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ORIGINAL ARTICLE

Minimally invasive esophagectomy in the lateral-prone position: Experience of 124 cases in a single center

Shaohua Ma, Tianshen Yan, Dandan Liu, Keyi Wang, Jingdi Wang, Jintao Song, Tong Wang, Wei He, Jie Bai & Liang Jin

Department of Thoracic Surgery, Peking University Third Hospital, Beijing, China

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Correspondence
Tianshen Yan, Department of Thoracic Surgery, Peking University Third Hospital, 49 North Garden Rd, Haidian District, Beijing, 100083 China.
Tel: +86 10 8226 7300
Fax: +86 10 8226 7300
Email: yts8966@163.com

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Abstract

Background: Minimally invasive esophagectomy was first introduced as a new technique for esophageal cancer treatment 20 years ago. Performing this procedure in the lateral-prone position is the most appropriate method. Since May 2013, our center has performed 124 esophageal cancer operations using this procedure. Herein, we share our experience.

Methods: We retrospectively reviewed 124 consecutive patients who had received minimally invasive esophagectomy in the lateral-prone position from May 2013 to June 2017. The procedure, operative variables, postoperative complications, and oncology outcomes were assessed.

Results: The surgery was successful in all 124 patients; three cases converted to an abdominal opening procedure during surgery. The mean total lymph node harvest was 19.2: 12.9 in the thoracic cavity and 6.0 in the abdominal cavity. The average total operation duration was 376 minutes and blood loss was 156 mL. No mortality occurred within 30 postoperative days. Forty-three cases of postoperative morbidity occurred in 38 patients (30.6%), including 11 anastomotic leakages (8.9%), 1 chyle leak (0.8%), 12 lateral recurrent nerve palsies (9.7%), 11 pulmonary complications (8.9%), and 8 other complications (6.5%). A learning curve indicated that blood loss, operation duration, and the number of lymph nodes harvested would improve with time.

Conclusions: Surgical and oncological outcomes following minimally invasive esophagectomy for esophageal cancer were acceptable. There are some advantages to this technique compared to previous reports of opening procedures.

Introduction

Since Collard first reported thoracoscopic mobilization of the esophagus followed by laparotomy and preparation of the gastric conduit in 12 patients, several subsequent reports have demonstrated the feasibility of this approach.[1] However, at that time, no definitive benefit had been shown compared to open esophagectomy. In 2003, Luketich *et al*. reported excellent results in their study of 222 patients who underwent minimally invasive esophagectomy (MIE). This approach was successfully completed in 93% of the patients, with acceptable postoperative complication rates.[2] MIE has since emerged as an effective alternative to open techniques of esophagectomy. Evidence of short-term postoperative advantages over open procedures is accumulating, including a shorter hospital stay, less pain, a reduction in pulmonary complications, and improvement to quality of life. Most importantly, oncologic outcomes after MIE have been demonstrated to be equivalent to open procedures. However, MIE is a technically challenging approach, requiring advanced minimally invasive surgical skills and a long learning curve before the best outcome can be obtained. The aim of this study is to report our experience of 124 MIE procedures performed at Peking University Third Hospital, to describe the procedure details, and analyze the short-term postoperative outcomes.

Methods

Patients

Between May 2013 and June 2017, 124 patients were scheduled for MIE for esophageal cancer (EC) in our department: 93 (75%) men and 31 (25%) women with a mean age of 62 years (range 42–84). Patient characteristics are shown in Table 1. The standard preoperative workup included symptom evaluation, barium swallow radiography, flexible endoscopy with biopsy, enhanced computed tomography of the thorax, ultrasonography of the supraclavicular lymph nodes, and deep venous ultrasonography examination of the lower extremities. According to the seventh tumor node metastasis (TNM) classification, the location of the tumor was cervical in 3 cases, upper in 26, middle in 57, and lower in 38 cases. Patients were classified as clinical stage 0 (4 patients), Ib (26), IIa (19), IIb (51), IIIa (20), IIIb (3), and IIIc (1). Neoadjuvant chemotherapy (NAC) was conducted in 57 patients who suffered from T3 or T4a lesions and partial T2 lesions. After 1–4 cycles of taxol plus cisplatinum (TP) NAC, computed tomography restaging was performed. Whether patients agreed to undergo NAC or not, the criterion for MIE was the presence of a resectable lesion after staging and restaging.

