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Perioperative safety and short-term efficacy of functional minimally invasive esophagectomy

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Abstract

Background: Standard minimally invasive McKeown three-field esophagectomy (SMIE) results in high perioperative risk and poor postoperative quality of life owing to considerable surgical damage and numerous postoperative complications. We created a modified procedure, functional minimally invasive esophagectomy (FMIE), which preserves the azygos arch, bronchial artery, pulmonary branch of the vagus nerve, and the mediastinal pleura. Our aim was to evaluate the efficacy and safety of FMIE and to determine whether it has limited invasiveness.

Methods: Between 2018 and 2020, FMIE was performed for 48 patients who were compared with 76 SMIE cases; 44 paired cases were matched using propensity score matching.

Results: Operation time, extubation time, and postoperative hospital stay were significantly lower in the FMIE group. FMIE was also associated with fewer pulmonary infections. Postoperative drainage volume on postoperative day (POD) 1 and POD 2, and white blood cell counts on POD 2 and POD 4 were also significantly lower in the FMIE group. There was no statistically significant difference in the number of dissected lymph nodes, short-term recurrence, metastasis rates, or survival rate between the two groups.

Conclusions: FMIE is a less invasive procedure and may be a suitable alternative for lower and early middle esophageal carcinoma.

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Keywords

Minimally invasive esophagectomy, esophagectomy, esophageal carcinoma, improved surgery, complication, recurrence

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Introduction

Esophageal carcinoma is the most aggressive of all gastrointestinal malignancies. Globally, the 5-year overall survival rate is between 15% and 25%, and this disease is the sixth leading cause of cancer-related deaths in men.[1]

Currently, esophagectomy is the standard method of treatment for resectable esophageal cancer in Europe and the United States, since the Ivor Lewis surgical treatment was first reported in 1946. Complete resection of an esophageal tumor and the surrounding tissues is consistent with the principle of surgical treatment for malignant tumors.[2] With the emergence of minimally invasive surgery, minimally invasive esophagectomy (MIE) has been developed and has gained popularity. Retrospective and meta-analysis studies have revealed distinct benefits of MIE, namely improved clinical outcomes, such as shorter hospital stays, lower incidence of respiratory complications, and lower overall morbidity.[3,4]

For resectable esophageal cancer, MIE has become the standard surgical treatment in China. The main MIE approaches are minimally invasive Ivor Lewis esophagectomy, minimally invasive McKeown three-field esophagectomy, and minimally invasive transhiatal esophagectomy (THE).[5] Standard minimally invasive McKeown three-field esophagectomy (SMIE) has become our preferred surgical procedure owing to its various advantages, including more extensive lymph node dissection and easier management of anastomotic leakage. However, this method, which always involves three compartments of the body, is a highly invasive surgical procedure and is associated with high perioperative risk and poor postoperative quality of life.[6] Postoperative complications, especially pulmonary complications, remain a challenge. It is imperative to investigate how to modify surgical procedures to reduce surgical injuries and postoperative complications and improve patients' survival rates and quality of life.

A modified minimally invasive McKeown three-field esophagectomy, which we have named, functional minimally invasive esophagectomy (FMIE), is an improved surgical approach regarding the ability to repair the mediastinal pleura and retain the azygos arch, the vagus nerve and its pulmonary branches, and the bronchial arteries. However, it is unclear whether this procedure increases the risk of postoperative recurrence or decreases the perioperative risk. The purpose of this study was to evaluate the efficacy and safety of FMIE and, in particular, to evaluate the feasibility of this type of surgery and its impact on patients' short-term postoperative quality of life.

Materials and methods

Patients

From June 2018 to May 2020, 124 cases of esophageal carcinoma were confirmed in our department. We divided thoracic surgery into two wards, and patients diagnosed with esophageal cancer were randomly assigned to one of the two wards. Patients in one ward who met the criteria underwent FMIE, and the remaining were treated with

SMIE; all patients in the other ward underwent SMIE. All patients were diagnosed with esophageal carcinoma. Imaging examinations, including contrast-enhanced thoracoabdominal computed tomography (CT), upper gastrointestinal contrast radiography, and positron emission tomography were used to determine a patient's clinical stage. We used FMIE in patients whose tumors were located in the lower esophagus. FMIE was also performed for patients with middle esophageal cancer with a diagnosis of clinical stage II or earlier disease. All operations were performed by an experienced thoracic surgeon. The patients' clinical data, namely their demographic, intraoperative, and postoperative variables, were retrospectively analyzed.

