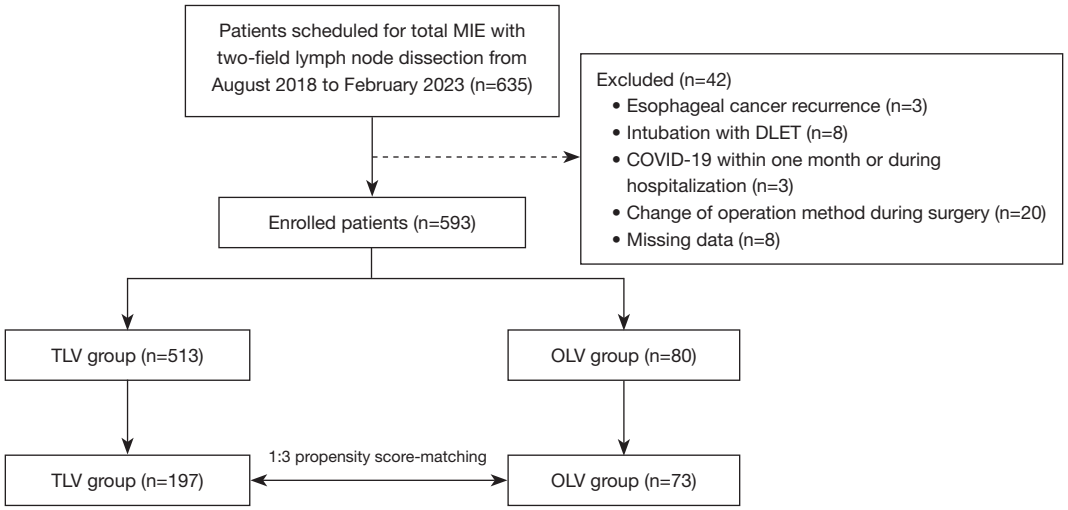

Figure 1 Study flow chart. MIE, minimally invasive esophagectomy; DLET, double-lumen endotracheal tube; COVID-19, coronavirus disease 2019; TLV, two-lung ventilation; OLV, one-lung ventilation.

Statistical analysis

Statistical analyses were performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). Categorical data were presented as numbers with percentage and were compared using the Pearson chi-square test or Fisher's exact test. Continuous data with a normal distribution were presented as means with standard deviation and were compared using the independent-samples *t*-test. Data with a non-normal distribution were presented as medians with interquartile range (IQR) and were compared using the Mann-Whitney *U* test. Propensity score matching (PSM) was performed to reduce confounding bias by balancing group differences in patient characteristics and PPC risk factors. Baseline characteristics with P<0.1 in univariate comparisons were included for propensity score calculations, as were known PPC risk factors [age, body mass index (BMI), pulmonary comorbidities, smoking status, intraoperative fluid intake, operative blood loss, and duration of surgery] (27-33). Propensity scores were created for each patient using a multivariate logistic regression model. Patients were matched at a 1:3 ratio between the OLV group and the TLV group using the nearest neighbor method without replacement and a caliper width of 0.2 of the standard deviation of the logit of the estimated propensity score. A standardized difference in means <0.1 between the groups was considered to indicate an adequate balance of matching. P<0.05 was considered significant.

Results

Among the 635 eligible patients, 593 met criteria and were included for analysis (513 in the TLV group and 80 in the OLV group). The PSM algorithm selected 197 individuals from the TLV group and 73 from the OLV group for analysis (*Figure 1*). *Table 1* shows patient characteristics in the groups before and after PSM. Patient characteristics did not significantly differ between the groups. In terms of intraoperative data, the groups significantly differed in terms of intraoperative fluid intake, operative blood loss volume, surgery duration, and anesthesia duration before PSM. After matching, intraoperative data were comparable between the groups except for anesthesia duration (P<0.01), which was defined as the time between entering and leaving the operating room (*Table 2*). The standardized disparities before and after matching significantly decreased, which suggested that the matched groups were homogenous.

