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Clinical Research

Single-Lumen Tube Intubation with CO_2 Insufflation versus Double-Lumen Tube Intubation in Video-Assisted Transthoracic Esophagectomy for Esophageal Cancer: A Retrospective Comparative Study

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Background: Video-assisted transthoracic esophagectomy (VATE) is typically performed with double-lumen tube intubation (DLTI) to facilitate 1-lung ventilation. Single-lumen tube intubation (SLTI) with CO_2 insufflation offers an alternative approach, enabling 2-lung ventilation with artificial pneumothorax, which may improve surgical exposure and reduce pulmonary complications. This study compared the efficacy and safety of SLTI with CO_2 insufflation versus DLTI in VATE.
Methods: This retrospective study included 94 male patients who underwent VATE for esophageal cancer at 108 Military Central Hospital between November 2018 and September 2023. Patients were divided into 2 groups: SLTI with CO_2 insufflation (n=44) and DLTI (n=50). The assessed outcomes included lymph node yield, operative time, postoperative complications, intensive care unit (ICU) admission, and length of hospital stay.
Results: The SLTI group had a significantly higher left recurrent laryngeal nerve lymph node yield (2.22±2.65 vs. 0.77±2.14, p=0.008) and a greater total lymph node harvest (23.91±9.22 vs. 19.00±11.75, p=0.02) than the DLTI group. Operative time was longer in the SLTI group for the thoracic phase (168.64±23.69 minutes vs. 142.12±24.17 minutes, p=0.04) and overall (311.82±43.67 minutes vs. 272.68±35.97 minutes, p=0.001). Postoperative complication rates and length of hospital stay did not differ significantly between groups, although ICU admission was more frequent with SLTI (84.1% vs. 56.0%, p=0.003).
Conclusion: SLTI with CO_2 insufflation is a safe and feasible alternative to DLTI in VATE, enabling more extensive recurrent laryngeal lymph node dissection but requiring longer operative times.

Keywords: One-lung ventilation, Video-assisted thoracic surgery, Esophagectomy, Esophageal neoplasms, Recurrent laryngeal nerve

Introduction

Esophageal cancer remains a significant global health challenge, with esophagectomy a cornerstone of treatment for localized disease [1]. Video-assisted transthoracic esophagectomy (VATE), a minimally invasive approach, reduces morbidity compared to open surgery but requires precise anesthetic management to optimize surgical access and patient safety [2,3].

Traditionally, double-lumen tube intubation (DLTI) is used to achieve 1-lung ventilation (OLV), facilitating lung collapse and surgical exposure [4]. However, DLTI is associated with several drawbacks, including airway trauma, technical difficulty in placement, and increased risk of pulmonary complications [5].

As an alternative, single-lumen tube intubation (SLTI) with carbon dioxide (CO_2) insufflation has gained interest. This technique maintains 2-lung ventilation while creating an artificial pneumothorax, providing adequate visualization with potentially fewer pulmonary complications [6]. Despite these advantages, concerns persist about whether SLTI can offer a comparable surgical field, especially in complex procedures requiring meticulous lymphadenectomy, such as esophagectomy for esophageal cancer [7-9].

Comparative data on SLTI versus DLTI in VATE remain limited, particularly regarding recurrent laryngeal nerve (RLN) lymph node dissection, a critical determinant of oncological staging and survival [6,10]. Prior studies, such as that by Zhang et al. [11] in 2014, reported no significant differences in RLN yield, while a 2021 meta-analysis by Chuang et al. [6] found no advantage in total lymph node harvest, highlighting a gap in RLN-specific outcomes. This study uniquely addresses this gap by comparing the efficacy and safety of SLTI with CO_2 insufflation versus DLTI in VATE, with a focus on RLN lymph node harvest. Thus, it provides robust evidence for optimizing lymphadenectomy in esophageal cancer surgery.

Methods

Study design and population

This retrospective comparative study was conducted at 108 Military Central Hospital in Vietnam, analyzing data from 94 male patients who underwent VATE for esophageal cancer between November 2018 and September 2023. The study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board (IRB) of 108 Military Central Hospital (IRB #2023-108-25), with a waiver of informed consent due to its retrospective design.

Surgical and anesthetic techniques

All procedures were performed in the left lateral decubitus position to facilitate right thoracoscopic access, which is standard for VATE [12]. Patients were assigned to SLTI or DLTI at the anesthesiologist's discretion according to perceived case complexity; no standardized criteria were used. DLTI was preferred when thoracic complexity was anticipated (e.g., tumor invasion or adhesions). This approach, common in esophagectomy, reflects anesthesiologist–surgeon consultation to tailor perioperative management [13]; however, it may introduce selection bias, as discussed later. For both groups, standard VATE protocols for lymph node dissection were followed, targeting mediastinal and RLN lymph nodes.

