Zhang *et al. BMC Cancer* (2025) 25:1110
https://doi.org/10.1186/s12885-025-14530-0

BMC Cancer

RESEARCH

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Comparison of single-port inflatable mediastinoscopic esophagectomy and thoracoscopic esophagectomy in patients with esophageal squamous cell carcinoma after neoadjuvant chemoimmunotherapy

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Abstract

Objective Currently, the application of single-port inflatable mediastinoscopic esophagectomy in patients with locally advanced esophageal squamous cell carcinoma receiving neoadjuvant chemoimmunotherapy is relatively rare. This study aims to compare the clinical efficacy of single-port inflatable mediastinoscopic esophagectomy with that of thoracoscopic esophagectomy for locally advanced esophageal squamous cell carcinoma following neoadjuvant chemoimmunotherapy.

Methods We retrospectively analyzed the perioperative data of 118 patients who underwent minimally invasive esophagectomy. Among them, 80 patients underwent thoracoscopy esophagectomy, and 38 patients underwent single-port inflatable mediastinoscopy esophagectomy. The number of mediastinal lymph nodes dissected, incidence of postoperative complications, and survival period were compared between the two groups.

Results The results revealed that the number of mediastinal lymph nodes dissected was similar between the two groups ($p = 0.185$); In terms of postoperative complications, the incidence of pneumonia was significantly lower in the single-port inflatable mediastinoscopic esophagectomy group than in the thoracoscopic esophagectomy group ($p = 0.038$), but the incidence of hoarseness was higher in the single-port inflatable mediastinoscopic esophagectomy group than in the thoracoscopic esophagectomy group ($p = 0.049$). Moreover, there were no significant differences in recurrence patterns, overall survival, or disease-free survival between the two groups.

Conclusions The results suggest that single-port inflatable mediastinoscopic esophagectomy is a safe and reliable option for patients with locally advanced esophageal squamous cell carcinoma who have received neoadjuvant chemoimmunotherapy.

Keywords ESCC, Neoadjuvant chemoimmunotherapy, SpIME, TE, Surgery

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Introduction

Esophageal cancer is one of the most common malignancies worldwide [1]. According to the 2022 global cancer data, esophageal cancer ranks 11th in terms of incidence, accounting for 2.6% of all malignancies, and is the 7th leading cause of overall mortality, accounting for 4.6% of cancer-related deaths [2]. The incidence of esophageal cancer is relatively high in China, with squamous cell carcinoma being the predominant pathological type [3]. Despite advancements in surgical techniques [4] and the implementation of neoadjuvant chemo(radio)therapy regimens [5, 6], survival remains relatively poor, with an estimated 5-year survival rate of 47% [7, 8].

In recent years, owing to continuous advancements in endoscopic technology and the widespread implementation of minimally invasive esophageal cancer surgery, thoracoscopic and laparoscopic techniques have been combined for radical resection of esophageal cancer, becoming the standard treatment option [9–11]. Compared with traditional thoracotomy, minimally invasive surgery is significantly advantageous in that the postoperative recovery time is shorter and the postoperative complication rates are lower [12].However, transthoracic surgery significantly disrupts cardiopulmonary function, and the procedure becomes even more challenging when there are adhesions in the chest. Additionally, some patients may be unable to tolerate transthoracic surgery because of their lung function, forcing them to forego surgical treatment altogether. In 2015, Fujiwara et al. [13] developed novel surgical methods for the dissection of upper mediastinal lymph nodes via single-port mediastinoscopy through a cervical incision and the lower mediastinal lymph nodes (including the subcarinal lymph nodes) via laparoscopy. This procedure allows access to the upper and middle segments of the esophagus via a cervical approach, eliminating the need for a thoracic approach, single-lung ventilation, chest wall incision, and intraoperative lung compression. Consequently, it has a minimal effect on cardiopulmonary function. This surgical approach also significantly reduces postoperative pain and promotes coughing and expectoration and therefore good postoperative recovery. However, single-port inflatable mediastinoscopic esophagectomy (SpIME) can be challenging and requires specific surgical instruments. Moreover, whether anatomical structures can be clearly visualized under mediastinoscopy to allow thorough lymph node dissection remains unclear [14]. Although SpIME is currently primarily performed in the treatment of early- to mid-stage esophageal cancer, there are few reports on SpIME following neoadjuvant therapy. We retrospectively analyzed data from patients who underwent thoracoscopic esophagectomy (TE) and SpIME following neoadjuvant chemoimmunotherapy in the Department of Thoracic Surgery at the First Affiliated Hospital of Zhengzhou University. Our aim was to investigate the differences in the number of mediastinal lymph nodes dissected, incidence of short-term complications, and prognosis between the two groups of patients.

