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Original Article

Initial experience of robot-assisted Ivor–Lewis esophagectomy: 61 consecutive cases from a single Chinese institution

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SUMMARY. **This study aims to report the technical details and preliminary outcomes of robot-assisted Ivor–Lewis esophagectomy (RAILE) using two different types of intrathoracic anastomosis from a single institution in China. From May 2015 to October 2017, 61 patients diagnosed with mid-lower esophageal cancer were treated with RAILE. The RAILE procedure was performed in two stages. The first 35 patients underwent circular end-to-end stapled intrathoracic anastomosis (stapled group), and the remaining 26 patients had a double-layered, completely hand-sewn intrathoracic anastomosis (hand-sewn group). Patient characteristics, surgical techniques, postoperative complications, and pathology outcomes were analyzed. The mean operating time and mean blood loss were 315.6 ± 59.4 minutes and 189.3 ± 95.8 mL, respectively. There was one patient who underwent conversion to thoracotomy. The 30-day and in-hospital mortality rates were 0%. Overall complications were observed in 22 patients (36.1%) according to the Clavien-Dindo (CD) and the Esophagectomy Complications Consensus Group (ECCG) classifications, of whom 6 patients (9.8%) had anastomotic leakage (ECCG, Type II). The median length of hospitalization (LOH) was 10 days (IQR, 5 days). Complete (R0) resection was achieved in all cases. The mean tumor size was 3.2 ± 1.5 cm, and the mean number of totally dissected lymph nodes was 19.3 ± 9.2. Regarding the operative outcomes between stapled and hand-sewn groups, there were no significant differences in the operative time (325.4 ± 66.6 vs. 302.3 ± 45.9 min, $P = 0.114$), blood loss (172.9 ± 74.1 vs. 211.5 ± 117.0 mL, $P = 0.147$), conversion rate (2.9 vs. 0%, $P = 1.000$), overall complication rate (37.1 vs. 34.6%, $P = 0.839$) or LOH (10 vs. 9.5 days, $P = 0.415$). RAILE using both stapled and hand-sewn intrathoracic anastomosis is safe and technically feasible with satisfactory perioperative outcomes for the treatment of mid-lower thoracic esophageal cancer.**

KEY WORDS: **esophagogastric anastomosis, esophageal cancers, Ivor Lewis, robotic surgery.**

ABBREVIATIONS

BMI:	body mass index
CD:	Clavien-Dindo
CRM:	circumferential margin
CT:	computed tomography
ECCG:	Esophagectomy Complications Consensus Group
EGD:	esophagogastroduodenoscopy
ESCC:	esophageal squamous cell carcinoma
FDG-PET:	fluorodeoxyglucose-18 positron emission tomography
ICS:	intercostal space
LOH:	length of hospitalization
MIE:	minimally invasive esophagectomy
RAILE:	robot-assisted Ivor–Lewis esophagectomy
RAMIE:	robot-assisted minimally invasive esophagectomy
RLN:	recurrent laryngeal nerve

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Specific author contributions: Hecheng Li and Yajie Zhang designed the study. Yu Han collected the data. Maosheng Huang and Yajie Zhang were responsible for data statistics and analysis. Yajie Zhang wrote the manuscript. Yajie Zhang, Jie Xiang, Junbiao Hang, and Hecheng Li performed the surgery. Hecheng Li and Abbas E. Abbas assisted in manuscript preparation and review. Hecheng Li and Abbas E. Abbas made the decision to submit for publication. All authors have read and approved the final version for publication.

INTRODUCTION

Minimally invasive esophagectomy (MIE) has become increasingly adopted for esophageal cancer.[1] Multiple available studies have shown that compared with open resection, MIE results in less blood loss, decreased morbidity, and mortality rates and shorter hospital stays with comparable oncological clearance.[2–4] Nevertheless, MIE is a difficult technique with a protracted learning curve[5] for thoracic surgeons. Conventional minimally invasive surgery involves rigid instruments and a two-dimensional view of the operating field, thereby providing a limited degree of freedom of movement and reduced hand-eye coordination.[6] MIE becomes technically more challenging in an Ivor–Lewis esophagectomy when lymph node dissection and intrathoracic anastomosis are needed deep in the mediastinum.[7]