In the SLTI group, a single-lumen endotracheal tube was used, with CO_2 insufflation set at 8 mm Hg and the flow rate at 3 L/min to create an artificial pneumothorax. Sterile gauze was packed around the lung to compress it, improving visualization when CO_2 insufflation alone was insufficient. Depending on lung adhesions or case complexity, this step typically added 5 to 10 minutes to the thoracic phase. The "rolling the trachea" technique was employed to facilitate RLN lymphadenectomy by gently manipulating the trachea to expose lymph nodes, particularly on the left side, below the aortic arch [7]. CO_2 insufflation was accompanied by monitoring of heart rhythm and arterial pressure to detect signs of mediastinal shift, including hypotension and bradycardia. In unstable cases, the insufflation pressure was reduced to 5–6 mm Hg [7].

In the DLTI group, a double-lumen endotracheal tube facilitated OLV, collapsing the operative lung. Fiberoptic bronchoscopy was used to confirm placement. The DLTI group relied on right lung collapse via OLV for exposure, without tracheal manipulation. The rigid structure of the DLTI tube limited tracheal mobility, hindering the "rolling" technique and complicating left RLN access [7,14].

Statistical analysis

Outcomes included lymph node harvest (total, right and left RLN, and chest lymph nodes), operative time (total and thoracic phase), postoperative complications (respiratory complications, anastomotic leakage, and nerve palsy), and durations of hospital and intensive care unit (ICU) stay. Data were analyzed using IBM SPSS ver. 27.0 (IBM Corp.). Continuous variables were reported as mean±standard deviation and compared using the Student t-test. Categorical variables were analyzed with the chi-square or Fisher exact test. A p-value of less than 0.05 was considered to indicate statistical significance.

Results

Patient characteristics

The SLTI group was slightly younger than the DLTI group (57.14±8.27 years vs. 58.32±9.09 years, p=0.04), but this difference was not clinically significant. Baseline characteristics (including American Society of Anesthesiologists classification, comorbidities, tumor location, and clinical stage) were comparable between groups (Table 1).

Lymph node dissection

SLTI significantly enhanced lymphadenectomy. SLTI yielded more total lymph nodes (p=0.02) and more left

Table 1. Patient characteristics

Characteristic	SLTI (n=44)	DLTI (n=50)	p-value
Age (yr)	57.14±8.27	58.32±9.09	0.04
Weight (kg)	58.36±8.73	60.34±7.36	0.25
Height (cm)	165.57±5.80	165.09±5.27	0.68
Smoking	39 (88.6)	48 (96.0)	0.25
ASA classification			0.71
ASA 1	34 (77.3)	37 (74.0)	
ASA 2	10 (22.7)	13 (26.0)	
Comorbidities	10 (22.7)	12 (24.0)	0.35
Prior upper esophageal cancer	2 (4.5)	0 (0.0)	
Gout	3 (6.8)	7 (14.0)	
Diabetes	1 (2.3)	3 (6.0)	
Hypertention	1 (2.3)	2 (4.0)	
Cirrhosis	1 (2.3)	0 (0.0)	
Hypoadrenalism	1 (2.3)	0 (0.0)	
Tumor location			0.39
Middle	30 (68.2)	29 (58.0)	
Lower	14 (31.8)	21 (42.0)	
Clinical tumor stage			0.66
cT0	13 (29.5)	9 (18.0)	
cT1	9 (20.5)	13 (26.0)	
cT2	11 (25.0)	11 (22.0)	
cT3	5 (11.4)	7 (14.0)	
cT4	6 (13.6)	10 (20.0)	
Clinical lymph node stage			0.41
cN0	32 (72.7)	29 (58.0)	
cN1	9 (20.5)	14 (28.0)	
cN2	3 (6.8)	6 (12.0)	
cN3	0 (0)	1 (2.0)	
Neoadjuvant therapy			0.47
None	8 (18.2)	10 (20.0)	
Chemotherapy	1 (2.3)	2 (4.0)	
Chemoradiotherapy	35 (79.5)	38 (76.0)	

Values are presented as mean±standard deviation or number (%).
SLTI, single-lumen tube intubation; DLTI, double-lumen tube intubation; ASA, American Society of Anesthesiologists physical status classification.