The reasons for excluding patients were as follows: age $\geq$80 years; neoadjuvant therapy before surgery; upper esophageal tumor; tumor stage IV; inability to tolerate surgery; concomitant multiple operations; and lack of informed consent.

All patients were informed that FMIE was an improved minimally invasive surgery, but that it was still in the experimental stage. This study was approved by the Clinical Ethics Committee of Jining Medical College, China. Each patient provided written informed consent.

Data collection

Demographics and clinical data. Demographics and clinical data were collected retrospectively. Preoperative data constituted age, sex, body mass index (BMI), smoking, drinking, comorbidities, tumor node metastasis (TNM) stage (International Union Against Cancer (UICC) Version 3, 2020), tumor location (middle, or lower third), pathologic stage, histology, adenocarcinoma, white blood cell (WBC) count, neutrophilic granulocyte percentage (NGP), and neutrophil count (NEUT). Intraoperative data constituted operation time, intraoperative blood loss, intraoperative blood transfusion, number of dissected mediastinal lymph nodes, extubation time, and length of postoperative hospital stay.

Postoperative complications. Postoperative respiratory failure, pneumonia, acute respiratory distress syndrome (ARDS), atelectasis, and pneumothorax all were classified as respiratory complications. These complications were diagnosed according to the presence of rhonchus and fever, lung radiographic findings, neutropenia, difficulty breathing, increased respiratory secretions, and/or positive sputum culture. Anastomotic leakage was diagnosed by saliva leakage through the neck wound or upper gastrointestinal series. We defined postoperative hoarseness and cough after drinking water as recurrent laryngeal nerve injury, and chylothorax was diagnosed by milky drainage.

Postoperative follow-up. During the postoperative follow-up, physical examination, blood examination, and CT examinations were performed to screen for suspected tumor recurrence and lymph node metastasis monthly for the first 3 months, and then every 3 months thereafter. Chemoradiotherapy was recommended for patients with a poor pathological classification of their tumor, if their physical condition permitted.

Operation technique

The SMIE procedure was described in detail by Suzuki et al.[7] The procedure for FMIE is similar to that of SMIE, with some tissue retained.

Following successful general anesthesia and endotracheal single-chamber intubation, patients were placed in the left lateral decubitus position and leaned forward 15 degrees. We began with the thoracic component and performed one-lung ventilation.

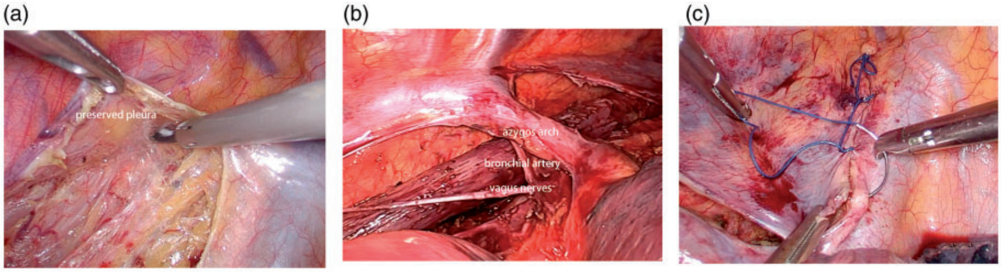

Figure 1. Surgical procedures in functional minimally invasive esophagectomy (FMIE). a, The right posterior superior mediastinal pleura is preserved. b, The esophagus and the lymph nodes are dissected, with the azygos arch, bronchial vessels, and vagus nerves preserved. c, The mediastinal pleura is sutured continuously.

With the aid of a thoracoscope, we accessed the chest cavity through three trocars; one camera trocar and two working trocars. The posterior mediastinal pleura was opened with an ultrasonic scalpel by making an L-shaped incision to determine the tumor location. Dissection was performed for the right recurrent laryngeal nerve and the azygos arch with the aid of thoracoscopy. The right recurrent laryngeal nerve para-lymph node was removed. Mobilization of the esophagus and the left recurrent laryngeal nerve were then performed, and the surrounding lymph nodes were dissected. The azygos arch and bronchial arteries were carefully protected; similarly, the vagus nerve and its branches were preserved. After dissecting the esophagus, the right posterior superior mediastinal pleura was closed using three continuous sutures (Figure 1 a–c). A careful examination was performed to confirm that there was no active bleeding, and then the chest was closed with an in-dwelling drain.