In the past two decades, robot-assisted surgery has offered advantages such as high-resolution three-dimensional optics and 7 degrees of freedom with the use of its articulated instruments, allowing surgeons to comfortably perform complex operations in the domain of hepatobiliary,[8] gynecological,[9] and urinary tract surgeries.[10] Although robot-assisted minimally invasive esophagectomy (RAMIE) was initiated in 2003,[11] limited cases of RAMIE have been published, especially those involving Ivor–Lewis approaches.[5] In addition, controversy still exists about the best method for constructing the intrathoracic anastomosis. Some institutions prefer a circular end-to-end stapled anastomosis,[12,13] and others suggest a completely hand-sewn anastomosis,[14,15] with inconsistent reporting of challenges and outcomes.

In our institution, a robot-assisted Ivor–Lewis esophagectomy (RAILE) approach was initiated in 2015 based on the experience of traditional open and minimally invasive Ivor–Lewis esophagectomy. This study aimed to describe the technical aspects of RAILE, including the different techniques used for intrathoracic anastomosis, and to report the initial results.

PATIENTS AND METHODS

Patient selection

The study population was a consecutive series of patients undergoing RAILE with curative intent for a diagnosed malignancy at Ruijin Hospital affiliated with Shanghai Jiaotong University School of Medicine between May 2015 and October 2017. The preoperative workup included a thorough clinical examination, esophagogastroduodenoscopy (EGD) with biopsy, cardiopulmonary function examination, endoscopic ultrasonography, contrast-enhanced computed tomography (CT) of the chest and abdomen, ultrasound of the neck and fluorodeoxyglucose-18 positron emission tomography (FDG-PET)/CT. The inclusion criteria for RAILE in this study were identical to those for open and conventional minimally invasive approaches as follows: (1) middle and distal esophageal carcinoma histologically proven by biopsy; (2) a tumor judged to be resectable, and the exclusion of enlarged cervical and supraclavicular lymph nodes based on the preoperative evaluation; (3) no prior history of gastrointestinal or thoracic surgery; (4) no potential surgical contraindications; and (5) a detailed understanding of all the patients about the perioperative features and total costs of robotic surgery, and signed informed consent forms. This study was approved by our institutional review board (2018–53).

Based on the different anastomotic techniques, two types of RAILE procedures were performed. The first group underwent a robot-assisted intrathoracic circular end-to-end stapled esophagogastrostomy (stapled group), and the other group received a double-layered, completely hand-sewn intrathoracic anastomosis (hand-sewn group). No other parts of the intraoperative and postoperative treatment protocol changed between the two groups. Data collection was obtained through a detailed review of patient charts. Basic demographics, including age, sex, and comorbidities were collected. Perioperative factors included operative time, blood loss, postoperative mortality and complications, and length of hospitalization (LOH). Oncologic variables included tumor stage, histology, circumferential margins (CRMs), and number of lymph nodes harvested. A positive CRM was defined as a tumor that was found within 1 mm of the surgical margin.[16] Clinicopathological stages were evaluated and based mainly on the 7th UICC-AJCC esophageal TNM staging system.[17] Patients with cT3 tumors or greater and/or nodal involvement were recommended for neoadjuvant chemoradiotherapy in our institution; however, final approval was required by the patients. Complications were described according to the Clavien-Dindo (CD)[18] and the Esophagectomy Complications Consensus Group (ECCG)[19,20] classifications. The comparisons of the perioperative outcomes were made between the two groups.

Surgical procedures

All surgical procedures were performed by the same surgical team using a da Vinci Surgical System (Model S; Intuitive Surgical, Inc., Sunnyvale, CA, USA). The surgery was led by the senior author of this paper (L.H.C.) and assisted by attending surgeons or surgical residents.

