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ORIGINAL SCIENTIFIC REPORT

Robotic Side-to-Side and End-to-Side Stapled Esophagogastric Anastomosis of Ivor Lewis Esophagectomy for Cancer

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Abstract

Background Both linear-stapled side-to-side esophagogastric anastomosis (LSEA) and circular-stapled end-to-side esophagogastric anastomosis (CEEA) are frequently used following esophagectomy. The aims of the present study were to review our experience of robotic intrathoracic alimentary tract reconstruction and to compare the short-term surgical outcomes of LSEA and CEEA in robotic Ivor Lewis esophagectomy.

Methods A prospectively collected dataset from 79 consecutive patients who underwent robot-assisted Ivor Lewis esophagectomy from February 2016 to December 2018 was retrospectively analyzed. Two groups (LSEA and CEEA) were classified according to the anastomotic mode. Demographic data, intraoperative characteristics and short-term surgical outcomes were compared between the two groups.

Results Two patients were converted to laparotomy. The remaining 77 patients (68 males and 9 females, mean age of 61.7 years) were successfully treated with completely robotic Ivor Lewis esophagectomy. According to the anastomotic procedure performed, 35 patients were categorized into the LSEA group and 42 patients were categorized into the CEEA group. The mean anastomotic time in the LSEA group was longer than that in the CEEA group (63.0 ± 9.0 vs. 44.2 ± 8.5 min, $p < 0.001$). No significant difference was detected in anastomotic complications, including leakage (8.6% with LSEA and 4.8% with CEEA, $p = 0.83$) and postoperative dysphagia (5.7% with LSEA and 16.7% with CEEA, $p = 0.26$). No statistical difference was observed for the other surgical outcomes. There was no incidence of in-hospital mortality and 30-day mortality in both groups.

Conclusions In robotic Ivor Lewis esophagectomy, both LSEA and CEEA were feasible and safe to be performed and surgeons can select either LSEA or CEEA based on their own technical expertise.

Introduction

Carcinoma of the distal esophagus and esophagogastric junction is an increasing public health burden [1, 2], for which Ivor Lewis minimally invasive esophagectomy (MIE) is considered as the preferred surgical approach. However, creating an intrathoracic esophagogastric anastomosis under conventional thoracoscopy is technically complex [3]. The procedure has been associated with increased morbidity, mortality and prolonged hospital stays if a leak occurs [4]; therefore, many surgeons prefer to perform open Ivor Lewis or laparoscopic gastric mobilization and open transthoracic esophagectomy.

In order to simplify intrathoracic esophagogastrostomy, da Vinci surgical robot was introduced. With the help of magnified three-dimensional visualization, improved articulation of instruments [5], da Vinci surgical system might facilitate the process of placing the anvil into the esophageal stump, suturing, and holding the anvil in place.

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Implementation of a surgical robot might therefore facilitate the extensive application of minimally invasive Ivor Lewis esophagectomy.

The optimal manner to construct the intrathoracic esophagogastric anastomosis for robot-assisted Ivor Lewis esophagectomy remains uncertain, and the anastomotic approach chosen is often based on surgeon preference. LSEA and CEEA are two most commonly used anastomotic techniques to reconstruct gastrointestinal continuity after esophagectomy [3]. Previous studies demonstrated that CEEA effectively reduced the leakage rate following esophagogastrostomy [6, 7]. However, compared with CEEA, LSEA was reported to be associated with a lower incidence of stricture rate [8], but LSEA is more complex because the anterior aspect of anastomosis is hand sewn. No sufficient evidence exists in the literature to definitively recommend one anastomotic technique over another [3]. To date, there is no comparative report for these two anastomotic techniques used in robotic Ivor Lewis MIE for patients with carcinoma of esophagus or cardia. The aims of the present study were to review our experience of robotic intrathoracic alimentary tract reconstruction and to compare the short-term surgical outcomes of LSEA and CEEA in robotic Ivor Lewis MIE.