Table 1 Patient characteristics

Characteristic	N = 124
Gender	
Male	93 (75%)
Female	31 (25%)
Mean age	62.0
Location of EC lesion	
Cervical esophagus	3 (2.4%)
Upper esophagus	26 (21.0%)
Middle esophagus	57 (46.0%)
Lower esophagus	38 (30.6%)
Clinical T stage	
Tis	4 (3.2%)
T1	29 (23.4%)
T2	27 (21.8%)
T3	63 (50.8%)
T4	1 (0.8%)
Clinical N stage	
N0	94 (75.8%)
N1	26 (21.0%)
N2	4 (3.2%)
Clinical stage	
0	4 (3.2%)
Ib	26 (21.0%)
IIa	19 (15.3%)
IIb	51 (41.1%)
IIIa	20 (16.1%)
IIIb	3 (2.4%)
IIIc	1 (0.8%)

EC, esophageal cancer.

Minimally invasive esophagectomy procedure

A thoracoscopic and laparoscopic combined approach was used as our method of MIE for resection of the esophagus and gastric mobilization. Two-field lymph nodes were routinely dissected, especially to clear lymph nodes in the bilateral recurrent laryngeal nerve, while cervical lymph node clearance was performed if ultrasonography or core needle biopsy yielded positive results. The gastric conduit was used as the substitute route to the esophageal bed to achieve anastomosis with the remnant cervical esophagus in all cases.

Thoracic stage

The patient was positioned in the left lateral decubitus 45 degrees forward, flexed over the operating table to increase the intercostal spaces. The surgeon and camera surgeon stood on the ventral side of the patient, and the assistant on the opposite side. We use a standard four-trocar approach with CO_2 insufflation at 5~8 mmHg (Fig 1). The four trocars were placed in the third (ϕ5 mm, port named S, surgeon) and sixth/seventh (ϕ10 mm, port named C, camera) intercostal spaces of the mid-axillary line, and the sixth (ϕ5 mm, port named E, exchange) and eighth/ninth intercostal (ϕ10 mm, named A, assistant) spaces of the subscapular line. With the exposure facilitated by port A, the surgeon combined port S with E to perform the supra-azygos area procedure, port S with E/A for the middle mediastinal area, and port E/S with A for the low mediastinal area.

The following steps are performed as standard:

1 Open the supra-azygos mediastinal pleura; follow the right vagus nerve to the right subclavian artery, and the right recurrent laryngeal (RLN) nerve is found just at the right subclavian artery. The fatty tissue containing lymph nodes around this area is dissected, and the RLN up to the inferior border of the thyroid gland is preserved.

2 Open the pleura posteriorly along the vertebra and roll the esophagus anteriorly from shallow to deep, cutting the soft tissues around the esophagus layer by layer to complete upper esophagus mobilization.

3 Open the sub-azygos pleura, cut the azygos arch using an Endo-GIA Universal (Medtronic Medical Appliance Technology & Service (Shanghai) Limited, Shanghai, China), and cut the right bronchial artery by using a 5 mm hem-o-lock and harmonic scalpel (Johnson & Johnson Medical [Shanghai] Ltd. Shanghai, China).

Figure 1 The sites of the four-trocar approach: the third (φ5 mm, port named S, surgeon) and sixth/seventh (φ10 mm, port named C, camera) intercostal spaces of the mid-axillary line, and the sixth (φ5 mm, port named E, exchange) and eighth/ninth intercostal spaces (φ10 mm, named A, assistant) of the subscapular line.