Patients and methods

Study design

This single-center retrospective study was conducted in the Department of Thoracic Surgery at the First Affiliated Hospital of Zhengzhou University, where we reviewed the data of patients who underwent esophagectomy between January 2022 and December 2022. This study was approved by the Institutional Review Board and Ethics Committee of the First Affiliated Hospital of Zhengzhou University (No. 2024-KY-1648-001). Since this study is retrospective, obtaining written informed consent from patients was not necessary. This study was conducted according to the principles of the Declaration of Helsinki.

Participants

The inclusion criteria were as follows: (1) patients aged > 18 years; (2) patients with a preoperative pathological diagnosis of esophageal squamous cell carcinoma (ESCC), a locally advanced clinical stage (T1b-T2N + M0, T3-T4aNanyM0), and who received neoadjuvant chemoimmunotherapy before surgery; (3) patients with an ECOG score: 0–1; (4) patients classified as ASA grades I-III; (5) patients with R0 resection.

The exclusion criteria were as follows: (1) patients diagnosed with distant metastasis during the operation, (2) patients who died from other diseases, and (3) patients with incomplete case data.

All the patients underwent various tests, including routine blood tests, biochemical analysis, coagulation studies, immunohistochemistry, esophageal barium swallow, electronic gastroscopy, ultrasound endoscopy, electrocardiogram, echocardiography, pulmonary function testing, chest and upper abdominal computed tomography (CT), as well as neck and abdominal ultrasound, to assess the size of the tumor, depth of the invasion, tissue relationships, and lymph node status and therefore rule out distant metastasis and significant esophageal tumor invasion. Certain individuals underwent positron emission tomography-computed tomography (PET-CT) scans for staging before receiving neoadjuvant chemoimmunotherapy. Both groups received 2 to 4 cycles of platinum-based doublet chemotherapy, which consisted of a platinum agent (cisplatin, carboplatin, or nedaplatin) combined with nab-paclitaxel. Simultaneously, patients were administered immune checkpoint inhibitors (ICIs), including pembrolizumab, nivolumab, camrelizumab, sintilimab, toripalimab, or tislelizumab (once every 3 weeks). The eighth edition of the AJCC TNM staging system was used for postoperative tumor staging.

Surgical techniques

All patients included with ESCC underwent radical esophagectomy with mediastinal and abdominal lymphadenectomy. Both groups of patients underwent surgery under general anesthesia with single-lumen endotracheal intubation for bilateral lung ventilation.

SpIME: The patients in the study were positioned supine, and the upper abdomen and neck were disinfected and draped simultaneously after proper fixation (Fig. 1A). A 5 cm incision was made on the medial margin of the left sternocleidomastoid muscle, opening the muscular layer. The cervical paraesophageal lymph nodes were resected, the left recurrent laryngeal nerve was identified and marked, the lymph nodes surrounding the left recurrent laryngeal nerve were excised, and the lymph nodes adjacent to the right recurrent laryngeal nerve were dissected (Fig. 1B). An incision protective sleeve was inserted, and insufflation with carbon dioxide at a pressure of 8–10 cmAq was initiated. The thoracic esophagus was dissociated downward to the level of the subcarina or lower pulmonary ligament, and the lymph nodes adjacent to the recurrent laryngeal nerve (Fig. 1C), esophagus and subcarina were dissected. Attention should be given to the protection of the recurrent laryngeal nerve, azygos vein arch and thoracic duct during surgery. Abdominal procedure: An observation hole was created 1 cm to the left of the umbilicus, an operative port was established in the upper abdomen, and an artificial pneumoperitoneum was established. The gastrocolic ligament was opened, and the left gastroepiploic vessels and their branches were isolated. The greater curvature of the stomach was freed, the hepatogastric ligament was opened, and the left gastric artery was isolated; the middle and lower segments of the esophagus were dissected upward along the esophageal hiatus, converging at the level of the carina, and the lymph nodes adjacent to the lower esophagus and beneath the carina were removed (Fig. 1D), then repair the esophageal hiatal. Finally, the cervical esophagus was transected through the left cervical incision. A portion of the stomach was removed from the abdominal cavity, shaped into a tube and then moved to the neck to reconstruct the esophagus for esophagogastrostomy.