Material and methods

Patients

From February 2016 to December 2018, 79 consecutive patients with carcinoma of distal esophagus or cardia underwent completely robot-assisted Ivor Lewis esophagectomy and two-field lymph node dissection in the Department of Thoracic Surgery, West China Hospital, Sichuan University. The data were retrospectively analyzed. All operations were performed by one surgical team, who had extensive experience in robotic McKeown esophagectomy and thoracolaparoscopic Ivor Lewis esophagectomy. Over 200 robot-assisted thoracic surgeries had been performed by our medical group before the first case of robotic Ivor Lewis MIE. In addition, our medical group also specialized in the techniques of CEEA and LSEA in esophagectomy [5, 9]. We initially performed robotic CEEA in 2016. Both LSEA and CEEA were conducted for robotic Ivor Lewis esophagectomy after August 2017. The indications for these two anastomotic procedures were identical. Neither randomized or selection bias existed for the selection of one anastomotic method over the other. The study protocol was approved by our institutional review board, and written informed consents were obtained from all of the patients.

All the patients underwent a systematic clinical examination and preoperative analysis. The inclusion criteria were as follows: (1) Patients were diagnosed with cancer of the lower esophagus or cardia by gastroscopy and biopsy; (2) the tumor was judged to be resectable based on chest and abdominal enhanced computed tomography (CT) and endoscopic ultrasound; (3) in selected cases, integrated fluorodeoxyglucose positron emission tomography was conducted to evaluate regional node involvement and excluded the presence of metastatic disease; (4) for the cardia tumors, patients were limited to those with Siewert I and II tumors. The exclusion criteria were as follows: (1) patients with severe comorbidities such as impaired cardiac, kidney, liver or lung function; (2) patients who required cervical lymphadenectomy; (3) tumors that involved a large proportion of the stomach and the patient who needed total gastrectomy and esophagojejunostomy; (4) the upper margin of the tumor was higher than the level of the inferior pulmonary vein as detected by the CT scan.

Surgical procedure

The surgical procedures were similar between two groups with the exception of the anastomotic techniques. A four-arm da Vinci Si robotic system (Intuitive Surgical, Inc., USA) was used. In the abdominal stage, the patient was placed in the reverse Trendelenburg position. One assistant port was created, and four ports for introducing camera and instruments were created (Fig. 1a). Insufflation with CO2 was used at a pressure of 12 mm Hg. The patient cart was positioned at the patient's head. The left lobe of the liver was retracted using two slings of Prolene suture as previously reported [10]. The left gastric artery and vein were secured by clips and divided with concomitant resection of the local lymph nodes along common hepatic artery, celiac trunk and origin of splenic artery. Afterward, the gastrocolic ligament and the short gastric vessels were transected. A 4-cm-wide gastric conduit was extracorporeally or intracorporeally created. Since extracorporeal gastric tube formation allowed maximal length to be achieved due to its full length while stapling, it was preferable to form the gastric conduit out of the abdominal cavity (through which a 5-cm incision was created below the xiphoid process) when the stomach was too small or a longer conduit was needed. From the incisura on the lesser curve to the fundus, a gastric conduit was created using four to six firings of an endoscopic linear stapler (ECHELON FLEX™ Powered ENDOPATH® Stapler, Johnson and Johnson Company, New Brunswick, NJ, USA). For patients who underwent laparoscopic gastric conduit formation, a portion of the proximal stomach was left connected, which facilitated delivering of the conduit into the right thorax. The staple line was over-sewn with barbed suture (Stratafix Sporal