Incidence of pneumonia within the first 3 days of surgery was higher in the TLV group (11.7% *vs.* 4.1%) but the difference was not significant (P=0.06; *Figure 2*). The incidence of radiographic infiltrate was 36.0% in the TLV group and 28.8% in the OLV group (P=0.26). Incidence of other major PPCs and major non-pulmonary postoperative complications did not differ significantly between the groups (*Tables 3*,*4*). Incidence of prolonged ICU stay (more than 2 days), was 5.6% in the TLV group and 2.7% in the OLV group (P=0.52). Length of hospital stay was

Table 1 Patient characteristics before and after propensity score matching

Characteristics	Before matching (n=593)			After matching (n=270)		
	TLV group (n=513)	OLV group (n=80)	P value	TLV group (n=197)	OLV group (n=73)	P value
Age, years	64.0 (58.0–68.0)	65.5 (60.0–68.8)	0.12	64.0 (59.0–68.0)	65.0 (59.0–68.0)	0.61
Sex			0.60			0.91
Male	424 (82.7)	68 (85.0)		169 (85.8)	63 (86.3)	
Female	89 (17.3)	12 (15.0)		28 (14.2)	10 (13.7)	
Height, cm	166.0 (162.0–171.0)	167.8 (163.3–172.8)	0.13	166.0 (162.0–171.5)	167.5 (163.5–172.5)	0.29
Weight, kg	65.0 (57.5–71.0)	67.0 (59.3–73.8)	0.13	64.0 (57.0–72.0)	67.0 (58.0–73.0)	0.33
BMI, kg/m^2	23.5 (21.5–25.7)	23.7 (21.4–26.3)	0.67	23.5 (21.1–25.5)	23.1 (21.3–26.3)	0.82
Pulmonary comorbidities	58 (11.3)	8 (10.0)	0.73	16 (8.1)	7 (9.6)	0.70
Diabetes mellitus	65 (12.7)	9 (11.3)	0.72	32 (16.2)	7 (9.6)	0.17
Anemia	116 (22.6)	13 (16.3)	0.20	47 (23.9)	12 (16.4)	0.19
Current smoker	28 (5.5)	3 (3.8)	0.71	7 (3.6)	3 (4.1)	>0.99
Creatine, μmol/L	66.0 (58.0–75.0)	67.5 (60.0–77.0)	0.31	67.0 (58.0–77.0)	68.0 (60.0–77.0)	0.71
Albumin, g/L	44.2 (41.7–46.1)	44.1 (41.8–45.9)	0.99	44.2 (41.4–46.2)	44.2 (41.9–46.0)	0.70
ASA classification			0.65			0.74
I	31 (6.0)	3 (3.8)		13 (6.6)	3 (4.1)	
II	445 (86.7)	73 (91.3)		170 (86.3)	66 (90.4)	
III	37 (7.2)	4 (5.0)		14 (7.1)	4 (5.5)	
Pathology			>0.99			0.63
SCC	485 (94.5)	77 (96.3)		182 (92.4)	70 (95.9)	
Adenocarcinoma	23 (4.5)	3 (3.8)		12 (6.1)	3 (4.1)	
Other malignancy	5 (1.0)	0 (0.0)		3 (1.5)	0 (0.0)	
Tumor location			0.83			0.47
Upper thoracic	65 (12.7)	12 (15.0)		28 (14.2)	11 (15.1)	
Middle thoracic	237 (46.2)	35 (43.8)		97 (49.2)	30 (41.1)	
Lower thoracic[†]	211 (41.1)	33 (41.3)		72 (36.5)	32 (43.8)	

Data shown are medians (interquartile range) or numbers (%). [†], included gastroesophageal junction. TLV, two-lung ventilation; OLV, one-lung ventilation; BMI, body mass index; ASA, American Society of Anesthesiologists; SCC, squamous cell carcinoma.

significantly longer in the TLV group [13.0 days (IQR, 10.0–15.0 days) *vs.* 11.0 days (IQR, 9.0–15.0 days); P=0.03].

Discussion

The main finding of this study was that TLV with CO_2 pneumothorax did not reduce the incidence of early PPCs after MIE compared with OLV with bronchial blockade. Among the 270 matched patients, 26 patients overall developed pneumonia within the first 3 days of surgery (9.6%), which is comparable to the rate reported in previous studies (34-36). Although the incidence of pneumonia in the TLV and OLV groups was 11.7% and 4.1%, respectively, the difference was not significant. Additionally, the incidence of other PPCs requiring treatment did not significantly differ between the groups. These results are in line with