Once the thoracic component of the esophagectomy was completed, the patient was placed in a supine position. Two groups of surgeons operated simultaneously; one group made an oblique incision (4 cm) on the cephalic side at the medial edge of the left sternocleidomastoid muscle and exteriorized the esophagus. The other group established artificial pneumoperitoneum, and the laparoscope and operating instruments were placed into the abdominal cavity, dissecting the stomach and the lymph nodes around the stomach.

After transecting the esophagus at the neck, the esophagus and the tumor were both removed via an upper abdominal incision (4 cm) in the mid-upper abdomen. Once the tumor was removed, a tubular stomach was established to replace the esophagus, using a linear cutting stapler. The cutting stump was then wrapped with a continuous suture, and the tubular stomach was drawn to the neck incision through the esophageal bed. A cervical end-to-side anastomosis was then performed using a circular stapler. Hand-sewn anastomosis was performed unless a stapled anastomosis was considered safer, for instance, if the cervical esophagus was too small or too short to insert the anvil head.

Statistical analysis

To address potential bias in the patients' characteristics between the two groups, we used propensity score matching (PSM). Variables such as age, sex, BMI, comorbidities, and TNM stage were computed as the conditional probability of undergoing either FMIE or SMIE. We created propensity score matching pairs with no replacement (1:1 matching), and set the caliper definition at

0.02. Data for continuous variables are reported as medians and quartile ranges, and data for categorical variables are reported as absolute numbers and percentages. The χ^2 test and Fisher's exact test were used for categorical data. Student's t-test was used for groups of data that were normally distributed, and the Mann–Whitney U test was used for non-normally distributed data. All statistical analyses were performed using SPSS 24 software (IBM Corp., Armonk, NY). Values of $P < 0.05$ were considered statistically significant.

Results

Clinical variables

FMIE was performed in 48 cases, and SMIE was performed in 76 cases. There were no statistically significant differences in the demographic data or clinical backgrounds between the two groups (Table 1). Table 2 shows the postoperative complications. Comparing FMIE vs SMIE, respectively, no significant differences were found for anastomotic leak (11.4% vs. 11.4%), surgical incision infection (20.4% vs. 11.4%), chylothorax (0 vs. 2.3%), or recurrent laryngeal nerve injury rates (9% vs. 2.3%). Although there were no statistically significant differences regarding pneumothorax, atelectasis, or respiratory failure between the two groups, FMIE was associated with fewer pulmonary infections (6.8% vs. 25%; $P = 0.039$). Two patients in the SMIE group were treated in intensive care for respiratory failure caused by a postoperative lung infection; there were no similar patients in the FMIE group.

Surgical findings

All procedures were performed under thoracoscopic laparoscopy without conversion to thoracotomy. The operation time (230 vs. 268 minutes; $P < 0.001$) was significantly lower in the FMIE group vs the SMIE group. Extubation time (5.18 vs. 11.66 days; $P < 0.001$) and postoperative hospital stay (10.5 vs. 12 days; $P = 0.014$) were significantly shorter for FMIE vs SMIE (Table 3). No statistically significant differences were observed between the FMIE and SMIE groups regarding the number of dissected mediastinal lymph nodes (27.25 vs. 26.68, respectively) indicating that the accuracy of lymphadenectomy for FMIE was equal to that for SMIE.

Perioperative drainage and inflammatory biomarkers

Figure 2 (a–d) shows the perioperative drainage volumes and inflammatory biomarker concentrations in the two groups. Compared with SMIE, the postoperative drainage volume of patients who underwent FMIE was significantly lower, particularly on postoperative day (POD) 1 ($P = 0.001$) and POD 2 ($P = 0.037$). A repeated-measures analysis of the Student's t-test also indicated that WBC and NEUT were statistically significantly higher in the SMIE group than in the FMIE group, according to different time-point comparisons. Although in the SMIE group, NGP on POD 2 was significantly lower than that of the FMIE group, WBC on POD 2 and POD 4 ($P = 0.004$ and $P = 0.001$, respectively) were significantly lower in the FMIE group. In addition, NEUT on POD 2 and POD 4 ($P = 0.006$ and $P = 0.005$, respectively) was significantly higher in the SMIE group.