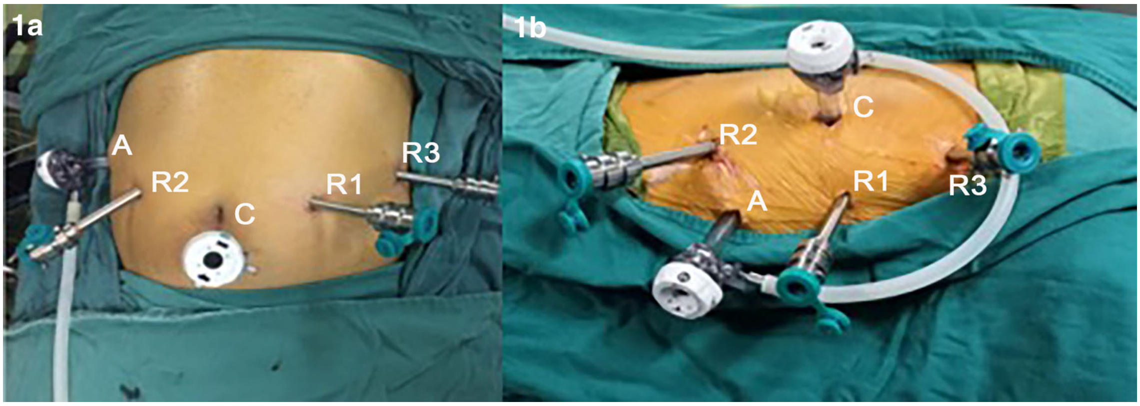

Fig. 1 **a** A 12-mm observational hole for the camera was created just below the umbilicus (C). A 12-mm trocar for the bedside assistant was placed at the right anterior axillary line below the costal arch (A). Three 8-mm trocars for the instruments were inserted: robotic arm 3 (R3) was placed at the left anterior axillary line about 2 cm below the costal arch; robotic arms 2 (R2) and 1 (R1) were placed at the left and right mid-clavicular line about 2 cm above the umbilicus plane, respectively; **b** A 12-mm trocar for the tableside assistant was placed at the 7th intercostal space in the posterior axillary line (A), and a 12-mm trocar for camera was inserted at the 6th intercostal space just below scapula angle (C). Three 8-mm trocars for robotic instruments were inserted: one for robotic arm 3 in the 3rd intercostal space anterior to scapula (R3), one for robotic arm 2 in the 8th intercostal space posterior to the posterior axillary line (R2) and the third one for robotic arm 1 in the 5th intercostal space between the scapula angle line and posterior axillary line (R1)

3/0, Ethicon Endo-surgery, USA). Finally, hemostasis was checked and the incisions were closed.

Thereafter, the patient was turned to the semi-prone position. Five ports were firstly created as shown in Fig. 1b. All patients underwent subtotal esophagectomy with two-field lymphadenectomy. A double-lumen endotracheal intubation was used to allow right-sided isolation of the lung. The patient cart was introduced at the dorsocranial side of the patient and was docked 45 degrees counterclockwise from the craniocaudal axis of the patient. Figure 2 illustrates the anastomotic techniques of LSEA and CEEA, respectively. Side-to-side linear-stapled anastomosis was created for the group of LSEA (Fig. 3). In detail, the esophagus was transected at the plane of predicted anastomotic site. The tip of the gastric tube lies behind the esophageal stump in the esophageal bed. A small gastrotomy was made at the conduit approximately 4 cm below the tip of the gastric tube. Then, a linear stapler was introduced from the assistant port and inserted into both the conduit and the esophageal lumen, and an

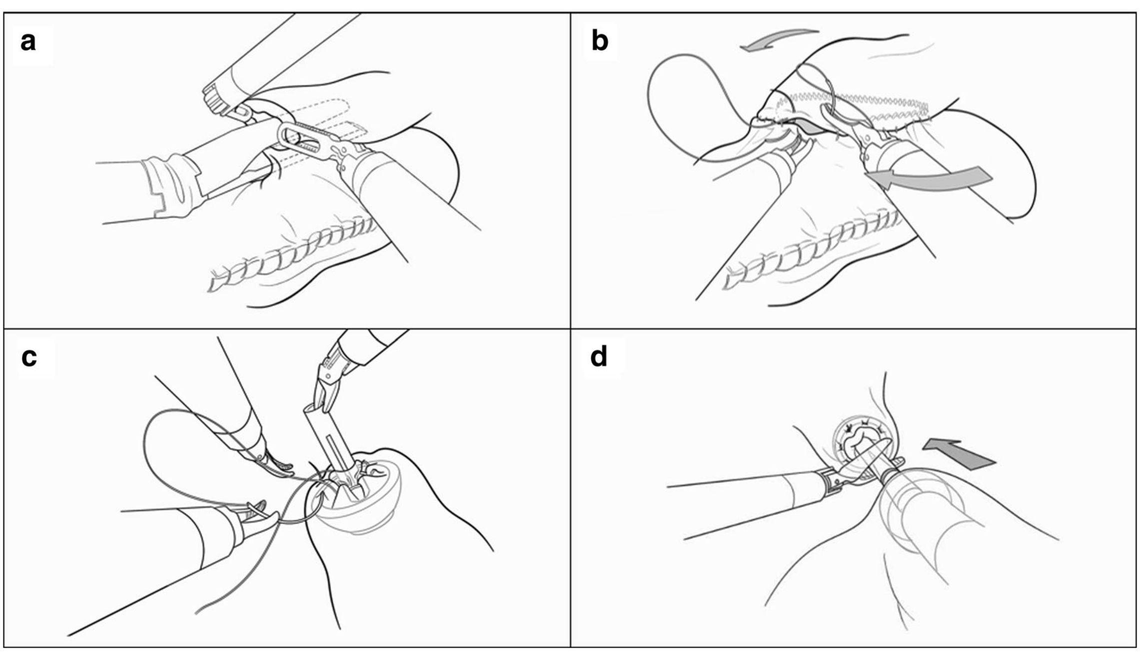

Fig. 2 Diagrams illustrating the technique of LSEA (**a**, **b**) and CEEA (**c**, **d**), respectively