Mobilize the middle and low esophagus from the sub-azygos to the pericardium following the same method. Pay particular attention to protect the thoracic duct, especially at the position under the azygos, and protect the main bronchus, especially the left main bronchus. A hem-o-lock and harmonic scalpel are used to deal with the left bronchial artery.

4 After total mobilization, the esophagus is pulled forward using a silk thread through port C to achieve better exposure and allow space to facilitate lymph node clearance of the carina and circumference of the esophagus.
5 Pull the trachea forward and downward using an appropriate device, expose the left RLN area, and dissect the lymph nodes around the left RLN, especially the lymph nodes under the aortic arch.
6 Check the thoracic duct from the sub-azygos to thoracic inlet, as most of these are full and plump. Thoracic duct ligation is only performed when there is evidence of a chyle leak.

Abdominal stage

The patient was repositioned to the supine position. The surgeon and camera surgeon both stood on the right side of the patient, and the assistant on the left. Five ports were arranged: the subxiphoid (ϕ10 mm, port named A1, assistant 1); the right subcostal (ϕ5 mm, port named S2, surgeon 2); the right upper belly button on the clavicle midline (ϕ12 mm, port named S1, surgeon 1); and the left symmetrical to port S1 (ϕ5 mm, port named A2, assistant 2); and umbilicus (ϕ10 mm, port named C, camera) (Fig 2). Gastric mobilization was standardized to a laparoscopic approach and a gastric conduit was made via a 5 cm mini incision at port A1.

The following steps are performed as standard (Fig 3):

1 Open the lesser omental sac, cut the hepatogastric ligament with a harmonic scalpel, and then lift up the proximal small curvature of the stomach. The left gastric, common hepatic, and splenic arteries form a cross sample structure. Completely dissect the lymph nodes around the left gastric artery before cutting it using an Endo-GIA. Follow the bilateral crura of the diaphragm to mobilize the abdominal esophagus.
2 After mobilization, immediately move to the arteriae gastricae breves, from the upper pole of the spleen to the splenic flexure of colon, and cut the short gastric arteries one by one with a harmonic scalpel.
3 Shift to the greater curvature of the stomach and cut the gastro colic ligament inner to the gastro omental vascular arch from the avascular area to the splenic flexure of the colon to complete proximal gastric mobilization.
4 Cut the abdominal esophagus using an Endo-GIA, make a 5 cm incision at port A1, and pull out the proximal stomach from the incision. The hepatogastric and gastro colic ligaments of the distal stomach are dealt with outside the incision. Ensure the right gastro omental vascular arch is protected.
5 The gastric conduit is closed using an Endo-GIA; whole and serosa muscularis sewing is preferred. The appropriate width of the gastric conduit is 4~6 cm. A jejunum nutrient tube to the duodenum is retained.

Cervical stage

An oblique left incision is performed over the anterior border of the sternocleidomastoid muscle. All anterior cervical