RAILE begins with the abdominal phase. With the patient in the supine reverse Trendelenburg position, a 12-mm camera port is placed in the subumbilical site, three 8-mm robotic ports are positioned in the right

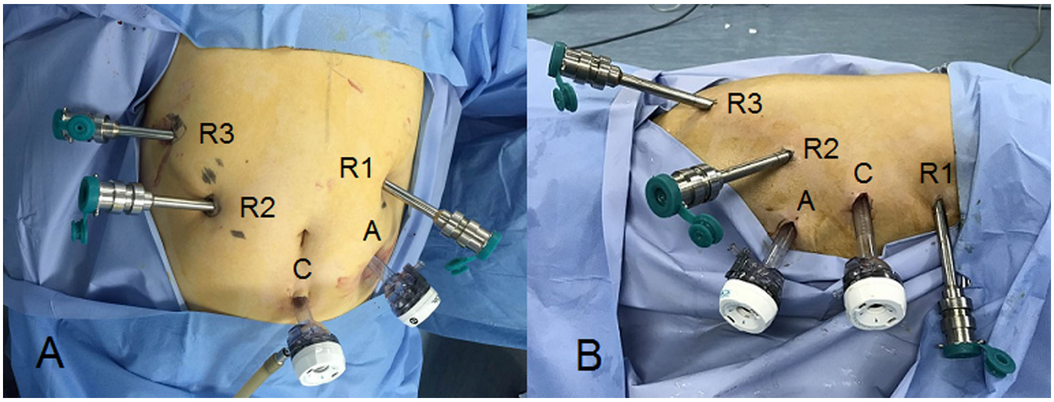

Fig. 1 Trocar placement is shown. (A) Abdominal phase. (B) Thoracic phase.

and left subcostal regions, and one 12-mm assistant port is placed in the left midclavicular line (Fig. 1A). After a V-shaped liver suspension has been created by the purse string suture and clips, the procedure begins with opening the lesser sac. The left gastric artery is then transected at its origin, and a complete celiac lymphadenectomy is performed. Gentle retraction of the stomach using the robot assistant arm and the bedside assistant allows for retrogastric exposure and dissection. The dissection is then performed along the greater curve of the stomach to the level of the short gastric vessels and then to the level of the left crus and downward to the level of the pylorus, taking great care to visualize and preserve the gastroepiploic arcade and the right gastroepiploic vessels. A 4-cm-wide gastric conduit is then created starting from the lesser curve and moving cephalad toward the fundus with several fires of an Endo GIA stapler (ENDOGIA 60 Covidien Surgical), which is introduced through the second robotic port. Once the specimen has been divided from the gastric conduit, the distal end of the specimen is temporarily reapproximated to the proximal end of the conduit, and a Penrose drain is placed around the esophagus in the abdomen. The hiatus is opened slightly, and the conduit and drain are placed into the lower aspect of the right side of the chest. Finally, using a standard non-robotic laparoscopic technique, a feeding jejunostomy tube is placed and brought through the assistant port site.

For the thoracic phase, the patient is positioned in the left lateral decubitus position and slightly prone, and one-lung ventilation is provided. A 12-mm robotic camera trocar is inserted into the fifth intercostal space (ICS) at the anterior axillary line. After carbon dioxide insufflation at 8 mmHg, another four trocars are inserted under thoracoscopic guidance as follows: an 8-mm port in the third ICS at the posterior axillary line for the first robotic arm, an 8-mm port in the eighth ICS at the posterior axillary for the second robotic arm, an 8-mm port in the tenth ICS posteriorly to the posterior axillary line for the third robotic arm, and a 12-mm assistant's port in the seventh ICS near the costal margin (Fig. 1B). The robot is positioned on the dorsocranial side, with one assistant on the anterior side. The initial dissection is begun by dissecting lymph nodes around the right recurrent laryngeal nerve (RLN). The azygos vein is then divided via a vascular stapler. The esophagus is then mobilized en bloc down to the gastroesophageal junction with dissection of all surrounding lymph nodes in the periesophageal, periaortic, and subcarinal areas. The conduit is pulled up through the hiatus, and the specimen and conduit are disconnected. The third robotic arm retracts the esophagus anteriorly and cephalad via the Penrose drain that is placed around it. The arterial branches are ligated with the bipolar cautery or clips. The trachea is retracted with a grasper by the bedside assistant, and the lymph nodes along the left RLN are dissected to the thoracic inlet. The proximal esophagus is divided with robotic scissors above the level of the azygos vein and sometimes to the thoracic inlet, depending on the location of the tumor. The specimen is placed in a disposable plastic bag and removed through the assistant port. For an end-to-end stapled anastomosis, the anvil of a 25-mm Premium Plus CEEA circular stapler (Covidien Surgical) is inserted and carefully introduced into the distal open esophagus by the bedside assistant. A robotically sewn purse-string suture is placed, as well as a superficial second purse-string suture for reinforcement. A gastrotomy is performed at the most proximal portion of the conduit and carefully held open with the assistance of robotic retraction. The circular stapler is introduced through the mini access incision, carefully placed into the proximal conduit, and brought out from the side of the gastric conduit. The spike and anvil are married with the aid of robotic graspers and the bedside assistant, and the anastomosis is created (Fig. 2). The proximal redundant conduit and gastrotomy are closed with an Endo GIA stapler (ENDOGIA 60 Covidien Surgical). For the hand-sewn anastomosis, a two-layered