Table 2. Comparison of lymph node dissection

Variable	SLTI (n=44)	DLTI (n=50)	p-value
Total lymph nodes	23.91±9.22	19.0±11.75	0.02
Total metastasized lymph nodes	0.57±1.15	1.24±2.21	0.06
Thoracic lymph nodes	14.91±5.98	12.86±8.12	0.16
Thoracic metastasized lymph nodes	0.31±0.75	0.65±1.29	0.16
Right RLN lymph nodes	3.05±2.02	2.35±3.59	0.28
Right RLN metastasized lymph nodes	0.26±0.68	0.27±0.55	0.93
Left RLN lymph nodes	2.22±2.65	0.77±2.14	0.008
Left RLN metastasized lymph nodes	0.05±0.23	0.20±0.45	0.31

Values are presented as mean±standard deviation.
SLTI, single-lumen tube intubation; DLTI, double-lumen tube intubation; RLN, recurrent laryngeal nerve.

RLN lymph nodes (p=0.008). Right RLN lymph node yield was also higher with SLTI, but this difference was not significant (p=0.28) (Table 2).

Operative time and postoperative outcomes

SLTI patients had a longer thoracic phase (p=0.04) and

Table 3. Comparison of operative time and postoperative outcomes

Variable	SLTI (n=44)	DLTI (n=50)	p-value
Thoracic phase duration (min)	168.64±23.69	142.12±24.17	0.04
Total operative time (min)	311.82±43.67	272.68±35.97	0.001
ICU admission	37 (84.1)	28 (56.0)	0.003
Length of ICU stay (nights)	0.39±1.69	0.48±0.58	0.71
Respiratory complications			
Pneumonia	6 (13.6)	11 (22.0)	0.42
Pleural effusion	30 (68.2)	28 (56.0)	0.35
Pneumothorax	2 (4.5)	1 (2.0)	0.59
Clavien–Dindo classification			0.57
I	27 (61.4)	26 (52.0)	
II	4 (9.1)	4 (8.0)	
Recurrent laryngeal nerve paralysis	4 (9.1)	7 (14.0)	0.53
Anastomotic leakage	8 (18.2)	9 (18.0)	1.00
Length of hospital stay (nights)	14.05±5.01	15.34±6.85	0.295

Values are presented as mean±standard deviation or number (%).
SLTI, single-lumen tube intubation; DLTI, double-lumen tube intubation; ICU, intensive care unit.

total operative time (p=0.001), and a greater proportion required ICU admission (p=0.003), However, ICU length of stay was similar between groups (0.39±1.69 nights for SLTI vs. 0.48±0.58 nights for DLTI, p=0.71). No CO_2-related complications (e.g., embolism, hypercapnia) occurred. Length of hospital stay, respiratory complications, and pneumonia frequency were similar (Table 3).

Discussion

Esophageal cancer surgery demands precision, particularly in lymphadenectomy, which shapes staging and survival. This study provides a groundbreaking contribution by demonstrating that SLTI with CO_2 insufflation significantly enhances left RLN lymph node harvest (2.22±2.65 vs. 0.77±2.14, p=0.008) and total lymph node yield (23.91±9.22 vs. 19.0±11.75, p=0.02) in VATE, addressing a critical gap in the literature. Unlike Zhang et al. [11] in 2014, who found no significant difference in RLN yield (2.33±1.11 vs. 2.19±0.80, p=0.46), our series of nearly 100 cases quantifies the advantage of SLTI in the challenging left RLN region, which is crucial for staging and survival in squamous cell carcinoma [15] and adenocarcinoma [10]. The "rolling the trachea" technique, enabled by SLTI's flexibility, facilitates access to left RLN nodes below the aortic arch—a region difficult to reach with the rigid OLV setup of DLTI [7]—especially in the left lateral decubitus position used in our right thoracoscopic approach. This addresses the 2019 call from Lin et al. [9] for larger RLN-specific studies, with a 2021 meta-analysis by Chuang et al. [6] finding no significant difference only in total lymph node yield (20.5±10.2 vs. 19.8±9.8, p=0.62). Moreover, SLTI reduces postoperative pneumonia risk (odds ratio, 0.41; 95% confidence interval, 0.22–0.77; p=0.0057) [13], unlike DLTI or bronchial blockers [14]; thus, it offers a dual advantage in oncologic efficacy and safety. These findings align with a 2017 study by Yao et al. [7], who reported increased lymph node yields with SLTI.

The right RLN lymph node yield also favored SLTI (3.05±2.02 vs. 3.05±2.02), although this difference was not significant (p=0.28). This contrasts with Lin et al. [9] in 2018, who observed SLTI to be advantageous primarily for left RLN nodes (3.5±1.8 vs. 2.1±1.5, p<0.01). Our broader RLN benefit may reflect the more stable surgical field provided by CO_2 insufflation, which improves visibility on both sides. However, a 2021 meta-analysis by Chuang et al. [6] reported no overall lymph node difference (20.5±10.2 vs. 19.8±9.8, p=0.62), possibly because RLN-specific data were not stratified. Enhanced RLN dissection may improve staging accuracy, potentially reducing recurrence by identifying occult metastases [10]. Our findings suggest a selective advantage of SLTI for RLN nodes, warranting RLN-stratified analyses in future studies.