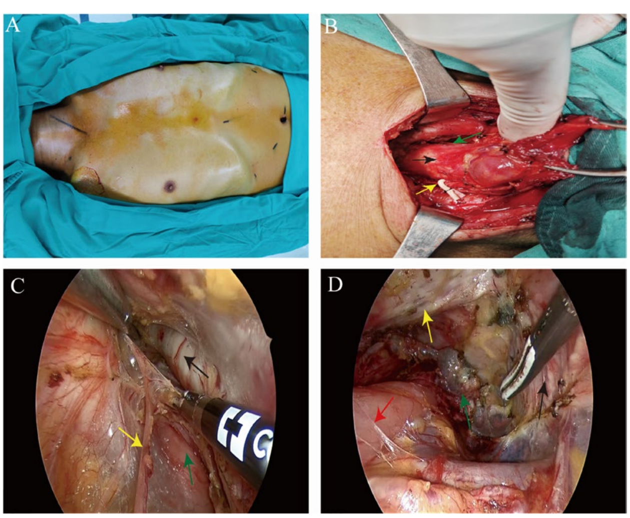

Fig. 1 Single-port inflatable mediastinoscopic esophagectomy. **A** The position of the patient and placement of the operation ports. **B** The bilateral recurrent laryngeal nerve was exposed, and para-nerve lymph node dissection was performed (yellow arrow: left recurrent laryngeal nerve, green arrow: right recurrent laryngeal nerve, black arrow: trachea). **C** "Skeletonization" of the left recurrent laryngeal nerve (yellow arrow: left recurrent laryngeal nerve, black arrow: trachea, green arrow: esophagus). **D** Subcarinal lymph node dissection(yellow arrow: left prinipal bronchus, black arrow: right prinipal bronchus, green arrow: subcarinal lymph nodes, red arrow: esophagus)

TE: The patient was placed in the left lateral decubitus position, and the chest was disinfected after proper fixation. Chest operation: An observation hole was created in the 7th intercostal space on the right axillary midline, and operation holes were established in the 4th intercostal space on the anterior axillary line, the 9th intercostal space on the posterior axillary line, and the 6th intercostal space on the posterior axillary line. An artificial pneumothorax was established, the posterior mediastinal pleura was opened, the transverse azygos vein arch was clamped using a Hem-o-lok, the thoracic esophagus was separated both bluntly and sharply, the bilateral recurrent laryngeal nerves were explored, the lymph nodes were cleared, and the lymph nodes under the carina and esophagus were removed. After the drainage tube was placed, the chest was closed, the patient positioned supine, and the chest was disinfected again. The abdominal procedure was similar to that of SpIME. A portion of the stomach was removed from the abdominal cavity, shaped into a tube and then moved to the neck to reconstruct the esophagus for esophagogastrostomy.

Postoperative management and follow-up

According to our protocol regarding postoperative care after esophagectomy, the endotracheal tube was routinely removed, and the patient returned to the thoracic surgery ward. A chest radiograph was performed at the bedside on postoperative day (POD) 1 to assess the patient's chest condition. Both groups of patients underwent esophagram examination on POD 7. If there was no anastomotic leakage or significant coughing, the patients were allowed liquids orally. The patients in both groups were subsequently discharged with instructions to maintain a semiliquid diet. The patients were switched to a normal diet on POD 14 and then regularly followed up, with appointments every 3 months for the first 2 years, every 6 months for the next 3 years, and then annually thereafter. During these visits, patients underwent physical examinations, blood tests, and CT scans, typically covering the head, neck, thorax, and abdomen. Additional specialized tests were arranged when necessary. In cases of recurrence, treatment options included chemotherapy, radiotherapy, and/or immunotherapy, with some patients also participating in clinical trials. The overall survival (OS) was defined as the period from the date of surgery until death or the last follow-up, whereas the disease-free survival (DFS) referred to the time between surgical resection and the first instance of recurrence, death, or the last follow-up.

Observation indicators

Clinical and pathological data from two groups of patients were collected. The data included age, sex, tumor location, duration of surgery, postoperative length of hospital stay, number of mediastinal lymph nodes dissected and metastasis status, postoperative pathological stage, postoperative anastomotic leakage, chylothorax, hoarseness, tumor metastasis and recurrence, pulmonary function tests, comorbidity, pneumonia, and pleural effusion requiring additional drainage procedure.

Statistical analysis

All the statistical analyses were performed via SPSS version 26.0. The normally distributed data are expressed as ±S, and categorical data were tested using the chi-square test and Fisher's exact test. An independent t test was used for normally distributed continuous data, whereas the Mann–Whitney U test was employed for data without a normal distribution. Survival probabilities were calculated using the Kaplan–Meier method, and differences in survival rates were assessed using the log-rank test. The strength of the relationship was determined via odds ratios, along with 95% confidence intervals (CIs). A 2-tailed p value < 0.05 indicated statistical significance.

Results

Patients

A total of 118 eligible patients were included in the study: 38 patients in the SpIME group and 80 patients in the TE group.

The demographic and preoperative features were comparable between the SpIME and TE groups, as shown in Table 1. There were no statistically significant differences in age, sex, tumor location, comorbidity, pulmonary function tests, operation duration, postoperative length of hospital stay, or postoperative pathological stage between the two groups of patients ($p > 0.05$).

Lymph node dissection

The results of mediastinal lymph node dissection are shown in Table 2. The number of lymph node dissected was similar between the two groups (22.90 ± 8.66 vs. 25.13 ± 8.40, $p = 0.185$). Further analysis revealed that the number of lymph nodes dissected adjacent to the left recurrent laryngeal nerve in the SpIME group was greater than that in the TE group, but the difference was not statistically significant (4.92 ± 3.71 vs. 3.79 ± 2.50, $p = 0.053$). The number of lymph nodes dissected adjacent to the right recurrent laryngeal nerve in the SpIME group was less than that in the TE group, but the difference was not statistically significant (3.55 ± 2.32 vs. 4.01 ± 2.49, $p = 0.344$). The number of subcarinal lymph nodes dissected in the SpIME group was similar to that in the TE group (5.87 ± 3.93 vs. 6.10 ± 3.20, $p = 0.765$).