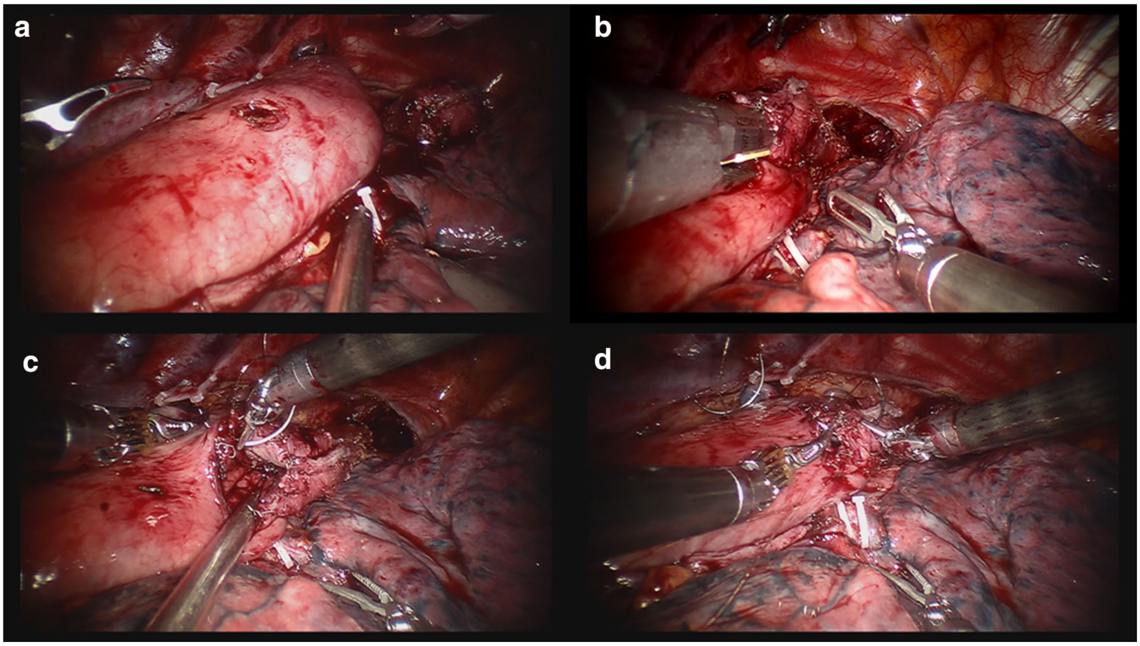

Fig. 3 Intrathoracic side-to-side linear-stapled anastomosis: **a** a small gastrotomy made at the conduit approximately 4 cm below the tip of the gastric tube; **b** creating the posterior wall of the anastomosis using linear stapler; and **c**, **d** continuously oversewing the anterior wall of the anastomosis with barbed suture

approximately 3 cm anastomosis was created with 3.8-mm staples. The gap of the anterior wall was closed with continuous single-layer barbed suture (Stratafix Sporal 3/0, Ethicon Endo-surgery, USA). For the end-to-side circular-stapled anastomosis in the group of CEEA (Fig. 4), the procedure involved placing the anvil into the esophagus stump as previously reported [11], and then, purse-string sutures were employed to secure the anvil of the stapler in place. The assistant port was extended and used for introducing the stapler and removing the specimen. The end-to-side anastomosis was completed using a 25-mm circular stapler with 3.5-mm staples (CDH stapler, Ethicon Endo-Surgery, USA), and then, the gastrotomy was transected with a linear stapler. Finally, the nasogastric tube and chest tube were positioned in the two groups.