In every case of anastomotic leakage, a diagnosis of surgical incision infection was made. No contaminants leaked into the chest cavity in the patients with anastomotic fistula in the FMIE group.

Postoperative short-term prognosis

Sixty-four of 124 patients (51.6%) received adjuvant therapy, with no differences

Table 1. Basic patient demographics and characteristics before and after propensity score matching.

	Before matching			After matching		
Characteristic	FMIE (n = 48)	SMIE (n = 76)	P-value	FMIE (n = 44)	SMIE (n = 44)	P-value
Age, years	63.5 (56.25–70.5)	67 (61–71)	0.271[c]	63.5 (58–70.5)	65 (60–68.75)	0.920[c]
Sex, male/female	34/14	58/18	0.532[b]	33/11	32/12	1[b]
BMI, kg/m^2	22.1 (20.2–24.3)	22.9 (20.7–25.9)	0.20[c]	22.1 (20.32–24.37)	22.8 (20.02–25.62)	0.823[c]
Smoking, yes/no	23/25	42/34	0.464[b]	23/21	21/23	0.831[b]
Drinking, yes/no	20/28	29/47	0.710[b]	19/25	17/27	0.829[b]
Comorbidities						
CVD	5 (10.4%)	7 (9.2%)	1[b]	4 (9%)	2 (4.5%)	0.676[b]
PD	3 (6.2%)	5 (6.5%)	1[b]	2 (4.5%)	3 (6.8%)	1[b]
Diabetes	2 (4.2%)	7 (9.2%)	0.480[b]	2 (4.5%)	1 (2.3%)	1[b]
Pathologic stage			0.320[b]			0.993[b]
0	1 (2.1%)	2 (2.6%)		1 (2.3%)	1 (2.3%)	
I	8 (16.7%)	14 (18.4%)		8 (18.2%)	7 (15.9%)	
II	11 (22.9%)	28 (36.8%)		11 (25%)	11 (25%)	
III	28 (58.3%)	32 (42.2%)		24 (54.5%)	25 (56.8%)	
Preoperative WBC ($\times 10^9$)				5.60 (4.33–6.67)	5.56 (4.52–6.25)	0.711[c]
Preoperative NGP (%)				63.4 (58–69.2)	62.6 (56.2–66.5)	0.898[c]
Preoperative NEUT ($\times 10^9$)				3.61 (2.66–4.67)	3.67 (2.56–3.89)	0.504[c]

Data are reported as medians and interquartile ranges for continuous variables. Data for categorical variables are reported as absolute numbers and percentages.
[a]Mann–Whitney U test; [b]Fisher's exact test; [c]Student's t test.
FMIE, functional minimally invasive esophagectomy; SMIE, standard minimally invasive three-field McKeown esophagectomy; BMI, body mass index; CVD, cardiovascular disease; PD, pulmonary disease; WBC, white blood cell count; NGP, neutrophilic granulocyte percentage; NEUT, neutrophil count.

Table 2. Perioperative complications in the functional minimally invasive esophagectomy (FMIE) group and standard minimally invasive McKeown three-field esophagectomy (SMIE) group.

Variable	FMIE, n = 44 (%)	SMIE, n = 44 (%)	P-value
Anastomotic leak	5 (11.4%)	5 (11.4%)	1[b]
Respiratory complications			
Pulmonary infection	3 (6.8%)	11 (25%)	0.039[b]
Atelectasis	4 (9%)	6 (13.6%)	0.739[b]
Respiratory failure	0	2 (4.5%)	0.494[b]
Pneumothorax	0	3 (6.8%)	0.241[b]
Surgical incision infection	9 (20.4%)	5 (11.4%)	0.383[b]
Chylothorax	0	1 (2.3%)	1[b]
Recurrent laryngeal nerve injury	4 (9%)	1 (2.3%)	0.360[b]
ICU admission owing to complications	0	2 (4.5%)	0.494[b]

Data are reported as medians and interquartile ranges for continuous variables. Data for categorical variables are reported as absolute numbers and percentages.
[a]Mann–Whitney U test [b]Fisher's exact test [C]Student's t test.
ICU, intensive care unit.