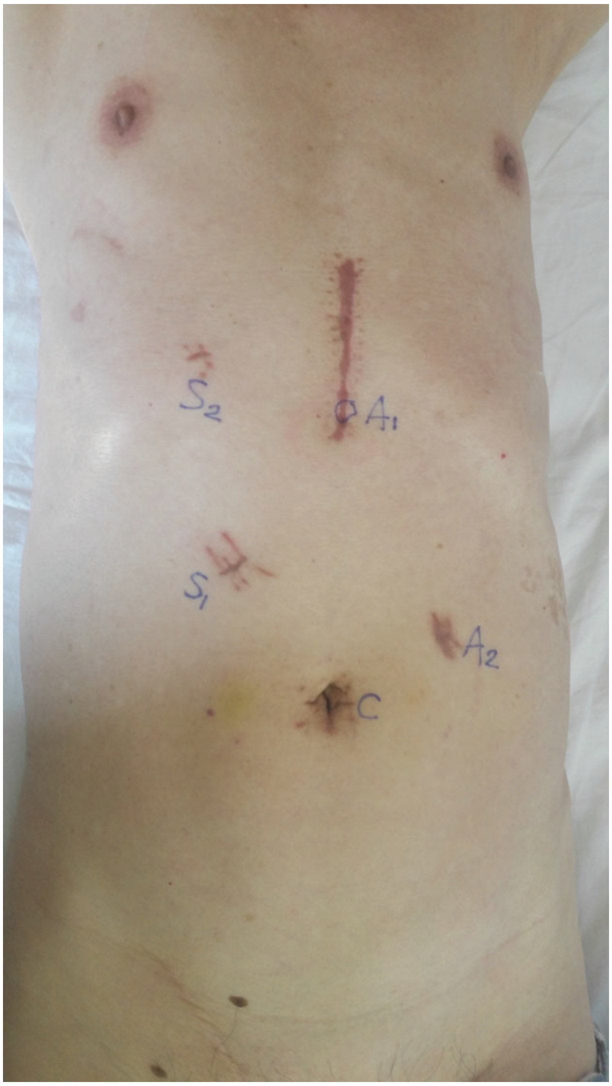

Figure 2 Five ports are arranged: the subxiphoid (φ10 mm,port named A1, assistant 1), the right subcostal (φ5 mm, port named S2, surgeon 2), the right upper belly button on the clavicle midline (φ12 mm, port named as S1,surgeon 1), and the left symmetrical to port S1 (φ5 mm, port named A2, assistant 2), and umbilicus (φ10 mm, port named C, camera).

muscles should be preserved. After mobilizing the cervical esophagus, the gastric conduit is pulled through the posterior mediastinum and brought out to the neck. Esophagogastric anastomosis is performed in one layer, end-to-side, using a mechanical device. The feeding tube is pulled out of the nose using a nasogastric tube.

Outcome variables

The short-term postoperative surgical records and outcomes of all cases were reviewed. Operative data points examined included operation duration, blood loss, quantity of blood transfused, intra-operative accidents, length of intensive care unit stay, length of overall hospital stay, and chest tube indwelling time. Postoperative short-term outcomes refer to complications within 30 days after surgery, such as anastomotic or gastric conduit leakage, chyle leak, recurrent nerve palsy, or pulmonary complications.

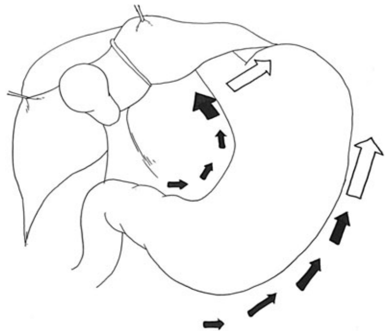

Figure 3 A schematic illustration of mobilization of the stomach.

Statistical analysis

SPSS 19.0 software was used to perform the statistical analysis. one- way ANOVA to evaluate the difference between the data relative to learn curve. A *P* value of less than 0.05 was considered significant.

Results

All procedures were completed using thoracoscopy, without the need for conversion to open thoracotomy. Three cases were converted to open abdominal procedures: two cases with uncontrollable bleeding in the short gastric artery at the upper pole of the spleen, and one case of severe adhesion in the abdomen. Two-field lymphadenectomy was performed in 114 cases and three-field dissection in 10. The operative and postoperative outcomes are shown in Table 2. The mean total lymph nodes harvested were 19.2: 12.9 in the thoracic cavity and 6.0 in the abdominal cavity. The pathological stage distribution of the patients was stage 0 in 14 cases (11.3%), stage I in 28 (22.6%), stage II in 58 (46.8%), stage III in 23 (18.5%), and stage IV in 1 case (0.8%). The mean operation duration was 376 minutes and only 3 (2.4%) patients required a blood transfusion of < 400 mL. Forty patients (32.3%) required surgical intensive care unit admission, with a mean duration of 3.7 days. No mortality occurred postoperatively within 30 days. Forty-three cases (34.7%) of postoperative morbidity occurred in 38 patients (30.6%), including 11 anastomotic leakages (8.9%), 1 chyle leak (0.8%) (secondary surgery was not required), 10 single lateral recurrent nerve and 2 bilateral recurrent palsies