Baseline demographic and clinical information were prospectively collected. Currently, the definitions and incidences of anastomotic stricture and leak after esophagectomy are diverse in the literature and there has been no standard criterion for anastomotic complications [12]. In the present study, dysphagia included patients with any complaint of postoperative dysphagia as previously reported [13]. The diagnosis of anastomotic leakage was based on routine radiographic findings, clinical symptoms and endoscopic assessments.

Statistical analysis

Data were described as mean ± standard deviation (SD) for continuous variables and frequency (%) for categorical variables and analyzed using the statistical software package version 20.0 (SPSS Inc., Chicago, IL, USA). The Chi-square test or Fisher's exact test was used to compare the distribution of categorical variables between groups. Continuous variables were analyzed using a Student's t test or Wilcoxon rank sum test. A two-sided p value < 0.05 indicates a statistically significant difference.

Results

From February 2016 to December 2018, a total of 79 patients received robot-assisted Ivor Lewis esophagectomy. Two patients in the CEEA group were converted to laparotomy, one for removing the fused lymph nodes invading the celiac trunk and the other underwent a total gastrectomy and esophagojejunostomy because of extensive gastric involvement. Among 77 patients (68 males and 9 females, mean age of 61.7 ± 8.2 years) who underwent completely robotic Ivor Lewis esophagectomy, 35 patients were categorized into the LSEA group and 42 patients were categorized into the CEEA group according to the anastomotic procedure they received. Neoadjuvant therapy was performed in sixteen of these patients. Baseline characteristics were shown in Table 1. Patients in two groups

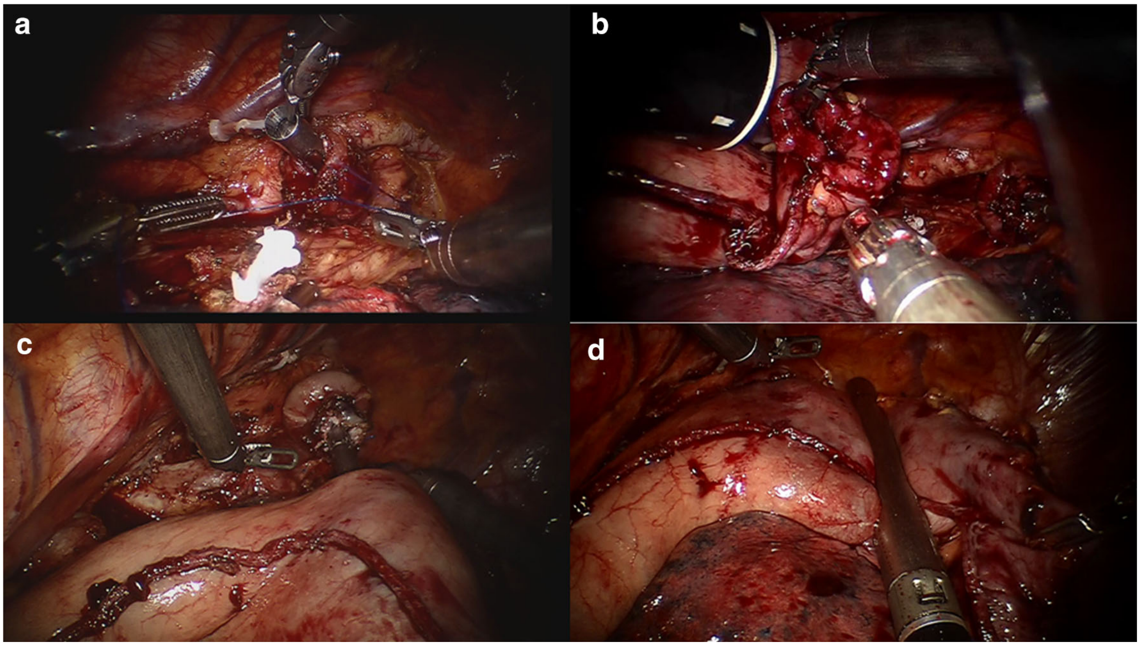

Fig. 4 Intrathoracic end-to-side circular-stapled anastomosis: **a** securing the anvil of the stapler in the esophageal stump, **b** the gastrotomy through which the circular stapler entered the stomach, **c** docking the stapler's center rod with the anvil shaft to complete the anastomosis, and **d** the linear stapler excising the gastrotomy site

were comparable for age, gender, BMI, tumor location, pathologic stage, neoadjuvant therapy and preoperative comorbidities. All of the patients were observed for at least 1 months (median follow-up was 2.8 months in the LSEA group and 3.0 months in the CEEA group) following surgery to assess postoperative short-term outcomes. The follow-up protocol included physical examination, chest abdominal CT scans and X-ray barium meal (Fig. 5). In selected cases, Upper GI endoscopy, radionuclide bone scans and PET-CT scans were performed.