Postoperative outcomes and complications

The short-term complications are shown in Table 3. We analyzed the incidences of postoperative anastomotic leakage, chylothorax, and hoarseness. The results indicated that there was no significant difference between the two groups in terms of the incidence of anastomotic leakage, chylothorax or pleural effusion requiring additional drainage procedure. However, the incidence of pneumonia was significantly lower in the SpIME group than in the TE group ($p = 0.038$). Regarding hoarseness, the incidence rate in the SpIME group was higher than that in the TE group ($p = 0.049$).

Survival analysis

All patients were observed until March 2025, with a median follow-up duration of 31 months (range,10–38 months). The OS and DFS rates of the TE group were not significantly different from those of the SpIME group (OS: HR:1.064,95%CI:0.430–2.570, $p = 0.891$; DFS: HR:0.959,95%CI:0.489–1.870, $p = 0.902$), as shown in Fig. 2. Given the limited number of Stage IVA patients in the SpIME group, we conducted separate survival analyses for subgroups, as shown in supplementary Fig. 1. The 1-year and 2-year OS rates for the TE group were 96.25% and 83.75%, respectively. In the SpIME group, the rates were 94.74% and 84.21%, respectively. The DFS rates for the TE group were 87.50% at 1 year and 75.00% at 2 years, and the corresponding rates for the SpIME group were 89.47% and 71.05%, respectively.

Recurrence pattern

During the follow-up period, 40 patients (33.90%,40/118) experienced recurrence; as the disease progressed, some patients developed multiple metastases, yet only the initial site of recurrence was considered in our analysis. In the TE group, 27 patients experienced recurrence, and the metastatic sites were as follows: supraclavicular lymph node (8.75%, 7/80), lung (7.50%, 6/80), mediastinal lymph node (6.25%, 5/80), liver (5.00%, 4/80), esophageal anastomosis (3.75%, 3/80), bone (1.25%, 1/80), and brain (1.25%, 1/80). In the SpIME group, the metastatic sites were as follows: supraclavicular lymph node (10.53%,

Table 1 Basic characteristics of the patients

Characteristic	SpIME($n=38$)n(%)	TE($n=80$) n(%)	p value
Age (years)	63.68 ± 7.28	64.64 ± 8.19	0.542
Gender			0.800
Female	11 (28.95)	25 (31.25)	
Male	27 (71.05)	55 (68.75)	
ASA classification			0.510
I/II	31(81.58)	69(86.25)	
III	7(18.42)	11(13.75)	
CCI			0.564
0	17(44.74)	38(47.50)	
1	14(36.84)	33(41.25)	
2	7(18.42)	9(11.25)	
Pulmonary function tests			
FEV1	2.61 ± 0.61	2.53 ± 0.64	0.426
FEV1%	79.78 ± 7.15	77.98 ± 12.37	0.384
Tumor location			0.693
Upper thoracic	3 (7.89)	10 (12.5)	
Middle thoracic	17 (44.74)	31 (38.75)	
Lower thoracic	18 (47.37)	39 (48.75)	
ypStage			0.416
I	19 (50.00)	32 (40.00)	
II	3 (7.90)	10 (12.50)	
III	14 (36.84)	27 (33.75)	
IVA	2 (5.26)	11 (13.75)	
Comorbidity			
Emphysema	9(23.68)	21(26.25)	0.765
Coronary heart disease	6(15.79)	9(11.25)	0.558
Hypertension	9(23.68)	15(18.75)	0.534
Interstitial lung diseases	2(5.26)	0(0)	0.102
Healed pulmonary tuberculosis	2(5.26)	0(0)	0.102
Diabetes	5(13.16)	6(7.50)	0.329
Recurrence			0.961
Absence	25(65.79)	53(66.25)	
Presence	13(34.21)	27(33.75)	
Prognosis			0.840
Alive	31(81.58)	64(80.00)	
Dead	7(18.42)	16(20.00)	
Total operative time (min)	305.13 ± 67.33	279.99 ± 74.92	0.081
The length of postoperative hospital stay (day)	8.89 ± 2.15	9.96 ± 4.40	0.160

ASA American Society of Anesthesiologists, *CCI* Charlson Comorbidity Index

Table 2 Comparison of lymph node dissection parameters between the two groups

Lymph nodes	SpIME($n=38$)	TE($n=80$)	p value
The number of dissected mediastinal lymph nodes	22.90 ± 8.66	25.13 ± 8.40	0.185
Lymph nodes adjacent to the left recurrent laryngeal nerve	4.92 ± 3.71	3.79 ± 2.50	0.053
Lymph nodes adjacent to the right recurrent laryngeal nerve	3.55 ± 2.32	4.01 ± 2.49	0.344
Subcarinal lymph nodes	5.87 ± 3.93	6.10 ± 3.20	0.765

4/38), lung (7.89%, 3/38), mediastinal lymph node (7.89%, 3/38), liver (5.26%, 2/38), and esophageal anastomosis (2.63%, 1/38). In the SpIME group, no bone or brain metastases were observed, and there was no significant difference in the incidence of metastasis at other sites between the two groups, as shown in Table 4.