Table 2 Operative and postoperative outcomes of the 124 cases

Outcomes	N = 124
Mean operation time (min)	376
Mean blood loss (mL)	156
Lymph nodes harvested (mean)	19.2
Thoracic lymph nodes harvested	12.9
Abdominal lymph nodes harvested	6.0
Pathological stage	
0	14 (11.3%)
I	28 (22.6%)
II	58 (46.8%)
III	23 (18.5%)
IV	1 (0.8%)
Mortality within 30 days	0
Total morbidity (patients)	38 (30.6%)
Respiratory complications	11 (8.9%)
Anastomotic leakage	11 (8.9%)
Chyle leakage	1 (0.8%)
Vocal cord paralysis	12 (9.7%)
Other complications	8 (6.5%)
SICU stay (cases)	40 (32.3%)
SICU stay (mean days)	3.7
Postoperative stay (mean days)	16.4
Chest tube indwelling time (mean days)	6.0

SICU, surgical intensive care unit.

(9.7%), 11 pulmonary complications (8.9%), and 8 other complications (6.5%). The mean postoperative stay was 16.4 days and chest tube indwelling duration was 6.0 days. Blood loss, operation duration, and the number of lymph nodes harvested is expected to improve over time (Table 3).

Discussion

Anesthesia and body position

Two different patient positions are beneficial for mobilizing the esophagus: thoracoscopic prone and lateral-prone positions. Although prone position provides good exposure during surgery, when bleeding occurs it is not convenient to move the patient to the lateral recumbent position and convert to open procedure. It is also inconvenient for anesthesiologists to manage the respiratory tract. The lateral prone position combines the advantages of the left recumbent and prone positions, and it is also convenient to change position during emergency transfer.[3]

Single lumen endotracheal intubation can reduce both intubation difficulty and the possibility of tracheal tear caused by double lumen endotracheal intubation. It can also reduce lung injury caused by single lung ventilation, enhance cardiopulmonary function recovery,[2] and is beneficial for left RLN lymph node dissection.[4] However, for experienced anesthesiologists, double lumen intubation does not increase the risk associated with anesthesia. The single lumen procedure is limited as it requires a high level of skill, and surgeons cannot use a suction device but must deal with intraoperative bleeding using gauze alone. In the 124 patients in our study, single lumen endotracheal intubation was performed in only 30 cases of early EC, while in 94 cases double lumen cavity intubation was used. Regardless of the intubation technique, artificial pneumothorax was used in all cases to facilitate intraoperative smoke discharge and promote lung collapse. If intraoperative hemorrhaging occurs, port A is immediately changed to an open hole, and suction is induced.

Data relevant to learning curve

All 124 cases were treated surgically via esophagectomy using an MIE procedure (thoracoscopy combined with laparoscopy) rather than hybrid MIE (either a thoracoscopic or laparoscopic approach). The mean surgical duration was 376 minutes, and the average blood loss was 156 mL, similar to results reported in previous studies.[5,6] A previous meta-analysis reported that the amount of bleeding that occurred during MIE was less than during opening esophagectomy (OE), but the operation time was slightly longer than that of OE.[7] However, two of our cases suffered from hemorrhage during mobilization of the stomach; the bleeding occurred at the short gastric artery upper pole of the spleen, which is also the area where bleeding often occurs during OE. We consider inadequate exposure and excessive tension on the short gastric artery during traction (so that the harmony scalpel fails to completely coagulate), as reasons for such bleeding. We expect that after approximately