Table 3. Surgical findings and perioperative clinical data.

Variable	FMIE, n = 44	SMIE, n = 44	P-value
Operation time (minutes)	230 (195–255)	268 (241–307)	<0.001[c]
Perioperative bleeding (mL)	139.05 (100–200)	160.23 (100–200)	0.375[c]
Dissected lymph nodes	27.25 (13–30)	26.68 (23.25–30)	0.652[c]
Positive lymph node	1.57 (0–1.75)	2.05 (0–3.75)	0.459[c]
Superior mediastinum	6.25 (4–7)	5.75 (4–7)	0.405[c]
Mid- to lower mediastinum	8.91 (7–11)	9.14 (7–10.75)	0.731[c]
Abdominal cavity	12.2 (10–15)	11.82 (9–13)	0.643[c]
Extubation time (days)	5.18 (4–6)	11.66 (6–12)	<0.001[c]
Postoperative hospital stay (days)	10.5 (9–13.5)	12 (10–14)	0.014[a]

Data are reported as medians and interquartile ranges for continuous variables. Data for categorical variables are reported as absolute numbers and percentages.
[a]Mann–Whitney U test; [b]Fisher's exact test; [c]Student's t test.
FMIE, functional minimally invasive esophagectomy; SMIE, standard minimally invasive McKeown three-field esophagectomy.

between the groups. Because of the influence of COVID-19, 23 patients were not followed up as required. We learned of the survival of these patients by telephone, and all survived; 118 patients (95.1%) survived to 1 year. Comparisons between the 46 (95.8%) survivors in the FMIE group and 72 (94.7%) survivors in the SMIE group were not significantly different. We excluded these cases because we did not know the patients' details; consequently, 101 patients were followed-up. As seen in Table 4, there was no statistically significant difference in short-term prognosis between the FMIE group and the SMIE group.

Discussion

With developments in minimally invasive technology, MIE has gradually become the preferred method for the treatment of esophageal cancer. Although MIE has