Discussion

The findings of the study are as follows. There was no significant difference in the number of mediastinal lymph nodes dissected between the two groups ($p=0.185$). In terms of postoperative complications, the incidence of pneumonia was significantly lower in the

Table 3 Comparison of postsurgical complications between patients in the two groups

Postoperative complications	SpIME(n = 38) n(%)	TE(n = 80) n(%)	*p* value
Anastomotic fistula	2 (5.26)	6 (7.50)	0.652
Chylothorax	1 (2.63)	1 (1.25)	0.573
Hoarseness	6 (15.79)	4 (5.00)	0.049
Pneumonia	4 (10.53)	22 (27.50)	0.038
Pleural effusion requiring additional drainage procedure	8 (21.05)	11 (13.75)	0.313

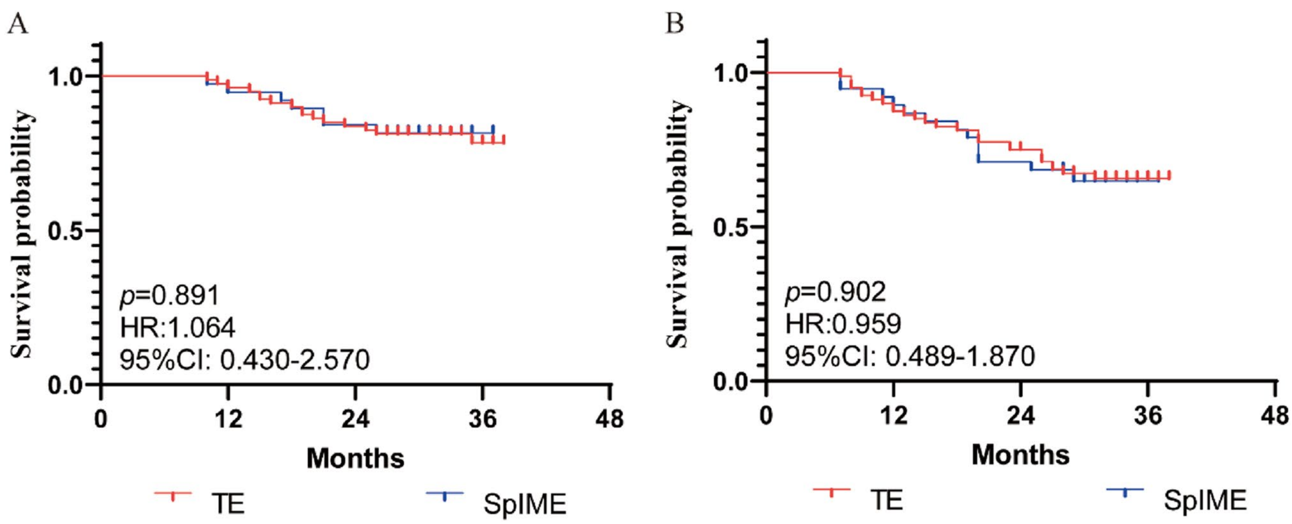

Fig. 2 Kaplan–Meier curves showing overall survival (OS) and disease-free survival (DFS) for each group. **A** No significant difference in OS was observed between the TE and SpIME groups (p = 0.891). **B** No significant difference in DFS was observed between the TE and SpIME groups (p = 0.902)

Table 4 Recurrence patterns by site

Recurrence site	SpIME(n = 38) n(%)	TE(n = 80)n(%)	*p* value
Supraclavicular lymph node	4(10.53)	7(8.75)	0.756
Lung	3(7.89)	6(7.50)	0.940
Mediastinal lymph node	3(7.89)	5(6.25)	0.740
Liver	2(5.26)	4(5.00)	0.952
Esophageal anastomosis	1(2.63)	3(3.75)	>0.999
Bone	0(0)	1(1.25)	>0.999
Brain	0(0)	1(1.25)	>0.999

SpIME group than in the TE group (p = 0.038), but the incidence of hoarseness was higher in the SpIME group (p = 0.049); there was no significant difference in the other complications between the two groups. Additionally, there were no differences in recurrence patterns or survival rates between the two groups. These results suggest that SpIME is a feasible approach for treating locally advanced esophageal cancer after neoadjuvant chemoimmunotherapy.