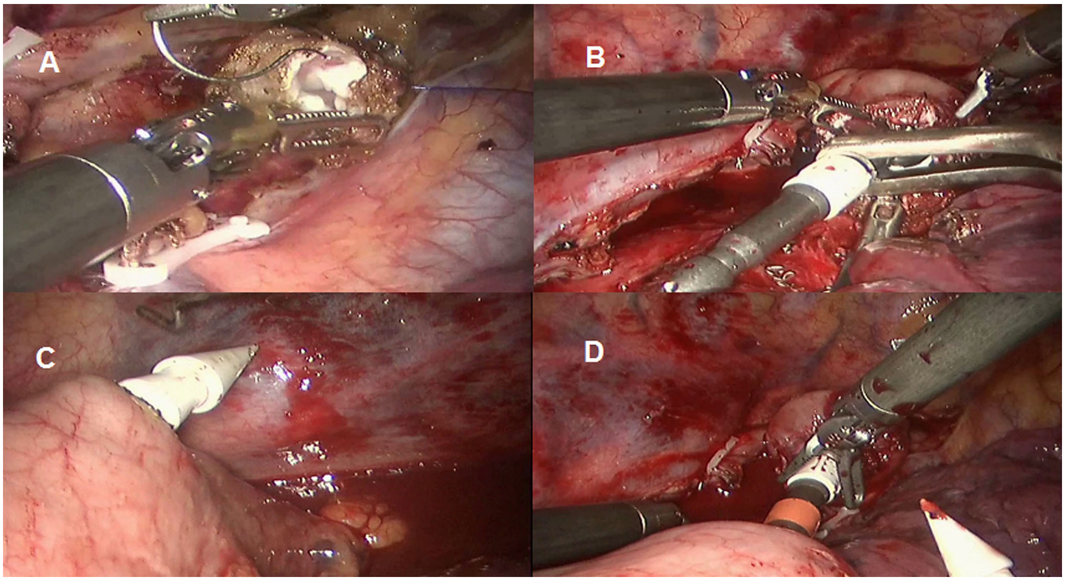

Fig. 2 The circular end-to-side stapled anastomosis was created. **(A)** A robotically sewn purse-string suture was placed. **(B)** The anvil of a 25-mm Premium Plus CEEA circular stapler was inserted and carefully introduced into the distal open esophagus. (C) A gastrotomy was performed at the most proximal portion of the conduit, and the circular stapler was placed into the proximal conduit. **(D)** The spike and anvil were married with the aid of robotic graspers and a bedside assistant.