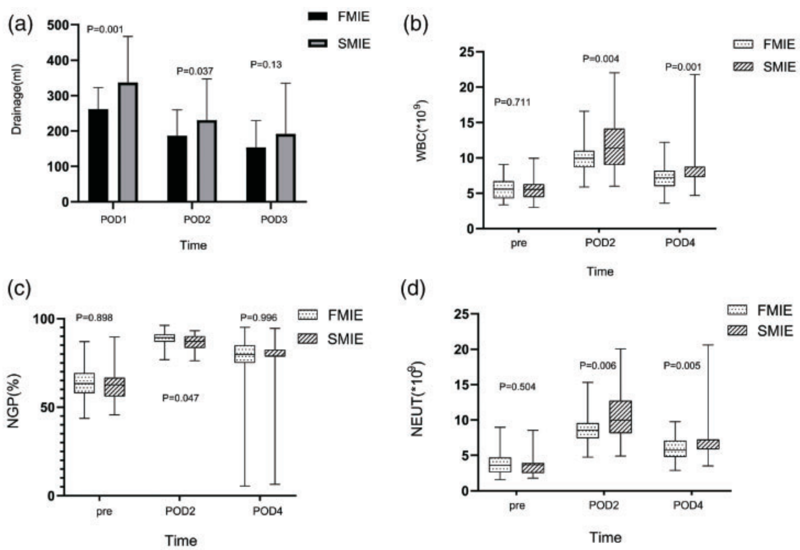

Figure 2. Perioperative drainage volumes and cytokine concentrations changes over time. a, Compared with standard minimally invasive McKeown three-field esophagectomy (SMIE), postoperative drainage volume in patients undergoing functional minimally invasive esophagectomy (FMIE), respectively, were significantly lower, particularly on postoperative day (POD) 1 [270 mL (212–300) vs. 327 mL (227–415); P = 0.001] and POD 2 [180 mL (122.5–247.5) vs. 200 mL (150–300); P = 0.037]. b, White blood cell (WBC) counts in patients undergoing FMIE were significantly lower than for SMIE, respectively, on POD 2 [9.95×10^9 (8.7–10.96) vs. 11.54×10^9 (9.05–14.3); P = 0.004] and POD 4 [7.18×10^9 (6.06–8.15) vs. 8.69×10^9 (7.59–8.82); P = 0.001]. c, Neutrophilic granulocyte percentage (NGP) for FMIE was significantly higher than that for SMIE, respectively, on POD 2 [89.3% (87.12%–91.1%) vs. 87.1% (83.6%–90%); P = 0.047]. d, The neutrophil count (NEUT) for FMIE was significantly lower than that for SMIE, respectively, on POD 2 [8.56×10^9 (7.46–9.53) vs. 9.98×10^9 (8.18–12.7); P = 0.006] and POD 4 [5.74×10^9 (4.83–7.06) vs. 7.19×10^9 (5.91–7.19); P = 0.005].

Table 4. Short-term recurrence and metastasis rates within 1 year.

Consequence	FMIE (n = 41)	SMIE (n = 60)	P
Local recurrence	3 (7.3%)	6 (10%)	0.735[b]
Anastomotic stoma	0	1 (1.7%)	
Cervical lymph node	0	2 (3.3%)	
Mediastinal lymph nodes	1 (2.4%)	2 (3.3%)	
Celiac lymph nodes	2 (4.9%)	1 (1.7%)	
Distant metastasis	3 (7.3%)	7 (11.7%)	0.736[b]
Lung	2 (4.9%)	5 (8.3%)	
Liver	0	1 (1.7%)	
Bone	1 (2.4%)	0	
Kidney	0	1 (1.7%)	

Data are reported as medians and interquartile ranges for continuous variables. Data for categorical variables are reported as absolute numbers and percentages.

[a]Mann–Whitney U test; [b]Fisher's exact test; [c]Student's t test.

FMIE, functional minimally invasive esophagectomy; SMIE, standard minimally invasive McKeown three-field esophagectomy.

considerable advantages over traditional open esophagectomy, such as less bleeding, larger lymph node dissection area, fewer postoperative complications, and better postoperative recovery,[8,9] perioperative morbidity and mortality rates are high.[10] By reducing surgical trauma and perioperative risk, it should be possible to reduce the perioperative morbidity and mortality rates.

Some scholars have investigated how to improve surgical methods. Oshikiri et al.[11] showed that thoracic duct (TD) resection does not improve patients' prognosis and increases the incidence of chylothorax and recurrent laryngeal nerve paralysis; therefore, preventive TD resection should be avoided. Boone et al. justified preserving the azygos through anatomical studies. Weijs et al.[12,13] also concluded from autopsies that it is feasible to preserve the pulmonary vagus branch during thoracoscopic esophagectomy.

The low invasiveness and good recovery of lung function following FMIE are considered the most important aspects of this study. Following surgical trauma, the body produces proinflammatory cytokines, such as tumor necrosis factor α (TNF-α) and interleukin-6 (IL-6), through innate immunity to activate neutrophils and macrophages. At the same time, chemokines, such as monocyte chemokine 1 (MCP-1) and IL-8 regulate the flow of WBCs so that the body produces inflammation in response to injury.[14–16] A previous report[17] showed that excessive surgical stress and postoperative complications lead to the release of large quantities of cytokines perioperatively, enhanced tumor metastasis, and a poor prognosis. Our ideas are compatible with the above consequences. In this study, we demonstrated that patients who underwent FMIE had less postoperative drainage volumes and lower inflammatory biomarker concentrations regarding WBC and NEUT levels, which is indicative of a reduced inflammatory response. Three reasons may explain this phenomenon. First, the improved surgical procedure reduces the surgical excision area, preserves certain tissues, and reduces surgical trauma. According to Watt et al.,[18] the concentration of inflammatory cytokines is associated with the degree of the stress response, and the degree of the stress response is consistently associated with the degree of surgical injury. The production of inflammatory cytokines may be reduced owing to increased tissue retention. Second, preserving the bronchial arteries and the azygos arch improves blood circulation in the mediastinum and promotes the metabolism of inflammatory factors. A lower accumulation of inflammatory cytokines may accelerate recovery following surgery. Finally, neuronal stimulation is an emerging field of research. A growing number of studies have shown that vagus nerve stimulation can effectively reduce disease severity and inflammatory responses in diseases such as rheumatoid arthritis, colitis, acute kidney injury, and pancreatitis.[19,20] FMIE preserves the pulmonary branch of the vagus nerve, which may reduce pulmonary inflammation. These features may explain the lower inflammatory response in patients who underwent FMIE. Our statistical data showed that the comparison of the NGP results between the two groups was contrary to the other indicators, which may be the result of confounding factors. These findings also suggest limitations in our retrospective analysis, and more rigorous, prospective studies are needed to confirm our conclusions.