The only difference between the two groups of patients was the chest surgery approach, all other surgical procedures were consistent. Therefore, we only studied the differences in mediastinal lymph node dissection. Slightly fewer lymph nodes adjacent to the right recurrent laryngeal nerve were removed in the SpIME group than in the TE group. However, SpIME was beneficial for the dissection of lymph nodes near the left recurrent laryngeal nerve. Neither of these differences were statistically significant (p > 0.05). The primary reason for this may be because we dissected the left recurrent laryngeal nerve in the neck or even because we exposed the nerve directly, allowing us to dissect more lymph nodes near the left recurrent laryngeal nerve. Subcarinal lymph node dissection is one of the most challenging aspects of SpIME. Different surgeons have adopted various approaches for dissecting subcarinal lymph nodes, such as the transesophageal hiatus approach or the cervical approach. In our study, we used the transesophageal hiatus approach for subcarinal lymph node dissection. The results revealed that fewer lymph nodes were dissected in the SpIME group than in the TE group, although the difference was not statistically significant. These findings suggest that the lymph node dissection efficiency of the SpIME group is comparable to that of the TE group, which aligns with the conclusions of Davakis' research [15].

In terms of postoperative complications, the incidence of recurrent laryngeal nerve injury was higher in the SpIME group. Among the affected patients in the SpIME group, five regained normal vocal function within six months postoperatively, whereas one patient exhibited persistent hoarseness without aspiration. We speculate that the main reason for this result is the difference in the lymph node dissection technique around the recurrent laryngeal nerve between the SpIME and TE groups. In the SpIME group, we performed "skeletonization" of the recurrent laryngeal nerve, as shown in Fig. 1C. During this process, intraoperative traction, compression, and thermal damage could induce neural trauma and edema, whereas over dissection and excessive exposure might lead to demyelination and compromised local blood supply. This finding is consistent with those of previous studies [16–18]. To mitigate this, Daiko [19] altered the surgical approach by changing the sequence of operations, opting to remove the lymph nodes near the left recurrent laryngeal nerve last. This modification reduced direct contact between the surgical instruments and the nerve and allowed the surrounding adipose tissue to protect the nerve, thus lowering the incidence of recurrent laryngeal nerve injury from 63 to 13%. Liu [20] further suggested that "skeletonizing" the recurrent laryngeal nerve during surgery can lead to nerve injury and therefore recommended minimizing "skeletonizing" as much as possible. In summary, we recommend that, in addition to limiting excessive dissection of the recurrent laryngeal nerve, thermal damage should be avoided, and excessive traction on the nerve during the procedure should be prevented. These measures may help reduce the risk of recurrent laryngeal nerve injury. Regarding pulmonary complications, our results showed that the incidence of pneumonia in the SpIME group was significantly lower than that in the TE group ($p = 0.038$). Compared to the TE group, the SpIME group did not require single-lung ventilation or lung compression during surgery, thereby avoiding chest wall damage and compression of intercostal nerves. Additionally, no chest drainage tube was needed postoperatively, which significantly reduced chest pain for the patients and facilitated their cooperation with postoperative rehabilitation [21, 22]. These factors are the primary reasons why the incidence of pneumonia was significantly lower in the SpIME group compared to the TE group. However, we observed that the incidence of pleural effusion in the SpIME group was higher than in the TE group, though this difference was not statistically significant ($p = 0.313$). The development of pleural effusion may be related to pleural inflammation caused by esophagectomy and lymph node dissection [23]. To reduce postoperative pleural effusion after SpIME surgery, Hisakura et al. [24] attempted to incise the left mediastinal pleura and place a 19Fr drainage tube through the esophageal hiatus into the left chest cavity, which was then punctured through the abdominal wall. The results showed that patients who underwent thoracic drainage through the esophageal hiatus had significantly lower rates of postoperative pleural effusion and thoracic puncture drainage compared to those who did not receive drainage ($p < 0.01$).

In terms of prognosis, there were no significant differences in recurrence patterns or survival outcomes between the two groups. This highlights the complexity of the factors influencing tumor recurrence and patient prognosis. Our preliminary research indicates that recurrence patterns may be influenced by the tumor stage, neoadjuvant treatment regimen, and quality of the surgical procedure. In this study, we found that the surgical approach is not a risk factor for recurrence. In other words, mediastinoscopic surgery may be a new option for treating locally advanced cases after neoadjuvant chemoimmunotherapy.

Conclusion

Our study results indicate that SpIME is a safe and reliable option for treating patients with locally advanced ESCC who have received neoadjuvant chemoimmunotherapy. Since this is a retrospective study with a limited follow-up period, potential selection bias may exist, and the recurrence patterns and survival outcomes of the two groups may not allow for definitive conclusions. Therefore, extending the observation period is necessary for a more robust comparative analysis of these clinical results.