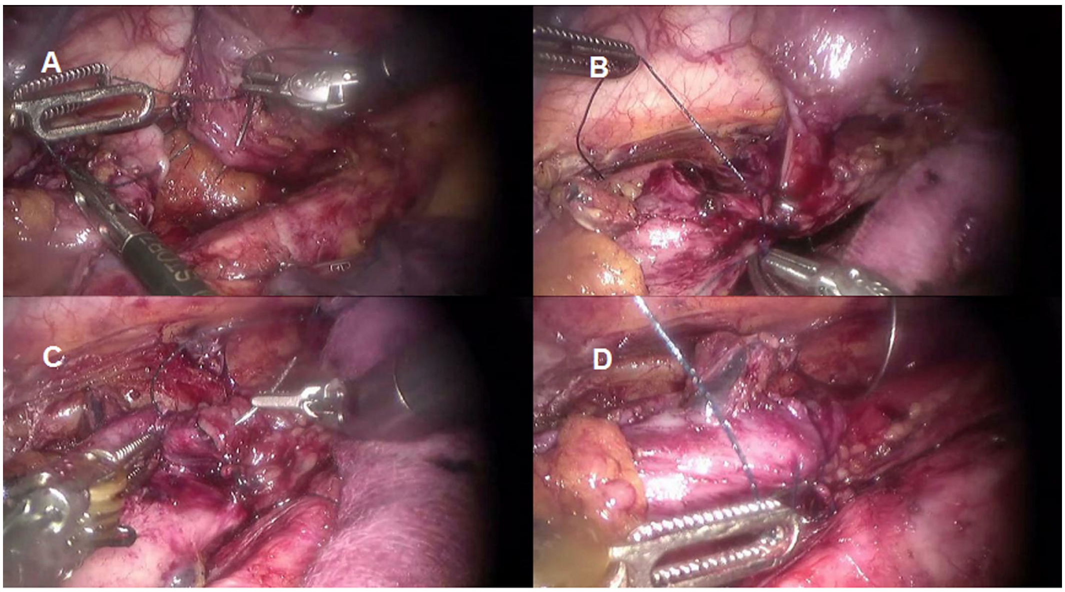

Fig. 3 The hand-sewn double-layered robotic chest anastomosis was created. **(A)** The posterior surface is completed with a running suture (V-Loc 3/0 Covidien, Mansfield, USA) in the back row to sew the muscular layer of the esophagus to the serosal layer of the stomach. **(B)** After opening the stomach, the inner layer of the anastomosis is constructed using an interrupted 3–0 Vicryl (Ethicon US, LLC, Cincinnati, OH) suture. **(C)** The anterior wall is completed using a running 3–0 V Loc suture for the inner layer. **(D)** A running 3–0 V Loc suture is used for the anterior muscular layer.

robotic chest anastomosis technique is used. The posterior surface is completed with a running suture (V-Loc 3/0 Covidien, Mansfield, USA) in the back row to sew the muscular layer of the esophagus to the serosal layer of the stomach. Then, the esophagus is sectioned with monopolar curved scissors. After opening the stomach, the inner layer of the anastomosis is constructed using an interrupted 3–0 Vicryl suture (Ethicon US, LLC, Cincinnati, OH). Once the posterior inner layer of the anastomosis is completed, the anterior wall is completed using a two-layered running 3–0 V Loc suture for the inner layer and the anterior muscular layer (Fig. 3). A portion of the greater omentum attached to the conduit is placed on top of the anastomosis using interrupted 3–0 Vicryl sutures. The thoracic phase is completed after insertion of a

28-Fr thoracic catheter and placement of a Jackson-Pratt drain posteriorly to the newly created anastomosis.

Statistical methods

SPSS 19.0 (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. Student's t-test or the Wilcoxon rank-sum test was used to compare continuous group variables. Categorical data were compared using the chi-square test or Fisher's exact test. A P-value <0.05 was considered statistically significant.

RESULTS

Demographic characteristics

Between May 2015 and October 2017, a total of 89 patients underwent robot-assisted esophageal resection. Of these patients, 10 underwent enucleation of an esophageal submucosal tumor, 18 underwent the McKeown procedure for esophageal cancer, and the remaining 61 met the entry criteria for this study and underwent the RAILE. The patient characteristics are shown in Table 1. The study population consisted of 45 male and 16 female patients. The mean age at the time of the procedure was 61.6 ± 7.7 years. The tumors in 26 cases (42.6%) were located in the middle esophagus, while the tumor in 35 cases (57.4%) were located in the distal esophagus. Two patients with cT3N2 tumors agreed to receive neoadjuvant chemoradiation; they were both restaged as ycT2–3N0–1 after neoadjuvant therapy and finally underwent RAILE. The first 35 patients (57.4%) underwent a circular end-to-end stapled intrathoracic anastomosis (stapled group), whereas the next 26 (42.6%) patients received a double-layered completely hand-sewn intrathoracic anastomosis (hand-sewn group).

Table 1 Patient characteristics.