The FMIE group had shorter extubation times and postoperative hospital-stay durations compared with the SMIE group. We also found that FMIE was performed in a shorter time compared with SMIE. The following aspects can account for this finding. First, it is possible that the indications for FMIE contribute to this phenomenon. We perform FMIE in patients with lower esophageal tumors as well as early middle esophageal carcinoma. Anatomical complexity was avoided because lower esophageal tumors were more common in the SMIE group. Additionally, there were no adhesions between mid-esophageal tumors and surrounding tissues, such as with the carina and azygos. Because of the clear anatomical hierarchy, separation of the esophagus and lymph nodes is accelerated. Second, FMIE does not necessitate amputation and hemostasis of the azygos vein. Third, we retained the mediastinal pleura and made an L-shaped incision in the pleura, which saved time because there was no need to remove the pleura altogether. Suture time was also minimal. In the first few patients, we used only interrupted sutures; this was later changed to continuous sutures, with a general suture time of 2 to 3 minutes. The FMIE group also had fewer postoperative pulmonary complications; in particular, a lower incidence of pulmonary infection and better short-term quality of life during hospitalization. Five patients in the SMIE group were treated in the intensive care unit for respiratory failure owing to lung infection; none in the FMIE group required this treatment. Additionally, the incidence of pulmonary infections was lower in the FMIE group. On the one hand, we reserved and sutured the mediastinal pleura. During postoperative recovery, the anastomotic site of the esophagus and the pleura become adhered, which could reduce the possibility of chest contamination in cases of anastomotic fistula (Figure 3a and b). We found that no contaminants leaked into the chest cavity in the patients with anastomotic fistula in the FMIE group. On the other hand, retaining the vagus pulmonary branches, bronchial arteries, and azygos arch improved the respiratory function of patients who underwent FMIE and accelerated the recovery of their postoperative lung function. The postoperative cough and sputum excretion ability of patients were unaffected, and thus, the incidence of postoperative pulmonary infection was lower.

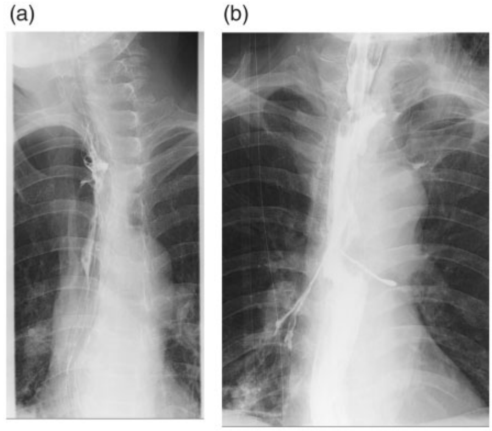

Figure 3. Comparison of upper gastrointestinal radiography between patients with anastomotic leakage in the functional minimally invasive esophagectomy (FMIE) group and standard minimally invasive McKeown three-field esophagectomy (SMIE) group. a, Leakage of contrast media is visible and confined to the mediastinum. b, Contrast media entering the chest cavity.

During surgery and postoperative pathological examination, we found no statistically significant difference between the groups regarding the number of lymph nodes removed, and we believe that using FMIE would not increase the risk of postoperative cancer metastasis or recurrence. Our results were consistent with the findings of Boone et al.[12]

Although our clinical data and analysis of inflammatory indicators verified that FMIE was associated with a low inflammatory response and limited invasiveness, our study has certain limitations. Inflammatory indicators cannot completely reflect the inflammatory response; therefore, proinflammatory cytokines, such as IL-6 and TNF-α, should be evaluated further. Although we used rigorous statistical methods to adjust for baseline differences among patients, this was a retrospective study, and we had no control variables. Further prospective studies should be considered. In the meantime, we are following our patients long-term to determine the 3- and 5-year survival rates and tumor recurrence rates.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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