Abbreviations

CT	Computed tomography
CIs	Confidence intervals
DFS	Disease-free survival
ESCC	Esophageal squamous cell carcinoma
ICIs	Immune checkpoint inhibitors
OS	Overall survival
POD	Postoperative day
PET-CT	Positron emission tomography-computed tomography
SpIME	Single-port inflatable mediastinoscopic esophagectomy
TE	Thoracoscopic esophagectomy

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12885-025-14530-0.

Supplementary Material 1: Supplementary Fig. 1. Kaplan–Meier curves showing overall survival (OS) and disease-free survival (DFS) for subgroups. (A) No significant difference in OS was observed for Stage I/II subgroups between the TE and SpIME groups (***p*** = 0.469). (B) No significant difference in DFS was observed for Stage I/II subgroups between the TE and SpIME groups (***p*** = 0.387). (C) No significant difference in OS was observed for Stage III/IVA subgroups between the TE and SpIME groups (***p*** = 0.713). B) No significant difference in DFS was observed for Stage III/IVA subgroups between the TE and SpIME groups (***p*** = 0.895).

Acknowledgements
We are sincerely grateful to all the patients who took part in this research.

Authors' contributions
KSZ and GQZ; Data curation: KSZ, GQZ,YJQ,PZ, and XFC; Formal analysis: KSZ, YJQ, and PZ; Methodology: KSZ,YJQ, and PZ; Project administration and supervision: XP and XNL; Writing-original draft: KSZ; Writing-review & editing: all authors. All authors read and approved the final manuscript.

Funding
This study was supported by 2021 Cultivation Project of Henan Health Science and Technology Innovation Talents (No. YXKC2021013) and Science and Technology Bureau basic research and applied basic research of Zhengzhou (No. 2024ZZJCYJ043).

Data availability
The datasets generated and/or analysed during the current study are not publicly available due to the privacy regulations of the First Affiliated Hospital of Zhengzhou University, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study design followed the international regulations of The Declaration of Helsinki. This study was approved by the Institutional Review Board and Ethics Committee of the First Affiliated Hospital of Zhengzhou University (No. 2024-KY-1648-001). Informed consent was waived by the Institutional Review Board and Ethics Committee of the First Affiliated Hospital of Zhengzhou University, because this is a retrospective study and the data used in this study were anonymized.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 9 May 2025 / Accepted: 17 June 2025
Published online: 01 July 2025