Variables	N (%)
Age (years), Mean ± SD	61.6 ± 7.7
Gender	
Male	45(73.8)
Female	16(26.2)
BMI (kg/m^2), Mean ± SD	22.5 ± 3.0
Tobacco use	
Current smokers	30(49.2)
Abstained for at least 1 year	4(6.6)
Never	27(44.3)
Comorbidity	
Diabetes mellitus	7(11.5)
Cardiac disease	2(3.3)
Pulmonary disease	2(3.3)
Hypertension	19(31.1)
Renal insufficiency	2(3.3)
Cerebrovascular disease	2(3.3)
ASA grading n (%)	
1	29(47.5)
2	31(50.8)
3	1(1.6)
Tumor location	
Mid thoracic	26(42.6)
Lower thoracic	35(57.4)
Type of anastomosis	
Stapled	35(57.4)
Hand-sewn	26(42.6)
Neoadjuvant chemoradiotherapy	2(3.3)

Operative outcomes

The surgical outcomes are shown in Table 2. The mean operating time calculated from the time of the skin incision to wound closure in all patients was 315.6 ± 59.4 min. The mean blood loss was 189.3 ± 95.8 mL. One patient was converted to open procedure in the thoracic phase due to intraoperatively intractable atrial fibrillation. There were no 30-day or in-hospital mortalities. Overall postoperative complications occurred in 22 (36.1%) patients. Anastomotic leakage occurred in 6 patients (9.8%) (ECCG, Type II), whereas postoperative pneumonia was observed in 4 patients (CD, Grade II, $n = 2$; Grade IIIa, $n = 2$). Vocal cord paralysis and chylothorax were observed in 5 patients (8.2%) (ECCG, Type IA, $n = 3$; Type IIA, $n = 1$; Type IIIA, $n = 1$) and 1 patient (1.6%) (ECCG, Type IIIB), respectively. There were 5 cases (8.2%) of atrial fibrillation (CD, Grade III). One patient (1.6%) experienced wound infection (CD, Grade I). The median LOH was 10 days (IQR, 5 days), and the median total hospital costs were $16,077.8 (IQR, $2520.6). Regarding the operative outcomes between stapled and hand-sewn groups, there were no significant differences in the operative time (325.4 ± 66.6 vs. 302.3 ± 45.9 min, $P = 0.114$), blood loss (172.9 ± 74.1 vs. 211.5 ± 117.0 mL, $P = 0.147$), conversion rate (2.9 vs. 0%, $P = 1.000$), overall complication rate (37.1 vs. 34.6%, $P = 0.839$), total hospital costs ($16,109.2 vs. $15,853.6, $P = 0.827$) or LOH (10 vs. 9.5 days, $P = 0.415$).

Oncologic outcomes

Pathological parameters are presented in Table 3. The predominant histologic diagnosis was squamous cell carcinoma (58 cases, 95.1%). The mean tumor size on pathologic examination was 3.2 ± 1.5 cm. R0 resection was achieved in all patients. For the two patients who received neoadjuvant chemoradiation, in one case, no residual tumor was found (ypT0N0M0) and in the other case, the tumor was down-staged from cT3N2 to ypT2N1. For those who did not receive neoadjuvant therapy, pathological stages ranged from TisN0M0 to T4N3M0. The mean number of totally dissected lymph nodes was 19.3 ± 9.2, with means of 10.3 ± 5.8 in the thorax and 9.0 ± 6.8 in the abdomen. The mean number of lymph nodes harvested along the

Table 2 Intraoperative characteristics and surgical outcomes

Variables	RAILE	Stapled anastomosis (n = 35)	Hand-sewn anastomosis (n = 26)	*P*-value
Operative time (minute), Mean ± SD	315.6 ± 59.4	325.4 ± 66.6	302.3 ± 45.9	0.114*
Blood loss (mL), Mean ± SD	189.3 ± 95.8	172.9 ± 74.1	211.5 ± 117.0	0.147*
Conversion to open, *N* (%)	1(1.6)	1(2.9)	0	1.000**
Overall complications, *N* (%)	22(36.1)	13(37.1)	9(34.6)	0.839**
Leakage†	6(9.8)	4 (11.4)	2(7.7)	0.960**
Pneumonia‡	4(6.6)	2(5.7)	2(7.7)	1.000**
Vocal cord paralysis§	5(8.2)	3(8.6)	2(7.7)	1.000**
Chylothorax¶	1(1.6)	1(2.9)	0	1.000**
Atrial fibrillation††	5(8.2)	3(8.6)	2(7.7)	1.000**
Wound infection‡‡	1(1.6)	0	1(3.8)	0.300**
LOH (day), Median (IQR)	10(5)	10(5)	9.5(5)	0.415***
30-day and in-hospital mortality, N (%)	0	0	0	
Total hospital Costs ($), Median (IOR)	16,077.8(2520.6)	16,109.2(2664.6)	15,853.6(2161.0)	0.827***

*Student's t-test; **chi-square test, Fisher's exact test; ***Wilcoxon rank-sum test.
†ECCG, Type II; ‡CD, Grade II-III; §Type I–III; ¶ECCG, Type III; ††CD, Grade III; ‡‡CD, Grade I.