Intraoperative variables were shown in Table 2. The mean total operation time was 355.6 ± 45.3 min in the LSEA group and 343.3 ± 41.6 min in the CEEA group ($p = 0.26$). The mean anastomotic time was 63.0 ± 9.0 min in the LSEA group and 44.2 ± 8.5 min in the CEEA group ($p < 0.001$), which revealed linear-stapled anastomosis required more time than the circular-stapled anastomosis. The mean numbers of lymph nodes harvested were 22.5 ± 6.1 in the LSEA group and 20.5 ± 6.0 in the CEEA group ($p = 0.20$). Estimated intraoperative blood loss was 108.6 ± 11.5 ml in the LSEA group and 113.4 ± 23.3 ml in the CEEA group ($p = 0.64$). All patients received R0 resection, and no intraoperative massive hemorrhage occurred.

Postoperative short-term outcomes are shown in Table 3. The mean duration of ICU stays, hospital stay and chest tube, postoperative complications and pathologic staging were not statistically different between the two groups. Postoperative complications (the group of LSEA and CEEA) included anastomotic leakage ($n = 3$; 8.6% and $n = 2$; 4.8%, $p = 0.83$), pulmonary infection ($n = 3$; 8.6% and $n = 4$; 9.5%, $p = 1.00$), hoarseness ($n = 2$; 5.7% and $n = 3$; 7.1%, $p = 1.00$), chylothorax ($n = 1$; 2.9% and $n = 0$, $p = 0.93$), arrhythmia ($n = 1$; 2.9% and $n = 0$, $p = 0.93$), diaphragmatic hernia ($n = 0$ and $n = 1$; 2.4%, $p = 1.00$), mediastinitis ($n = 0$ and $n = 1$; 2.4%, $p = 1.00$) and postoperative dysphagia ($n = 2$; 5.7% and $n = 7$; 16.7%, $p = 0.26$).

Intrathoracic anastomotic leaks in the two groups were managed effectively by mediastinal drainage through the chest tube. Only one patient in the CEEA group underwent stricture dilation, and other patients with dysphagia were managed conservatively. There was no incidence of in-hospital mortality and 30-day mortality in both groups.

Discussion

Conventional thoracoscopy has several limitations, including disturbed eye–hand coordination, limited motion of straight instruments, two-dimensional imaging and poor ergonomics for the surgeon. Therefore, creating an intrathoracic esophagogastric anastomosis using conventional thoracoscopy is still a technically complex procedure. In order to simplify intrathoracic esophagogastrostomy, da Vinci surgical robot was introduced. With the help of magnified three-dimensional visualization, improved articulation of instruments, robotic

Table 1 Baseline characteristics of the patients

Characteristics	LSEA (*n* = 35)	CEEA (*n* = 42)	*p* value
Age (year), mean ± SD	61.4 ± 9.2	61.9 ± 7.8	0.82
Gender, *n* (%)			0.26
Male	33 (94.3%)	35 (83.3%)	
Female	2 (5.7%)	7 (16.7%)	
BMI, mean ± SD	22.6 ± 4.4	22.9 ± 2.2	0.69
Tumor location, *n* (%)			0.33
Distal esophagus	27 (77.1%)	36 (85.7%)	
Cardia	8 (22.9%)	6 (14.3%)	
Comorbidities, *n* (%)			
Hypertension	4 (11.4%)	10 (23.8%)	0.16
COPD	5 (14.3%)	7 (16.7%)	0.77
Diabetes mellitus	2 (5.7%)	4 (9.5%)	0.85
Arrhythmia	2 (5.7%)	2 (4.8%)	1.00
Cerebral infarction	0	1 (2.4%)	1.00
Pathological pattern, *n* (%)			
Squamous cell carcinoma	25 (71.4%)	34 (81.0%)	0.33
Adenocarcinoma	9 (25.7%)	5 (11.9%)	0.45
Adenosquamous carcinoma	0	1 (2.4%)	1.00
Small cell carcinoma	1 (2.9%)	2 (4.8%)	1.00
pTNM, *n* (%)			
0	0	2 (4.8%)	0.56
IA	2 (5.7%)	1 (2.4%)	0.87
IB	2 (5.7%)	1 (2.4%)	0.87
IIA	7 (20.0%)	6 (14.3%)	0.51
IIB	12 (34.3%)	8 (19.0%)	0.13
IIIA	3 (8.6%)	10 (23.8%)	0.08
IIIB	6 (17.1%)	9 (21.4%)	0.64
IIIC	3 (8.6%)	3 (7.1%)	1.00
Neoadjuvant therapy, *n* (%)	8 (22.9%)	8 (19.0%)	0.68