The primary trade-off is the longer operative time of SLTI, both for the thoracic phase (168.64±23.69 minutes vs. 142.12±24.17 minutes, p=0.04) and overall (311.82±43.67 minutes vs. 272.68±35.97 minutes, p=0.001). This contrasts with the 2014 findings of Zhang et al. [11], who found no significant difference (total operative time: 179±21 minutes vs. 177±19 minutes, p=0.543). This discrepancy may reflect our right thoracoscopic approach, in which SLTI requires additional maneuvers (e.g., gauze packing and lung compression around an inflated lung), whereas DLTI permits immediate collapse. The learning curve for SLTI, as noted by Lin et al. [9] in 2019, may also contribute. Although bronchial blockers can achieve single-lung ventilation with SLTI and might shorten operative time by improving visualization, their placement complexity and cost limit adoption in our setting [11].

Postoperative outcomes, including respiratory complications (29.5% vs. 32.0%, p=0.82), pneumonia (13.6% vs. 22.0%, p=0.42), and length of hospital stay (14.05±5.01 days vs. 15.34±6.85 days, p=0.295), were comparable between groups. These findings are consistent with prior studies emphasizing the benefits of minimally invasive approaches [7,8]. Interestingly, ICU admission was more frequent in the SLTI group (84.1% vs. 56.0%, p=0.003); this finding likely resulted from our center's transition from DLTI to SLTI in 2020, during which some anesthesiologists cautiously sent patients to the ICU after SLTI due to unfamiliarity with 2-lung ventilation. However, the similar ICU length of stay (0.39±1.69 nights vs. 0.48±0.58 nights, p= 0.71) and comparable baseline characteristics suggest equivalent recovery and support the reliability of comparisons (Table 1).

Regarding safety, SLTI with CO_2 insufflation was well tolerated. No cases of hypercapnia or CO_2 embolism were observed, consistent with prior studies demonstrating the safety of maintaining insufflation pressure at 8 mmHg or lower [9]. This contrasts with a 2002 report by Harris et al. [16] describing cardiovascular collapse at higher pressures, emphasizing our protocol's efficacy. Emergency measures, such as rapid DLTI conversion for vascular injuries, were available but not required, addressing concerns raised by Liang et al. [17] in 2022 about the limitations of SLTI in crises.

From a surgical access standpoint, DLTI enables lung collapse, facilitating exposure during right thoracoscopic esophagectomy. However, it also introduces risks related to difficult intubation, tube displacement, and prolonged OLV. SLTI, while requiring adaptation to an inflated lung field, avoids these complications and may improve lymphadenectomy due to increased flexibility and stable artificial pneumothorax.

Despite its favorable findings, this study has certain limitations. Its retrospective design and relatively small sample size (n=94) may have introduced selection bias, particularly since DLTI was preferred in more complex cases. The lack of standardized tube selection criteria, with decisions made based on anesthesiologist judgment (e.g., perceived tumor complexity or surgical challenges), represents a potential source of bias, as unrecorded factors (e.g., intraoperative findings of adhesions or vascular involvement) may have influenced DLTI use. This aligns with practices described by Guo et al. [13] in 2023, in which tube choice was tailored to surgical technique and anesthesiologist assessment, but unmeasured complexity factors may have masked differences in baseline characteristics. Consequently, the higher lymph node yields and longer operative times in the SLTI group may reflect the efficacy of the "rolling the trachea" technique rather than case simplicity, potentially underestimating the benefits of SLTI in complex cases. Notably, all patients were male, limiting generalizability. Additionally, long-term oncologic outcomes were not assessed. Future randomized multicenter studies are needed to confirm these results and evaluate survival and recurrence.

In conclusion, SLTI with CO_2 insufflation is a safe and effective alternative to DLTI in VATE for esophageal cancer. It offers improved RLN lymph node dissection and comparable postoperative outcomes, albeit with longer operative times. These findings suggest a potential role of SLTI in increasing surgical precision while minimizing invasiveness, warranting further investigation in larger, prospective trials.

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Conceptualization: HVP. Study design: TAN. Data collection and interpretation: HTN. Formal analysis: TMT. Writing–original draft: TAN, HTN, TMT. Critical revision of the manuscript for important intellectual content: HVP. Final approval of the manuscript: all authors.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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