Table 3 Minimally invasive esophagectomy learning curve

Outcome	Fist period (*n* = 31)	Second period (*n* = 31)	Third period (*n* = 31)	Forth period (*n* = 31)	*P*
Mean operation duration (min)	392	378	347	321	0.18
Mean blood loss (mL)	216	182	150	76	0.032
Lymph nodes harvested (mean)	16.6	16.1	20.0	24.1	< 0.001
Thoracic lymph nodes harvested	10.7	12.5	13.4	15.1	0.002
Abdominal lymph nodes harvested	5.7	3.7	6.4	8.1	0.007

30~60 more MIA procedures, a plateau of experience will be reached, as suggested by Oshikiri *et al.*[8]

Complications

Minimally invasive esophagectomy is a complex and technically challenging surgical procedure, associated with high morbidity and mortality. Of our 124 cases, the overall complication rate was 30.6%, lower than previously reported for OE.[9] However, there is no widely accepted system to document the occurrence or severity of complications associated with esophagectomy, particularly pulmonary and cardiovascular complications. Thus, it is difficult to assess and compare morbidity related outcomes at different individual institutions. Meta-analysis may present a possible solution to this problem. To our knowledge, six meta-analyses comparing MIE to OE have been conducted.[7,10–14] Overall, MIE was associated with dramatically decreased pulmonary and cardiovascular complications, and a low incidence of chylothorax, while the incidence of RLN paralysis slightly increased, and anastomotic leakage incidence was almost the same.

In our study, the incidence of pulmonary complications was about 8.9%, lower than in previous reports, which range from 16–30%.[11,12] Our lower complication rate may have occurred as a result of our technique; the sputum suction tube was indwelled through the nose into the trachea and aspirated by a nurse every two to three hours, which may significantly reduce pulmonary complications, especially in patients experiencing hoarseness. The incidence of chylothorax was very low in our series, at only 0.8%. Thoracoscopy provides a good field of view and magnification, enabling the entire thoracic duct to be surveyed, which is the most important factor to avoid injury. Ligation of the thoracic duct is not a routine procedure during esophagectomy for patients with EC as it cannot effectively prevent chylothorax.[15] The thoracic duct can be examined from the azygos arch at the end of the thoracic stage to see whether it is fully filled, which may indicate the occurrence of damage. Among our cases, ligation of the thoracic duct was only performed in two suspected injury cases; however, the incidence of laryngeal recurrent nerve palsy was significant higher in our cases (9.7%) compared to previous studies. Lymph node dissection is a very important procedure during esophagectomy, because lymph node metastasis is the most important factor of EC prognosis; the lymph node metastasis rate is as high as 26–53%, even in submucosal lesions.[16] Lymph node metastasis is mainly concentrated in the bilateral RLN chain, especially around the RLN at the site of vascular fold back where it is very difficult to accomplish clearance.[17] Pursuing excessive lymph node dissection in order to achieve long-term survival can cause damage to the RLN, as electrical interference can cause postoperative hoarseness.[18] Weighing long-term survival against postoperative safety is a worthy and continuing debate.

The last major complication of esophagectomy is anastomotic leakage, which occurred in 8.9% of the cases in our series. Previous meta-analyses showed no difference between MIE and OE techniques regarding anastomotic leakage.[19] The underlying reason for our result may be the similarities in the adequately exposed operative field and level of ischemic gastric conduit between the MIE and OE groups.

Radical cure of tumor

Lymph node metastasis is the most important factor for the prognosis of EC. Lymph node status is an independent prognostic factor for survival after esophagectomy and complete lymph node dissection is associated with better survival.[20] Although long-term survival data of our study sample is not available, oncologic results of different procedures can be compared with respect to the number of harvested lymph nodes and survival rates. In our series, the average number of harvested lymph nodes was 19.2, which is similar to previous meta-analyses, and is even higher compared to the best OE series conducted.[10,11] Therefore, we believe that long term survival of MIE will be better than OE, or at least equal, as reported by Wang *et al.*[21]

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Disclosure

No authors report any conflict of interest.

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