References

1. Liu CQ, Ma YL, Qin Q, Wang PH, Luo Y, Xu PF, Cui Y. Epidemiology of esophageal cancer in 2020 and projections to 2030 and 2040. Thorac Cancer. 2023;14(1):3–11.
2. Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I, Jemal A. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2024;74(3):229–63.
3. Short MW, Burgers KG, Fry VT. Esophageal Cancer. Am Family Phys. 2017;95(1):22–8.
4. Gottlieb-Vedi E, Kauppila JH, Malietzis G, Nilsson M, Markar SR, Lagergren J. Long-term survival in esophageal cancer after minimally invasive compared to open esophagectomy: a systematic review and meta-analysis. Ann Surg. 2019;270(6):1005–17.
5. van Putten M, de Vos-Geelen J, Nieuwenhuijzen GAP, Siersema PD, Lemmens V, Rosman C, van der Sangen MJC, Verhoeven RHA. Long-term survival improvement in oesophageal cancer in the Netherlands. Eur J cancer (Oxford England: 1990). 2018;94:138–47.
6. Kuijper SC, Pape M, Vissers PAJ, Jeene PM, Kouwenhoven EA, Haj Mohammad N, Ruurda JP, Sosef MN, Verhoeven RHA, van Laarhoven HWM. Trends in best-case, typical and worst-case survival scenarios of patients with non-metastatic esophagogastric cancer between 2006 and 2020: a population-based study. Int J Cancer. 2023;153(1):33–43.
7. Shapiro J, van Lanschot JJB, Hulshof M, van Hagen P, van Berge Henegouwen MI, Wijnhoven BPL, van Laarhoven HWM, Nieuwenhuijzen GAP, Hospers GAP, Bonenkamp JJ, et al. Neoadjuvant chemoradiotherapy plus surgery versus surgery alone for oesophageal or junctional cancer (CROSS): long-term results of a randomised controlled trial. Lancet Oncol. 2015;16(9):1090–8.
8. van Hagen P, Hulshof MC, van Lanschot JJ, Steyerberg EW, van Berge Henegouwen MI, Wijnhoven BP, Richel DJ, Nieuwenhuijzen GA, Hospers GA, Bonenkamp JJ, et al. Preoperative chemoradiotherapy for esophageal or junctional cancer. N Engl J Med. 2012;366(22):2074–84.
9. Luketich JD, Alvelo-Rivera M, Buenaventura PO, Christie NA, McCaughan JS, Litle VR, Schauer PR, Close JM, Fernando HC. Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surg. 2003;238(4):486–94. discussion 494– 485.
10. Osugi H, Takemura M, Higashino M, Takada N, Lee S, Kinoshita H. A comparison of video-assisted thoracoscopic oesophagectomy and radical lymph node dissection for squamous cell cancer of the oesophagus with open operation. Br J Surg. 2003;90(1):108–13.
11. Palanivelu C, Prakash A, Senthilkumar R, Senthilnathan P, Parthasarathi R, Rajan PS, Venkatachlam S. Minimally invasive esophagectomy: thoracoscopic mobilization of the esophagus and mediastinal lymphadenectomy in prone position–experience of 130 patients. J Am Coll Surg. 2006;203(1):7–16.
12. Biere SS, van Berge Henegouwen MI, Maas KW, Bonavina L, Rosman C, Garcia JR, Gisbertz SS, Klinkenbijl JH, Hollmann MW, de Lange ES, et al. Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet (London Engl). 2012;379(9829):1887–92.
13. Fujiwara H, Shiozaki A, Konishi H, Kosuga T, Komatsu S, Ichikawa D, Okamoto K, Otsuji E. Single-port mediastinoscopic lymphadenectomy along the left recurrent laryngeal nerve. Ann Thorac Surg. 2015;100(3):1115–7.
14. Tokairin Y, Nakajima Y, Kawada K, Hoshino A, Okada T, Ryotokuji T, Ogo T, Okuda M, Kume Y, Kawamura Y, et al. A feasibility study of mediastinoscopic radical esophagectomy for thoracic esophageal cancer from the viewpoint of the dissected mediastinal lymph nodes validated with thoracoscopic procedure: a prospective clinical trial. Esophagus. 2019;16(2):214–9.
15. Davakis S, Charalabopoulos A, Kyros E, Sakarellos P, Tsourouflis G, Dimitroulis D, Nikiteas N. Minimally invasive transcervical esophagectomy with mediastinal lymphadenectomy for cancer. A comparison with standardized techniques. Anticancer Res. 2022;42(2):675–80.
16. Jin Y, Lu X, Xue L, Zhao X. Retrospective comparison of two minimally invasive esophagectomy in the treatment of esophageal cancer: pneumatic mediastinoscopy versus thoracoscopy. J Laparoendosc Adv Surg Tech A. 2019;29(5):638–42.
17. Sasaki K, Tsuruda Y, Shimonosono M, Noda M, Uchikado Y, Arigami T, Matsushita D, Kita Y, Mori S, Kurahara H, et al. A comparison of the surgical invasiveness and short-term outcomes between thoracoscopic and pneumatic mediastinoscopic esophagectomy for esophageal cancer. Surg Today. 2022;52(12):1759–65.
18. Liu W, Guo X, Zhao H, Yu X, Wang C, Du L, Wang F, Mu J. Mediastinoscopy-assisted transhiatal esophagectomy versus thoraco-laparoscopic esophagectomy for esophageal cancer: a single-center initial experience. J Thorac Dis. 2020;12(9):4908–14.
19. Daiko H, Oguma J, Fujiwara H, Ishiyama K, Kurita D, Sato T, Sato K, Faiz Z, Fujita T. Novel universally applicable technique for performing bilateral transcervical mediastinoscopic-assisted transhiatal laparoscopic esophagectomy: a truly minimally invasive procedure. Surg Endosc. 2021;35(9):5186–92.
20. Liu C, Chen Z, Wei R, Huang K, Wu B, Xu Z, Fang Y, Ding X, Tang H. Intra-operative events and countermeasures during esophagectomy via transcervical incision inflatable single-port mediastinoscope combined with laparoscopy. J Thorac Dis. 2021;13(1):133–9.
21. Chen Z, Huang K, Wei R, Liu C, Fang Y, Wu B, Xu Z, Ding X, Tang H. Transcervical inflatable mediastinoscopic esophagectomy versus thoracoscopic esophagectomy for local early- and intermediate-stage esophageal

squamous cell carcinoma: a propensity score-matched analysis. J Surg Oncol. 2022;125(5):839–46.
22. Shi K, Qian R, Zhang X, Jin Z, Lin T, Lang B, Wang G, Cui D, Zhang B, Hua X. Video-assisted mediastinoscopic and laparoscopic transhiatal esophagectomy for esophageal cancer. Surg Endosc. 2022;36(6):4207–14.
23. Hamada J, Konishi H, Shiozaki A, Fujiwara H, Shoda K, Kosuga T, Kubota T, Okamoto K, Arita T, Morimura R, et al. Management of pleural effusion after mediastinoscopic radical esophagectomy. Anticancer Res. 2018;38(12):6919–25.
24. Hisakura K, Ogawa K, Akashi Y, Kim J, Moue S, Ohara Y, Owada Y, Hashimoto S, Enomoto T, Oda T. Transhiatal chest drainage in mediastinoscope and laparoscope-assisted esophagectomy for esophageal cancer: a retrospective study. J Cardiothorac Surg. 2022;17(1):200.

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