Table 2 Intraoperative data before and after propensity score matching

Variables	Before matching (n=593)			After matching (n=270)		
	TLV group (n=513)	OLV group (n=80)	P value	TLV group (n=197)	OLV group (n=73)	P value
Fluid intake, mL	2,250.0 (2,000.0–2,500.0)	2,350.0 (2,000.0–2,600.0)	0.04*	2,300.0 (2,000.0–2,625.0)	2,300.0 (2,000.0–2,600.0)	0.30
Blood loss, mL	100.0 (50.0–100.0)	100.0 (62.5–100.0)	0.04*	100.0 (50.0–100.0)	100.0 (100.0–100.0)	0.24
Urinary output, mL	300.0 (200.0–500.0)	400.0 (200.0–600.0)	0.10	350.0 (200.0–500.0)	400.0 (275.0–600.0)	0.15
Duration, min						
Surgery	201.0 (185.0–227.0)	229.5 (195.0–259.5)	<0.01*	225.4±44.8	233.0±45.9	0.22
Anesthesia	250.0 (232.0–280.0)	300.0 (250.0–327.0)	<0.01*	278.1±50.1	297.0±50.2	<0.01*

Data shown are medians (interquartile range) or means ± standard deviation. *, significant. TLV, two-lung ventilation; OLV, one-lung ventilation.

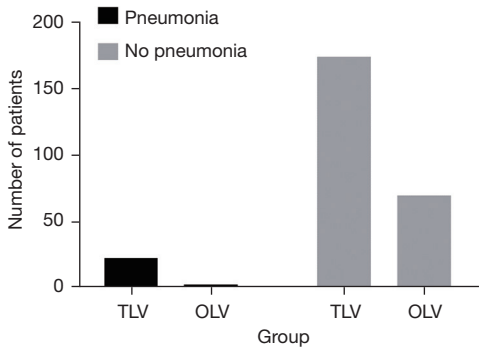

Figure 2 Pneumonia within the first 3 days of surgery. TLV, two-lung ventilation; OLV, one-lung ventilation.

several earlier studies, which also found no significant distinctions in terms of PPCs between individuals who underwent TLV or OLV for esophagectomy (8,9,23,37). Contrary to our results, in a recent meta-analysis, TLV was associated with decreased incidence of PPCs (13); however, the TLV group underwent thoracoscopy, whereas the OLV group underwent either thoracoscopy or thoracotomy, which might have contributed to the difference. In their subgroup analysis of patients who only underwent thoracoscopy, incidence of PPCs did not differ. Compared with DLET intubation, bronchial blocker use in thoracic surgery patients is associated with lower risks of respiratory

Table 3 Incidence of pulmonary complications within the first 3 days of surgery

PPCs	TLV group (n=197)	OLV group (n=73)	χ^2	P value
Pneumonia	23 (11.7)	3 (4.1)	3.503	0.06
Pleural effusion	13 (6.6)	0 (0.0)	3.723	0.05
Pneumothorax	4 (2.0)	0 (0.0)	–	0.58
Atelectasis	5 (2.5)	0 (0.0)	–	0.33
Respiratory failure	7 (3.6)	2 (2.7)	0.000	>0.99
ARDS	1 (0.5)	0 (0.0)	–	>0.99
Acute aspiration	0 (0.0)	1 (1.4)	–	0.27
Tracheobronchial injury	0 (0.0)	0 (0.0)	–	–
Re-intubation	3 (1.5)	1 (1.4)	–	>0.99
Tracheotomy	3 (1.5)	0 (0.0)	–	0.57

Data shown are numbers (%). PPCs, postoperative pulmonary complications; TLV, two-lung ventilation; OLV, one-lung ventilation; ARDS, acute respiratory distress syndrome.

Table 4 Incidence of major non-pulmonary postoperative complications during hospitalization

Postoperative complication	TLV group (n=197)	OLV group (n=73)	χ^2	P value
Recurrent laryngeal nerve injury	5 (2.5)	1 (1.4)	–	>0.99
Anastomotic leak	25 (12.7)	7 (9.6)	0.490	0.49
Chylothorax	1 (0.5)	1 (1.4)	–	0.47
Wound infection	3 (1.5)	2 (2.7)	–	0.62

Data shown are numbers (%). TLV, two-lung ventilation; OLV, one-lung ventilation.

infections and PPCs (18). However, in contrast to our study, most previous ones used a DLET for OLV. Only one retrospective study compared TLV and OLV with bronchial blockade for thoracoscopic esophagectomy (9); although PPCs were not its main focus, it reported no significant difference in incidence of PPCs between the different ventilation strategies.