BMI body mass index, *COPD* chronic obstructive pulmonary disease

intrathoracic anastomosis seems a more promising procedure compared with conventional VATS operation. Since we introduced surgical robot for Ivor Lewis esophagectomy for cancer in 2016, our standard surgical policy for the treatment of resectable carcinoma of the distal esophagus and esophagogastric junction has been robot-assisted Ivor Lewis esophagectomy with two-field lymph node dissection.

The major complications after esophagectomy, such as anastomotic leakage and anastomotic stricture, were frequently encountered and can compromise postoperative quality of life or be life threatening [8, 14]. Therefore, successful anastomosis is essential for minimizing morbidity and improving postoperative quality of life. Furthermore, the incidence of anastomotic complications is a good indicator to evaluate the effectiveness of an anastomotic mode.

We initially performed CEEA for robotic Ivor Lewis MIE in 2016. According to our practical experience, the exposure of the operative field during the creation of the circular-stapled anastomosis was more limited than that of linear-stapled one, particularly when inserting the circular stapler into the gastric tube and piercing the stapler's center rod through the wall of gastric conduit. Since August 2017, LSEA was also conducted for robotic Ivor Lewis MIE. The indications for these two anastomotic procedures were identical in our study.

Anastomotic leakage is a serious surgical complication following esophagectomy. The incidence of anastomotic leak in our patient cohort (6.49%) was similar to that reported elsewhere [15, 16]. We speculated there was a trend toward higher leak rates in the LSEA group compared to the CEEA group, even though no statistical difference was found (8.6% with LSEA and 4.8% with CEEA,