Table 3 Pathologic outcomes.

Variables	*N* (%)
Tumor size (cm), Mean ± SD	3.2 ± 1.5
Histology	
Squamous cell carcinoma	58 (95.1)
Adenosquamous carcinoma	2 (3.3)
Squamous cell carcinoma with areas of neuroendocrine differentiation	1(1.6)
Adenocarcinoma	0
Pathologic stages	
CR	1(1.6)
TisN0M0	4 (6.6)
T1N0M0	12(19.7)
T1N1M0	2(3.3)
T1N2M0	1(1.6)
T2N0M0	7(11.5)
T2N1M0	3(4.9)
T2N2M0	2(3.3)
T3N0M0	14(1.6)
T3N1M0	5(8.2)
T3N2M0	6(9.8)
T3N3M0	2(3.3)
T4N1M0	1(1.6)
T4N3M0	1(1.6)
R0 Resection	61(100)
Nerve invasion	7(11.5)
No. of harvested lymph nodes, Mean ± SD	19.3 ± 9.2
Abdominal	9.0 ± 6.8
Thoracic	10.3 ± 5.8
Along the right RLN	1.5 ± 1.7
Along the left RLN	1.6 ± 2.3

right RLN and left RLN was 1.5 ± 1.7 and 1.6 ± 2.3, respectively.

DISCUSSION

The initial experience of RAMIE was described in 2003 by Giulianotti *et al.*[11] Since then, RAMIE has been introduced as a surgical treatment for esophageal cancer. However, compared with conventional MIE, published studies regarding RAMIE remain limited. Furthermore, the vast majority of series detail a modified McKeown (3-hole)[21–23] or transhiatal approach.[24–26] Only a few groups have reported the robot-assisted Ivor–Lewis approach, with limited cases and different methods of anastomosis.[12–14,27–32] Due to its degree of complexity, intrathoracic anastomosis was usually avoided in minimally invasive surgery or performed using an open approach. However, from the results of a large cohort studies in the database, it was found that chest anastomosis was associated with a lower rate of leakage, alterations in swallowing and pharyngeal transit, and less RLN injury compared with neck anastomosis.[3,33] In February 2012, our team began to perform total MIE Ivor–Lewis procedures. Our pilot study demonstrated a mature technique of chest anastomosis and feasible outcomes with conventional MIE Ivor–Lewis procedures.[34] We began using RAILE to treat patients with mid-lower thoracic esophageal cancers when robot-assisted thoracic surgery became available in our department beginning in May 2015.

To date, the best manner in which to construct the intrathoracic anastomosis for the RAILE procedure remains controversial (i.e. stapled vs. hand-sewn). Some authors favor stapling the back part of the anastomosis and hand-sewing the anterior aspect. Hodari *et al.* reported a series of 54 patients using this robot-assisted technique. The mean operative time was 362 min, and the anastomotic leakage rate was 5.5% (3/54).[29] Sarkaria *et al.* first advocated performing a RAILE using the end-to-end anastomosis (EEA) with a circular stapled device. They reported a major postoperative complication (Grade III or greater) rate of 24% (5/21) and a significant anastomotic leakage (Grade II or greater) rate of 14% (3/21).[13] Recently, they updated their data with a series of 100 successive RAILEs, which represented the largest series of RMILE with EEA. Median operative times decreased significantly between the two halves of the experience from 447 to 357 minutes, and they reported a low anastomotic leakage rate of 6% (6/100).[35] Okusanya *et al.* reported an excellent experience in 25 patients who underwent RAILE with EEA with an anastomotic leakage rate of 4% (1/25).[36] As an alternative option, some studies proposed purely hand-sewn chest anastomosis. Cerfolio *et al.* first reported RAILE with a double-layer hand-sewn chest anastomotic technique in 16 patients.[15] The median operative time was 6 hours and 7 minutes, and there was a low complication rate (6.3%) with no anastomotic leakage.