The incidence rates of early postoperative pneumonia and pleural effusion requiring drainage in our study were higher in the TLV group, although the differences were not significant. However, the length of hospital stay was significantly longer in the TLV group (13.0 *vs.* 11.0 days), even though the two groups did not differ significantly in other major non-pulmonary complications. We speculate this may be related to the non-significant differences in PPCs between the TLV and OLV groups. Our results contrast with the theory that OLV acts as a risk factor for lung damage and may cause more lung damage because of higher lung volume and ventilation pressure in the ventilated lung and atelectasis and ischemia–reperfusion injury in the collapsed lung (12,38). We suppose that there are several reasons for the unexpected results. Although a low insufflation rate and a maximum pneumothorax pressure of 8 to 10 mmHg have been considered safe for TLV with artificial pneumothorax, a recent study has shown that intrathoracic pressure overshoot frequently occurs when TLV with pneumothorax is used for thoracoscopic surgery (39). Peak airway pressure increases during this overshoot and may result in stress injury to the pulmonary alveoli. Another retrospective study similarly showed that peak inspiratory pressure increases after artificial pneumothorax is induced (40). High airway pressure during mechanical ventilation damages endothelial cells, disrupts the pulmonary surfactant system, increases pulmonary permeability, and may raise the danger of ventilator-associated lung damage and PPCs (41,42). This could in part explain the higher incidence of infiltrates on chest radiography in the TLV group in our study (36.0% *vs.* 28.8%; P=0.26). Therefore, we speculate that pulmonary damage is related to increased airway pressure during TLV with artificial pneumothorax. The fact that tidal volume is typically set at a minimum tolerable value in the TLV group to achieve sufficient lung collapse to enable a workable surgical field is another potential explanation. At low lung volumes, repeated lung unit opening and closing may be harmful, especially if lung inflation is not uniform. Therefore, low lung volumes can cause lung damage, which has systemic, physiologic, structural, and biologic repercussions (43). Unfortunately, no studies have specifically examined these differences between TLV with artificial pneumothorax and OLV with bronchial blockade during mechanical ventilation. To better comprehend this issue, additional research is required, particularly prospective randomized controlled trials.

Researchers have demonstrated that TLV is advantageous for MIE because SLET intubation causes less airway injury than OLV. However, DLET intubation was employed in the OLV group in every pertinent previous study (11,13). Airway injury was not examined in the one study that compared perioperative outcomes between TLV and OLV with bronchial blockade (9). In our study, neither group had a patient with tracheobronchial damage, perhaps because all intubations were handled by a team of experienced thoracic anesthesiologists who were familiar with using a bronchial blocker. Studies have also shown that using a bronchial blocker causes significantly less airway injury than using a DLET (17-19). Therefore, we argue that airway injury is less of an issue in patients intubated using a bronchial blocker for OLV, especially in the hands of skilled anesthesiologists. However, we did notice a shorter anesthesia time in the TLV group, which is consistent with a prior study (11). This was not unexpected because all preparation was performed in the operating room and use of a bronchial blocker has been associated with longer

intubation and tube localization times. After anesthesia induction, bronchial blocker positioning was aided using a bronchofiberscope in the supine position and re-checked after the patient was moved to the left lateral-prone position. Obviously, more time is required for intubation preparation and fiberoptic confirmation of a bronchial blocker. In addition, prolonged anesthesia duration may also be related to a higher malposition rate of bronchial blocker (44). Because of the study's retrospective design, we could not collect data on this issue. Nevertheless, prolonged anesthesia time was not associated with a worse clinical outcome.

This study has several limitations. First, it was retrospective in design. Although we performed PSM analysis to account for confounding factors, bias still may have been present because of variations in clinical practice. Second, potentially crucial intraoperative data such as ventilator parameters (tidal volume, positive end-expiratory pressure, and peak airway pressure) were not included for analysis because of the retrospective design. These data may have an impact on PPCs. Nevertheless, the same team of thoracic anesthesiologists directed all anesthetic management, which ensured a certain level of uniformity and consistency. Third, certain technical details of the procedure (e.g., the number of the harvest lymph nodes along the RLN and details of the drainage procedure) were not collected. However, the incidence of RLN injury, which is more directly related to the occurrence of PPCs, was analyzed. Finally, even though the study included 593 patients, only 270 of them were included in the PSM analysis; this sample size may not be sufficient to detect certain trends. Large-scale randomized controlled trials are warranted.

Conclusions

Compared with OLV with bronchial blockade, TLV with CO_2 pneumothorax did not reduce the incidence of early PPCs after MIE. Further investigation is needed to understand the underlying mechanism, particularly prospective randomized controlled trials.

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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-23-1667/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1667/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1667/coif). The authors have no conflicts of interest to declare.

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 at Peking University Cancer Hospital (No. 2023YJZ36). The requirement for written informed consent was waived because of the study's retrospective design.

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