In our institution, both the stapled and hand-sewn anastomotic techniques have been used. The comparisons of the perioperative outcomes between the two groups showed no significant difference, and both methods were safe and feasible. At the early stage of RAILE, based on our extensive experience of conventional MIE with circular-stapled anastomosis,[34] robot-assisted circular stapled anastomosis was routinely performed. However, the procedures have been switched to robot-assisted hand-sewn anastomosis from the 36th operation for multiple reasons. First, due to the lack of feedback and the availability of a robot-assisted circular stapler, when performing the stapled intrathoracic anastomosis, the bedside assistant places the stapler into the conduit in the correct orientation via the anterior assistant's port, handles part of the conduit and maintains the touch sensation and force control. With the simultaneous aid of robotic graspers and the bedside assistant, the spike and anvil can be married. With the rigid stapler in limited thoracoscopic space, the control of this process requires a good fit between the surgeon who manipulates the console and the assistant, which is sometimes difficult with the robot arms in place. Second, as we gained much experience from robot-assisted surgery, including lobectomy, segmentectomy and esophagectomy, we found that the robotic platform effectively and significantly improved the surgeon's ability to suture and make a visceral anastomosis, especially in deep and narrow sites such as the upper mediastinum. Compared with the stapled anastomosis, our hand-sewn technique is more controlled by the surgeon who manipulates the console, which leads to a more precise anastomosis. Third, we have been continuously optimizing our suture method for anastomosis. In the first half of the hand-sewn series, the posterior surface of the anastomosis was sutured with double-layer interrupted 3–0 Vicryl sutures. The whole process of anastomosis was long in duration, and our two cases of hand-sewn anastomotic leakage among these patients were possibly related to loose sutures. For the subsequent patients, we changed from an interrupted suture to a running 3–0 V Loc suture between the muscular esophageal layer and the gastric serosa. The operating time was reduced, and anastomotic leakage no longer occurred.

Another important issue is mediastinal lymph node dissection, which ensures patient survival after a radical esophagectomy for the treatment of esophageal carcinoma.[37] It has been shown that the RLN was the most common location of mediastinal nodal metastasis in esophageal squamous cell carcinoma (ESCC).[38] For conventional MIE, the rigid instruments have to reach deep into the thorax in a parallel manner during mediastinal lymph node dissection, which imposes problems for manipulation through the fulcrum effect at the ribs, thereby compromising maneuverability. The advantages of dexterity and accuracy with the robot system contribute to precise dissection and lymphadenectomy. One study by Park found that RAMIE enabled a more radical lymphadenectomy than a thoracoscopic esophagectomy, especially in the upper mediastinum.[32] Recently, Chao *et al.* reported that RAMIE resulted in a higher lymph node yield along the left RLN without increasing morbidity.[39] In this study, we reported similar results in an adequate lymphadenectomy, especially along the bilateral RLNs with the predominant pathological type of ESCC.

To our knowledge, this study represents the first report of RAILE for esophageal cancer from a large single institution in China, especially with two different methods of chest anastomosis. There are some limitations to this study. First, the use of the da Vinci Surgical System was not covered by medical insurance in China. Different from open and conventional MIE, patients had to pay a fixed additional fee of $4615 (RMB 30,000) for the robot-assisted surgery, which may be attributable to the boot fee of the robotic system and costs of the disposable robotic instruments. The patients were selected based on whether they agreed with the uninsured use of robot-assisted surgery, which may have caused selection bias. Second, the comparisons of the perioperative outcomes between the two groups were limited by the relatively small number of patients, as well as the impact of a learning curve. In addition, long-term survival outcomes were not reported in our study because of the short follow-up time of our cohort. One larger phase II trial, which is currently underway in our institution (NCT03140189), should provide more definitive data addressing the short- and long-term outcomes of RAILE.

Our initial experience of RAILE with both stapled and hand-sewn anastomosis is encouraging with acceptable complication rates, short hospital stays, and an adequate number of harvested lymph nodes. Regarding the best method for chest anastomosis, the level of evidence is suboptimal due to the relatively small difference between the two methods. Larger numbers of patients and a prospective study will be needed in the future to enable a proper statistical analysis.

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