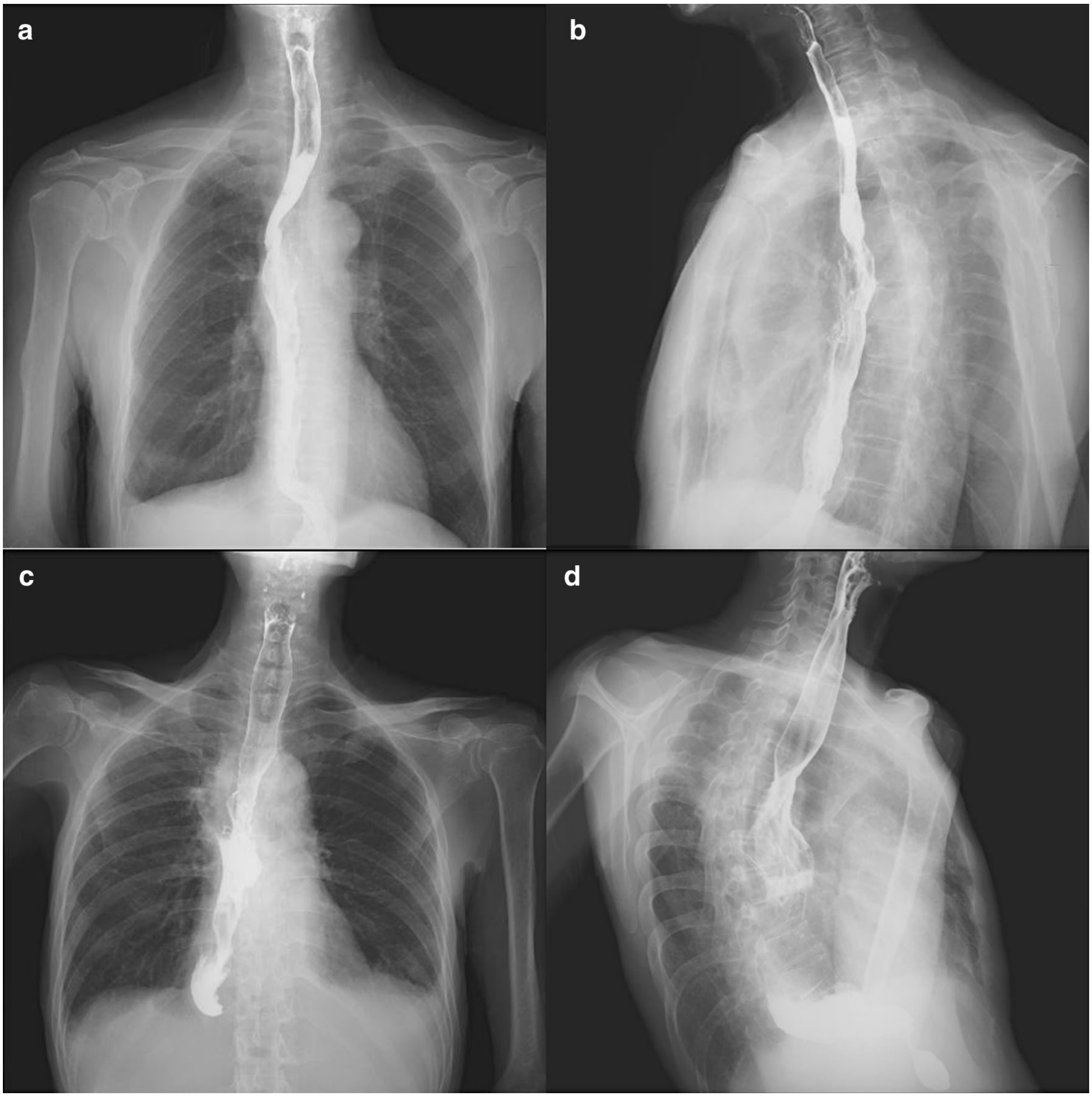

Fig. 5 Barium swallow comparing these two anastomotic procedures: LSEA (**a**, **b**) and CEEA (**c**, **d**)

Table 2 Intraoperative data

Variables	The group of LSEA (n = 35)	The group of CEEA (n = 42)	p value
Total operation time (min), mean ± SD	355.6 ± 45.3	343.3 ± 41.6	0.26
Anastomotic time, mean ± SD	63.0 ± 9.0	44.2 ± 8.5	< 0.01
ASA, mean ± SD	2.5 ± 0.5	2.6 ± 0.5	0.56
Number of lymph nodes dissection, mean ± SD	22.5 ± 6.1	20.5 ± 6.0	0.20
Estimated blood loss (ml), mean ± SD	108.6 ± 11.5	113.4 ± 23.3	0.64

ASA American Society of Anesthesiologists

p = 0.83). These observation may be due to the following factors: (I) as adequate mobilization of the proximal esophagus was needed for LSEA [17], a longer mobilized esophageal stump might be associated with a poor blood supply and (II) lack of tactile feedback resulted in inadvertent injury, especially when manipulating friable tissue

Table 3 Postoperative variables

Variables	The group of LSEA (*n* = 35)	The group of CEEA (*n* = 42)	*p* value
Median follow-up (months)	2.8 (1–5)	3.0 (1–6)	0.52
ICU length of stay, mean ± SD	0.9 ± 0.3	1.1 ± 0.6	0.07
Hospital stay, mean ± SD	11.7 ± 4.6	12.8 ± 4.7	0.37
Duration of chest tube, mean ± SD	8.1 ± 1.8	8.9 ± 4.4	0.43
Complications, *n* (%)			
Anastomotic leakage	3 (8.6%)	2 (4.8%)	0.83
Hoarseness	2 (5.7%)	3 (7.1%)	1.00
Pneumonia	3 (8.6%)	4 (9.5%)	1.00
Chylothorax	1 (2.9%)	0	0.93
Atrial fibrillation	1 (2.9%)	0	0.93
Diaphragmatic hernia	0	1 (2.4%)	1.00
Mediastinitis	0	1 (2.4%)	1.00
Postoperative dysphagia[a], *n* (%)	2 (5.7%)	7 (16.7%)	0.26
30-day mortality	0	0	

[a]Postoperative dysphagia was defined in this study as any complaint of dysphagia

near the anastomosis. This possible injured tissue was removed in the CEEA group after completing the anastomosis while reserved as part of the anastomotic wall in the LSEA group.

Due to the creation of an enlarged anastomotic caliber and postoperative symptomatic dysphagia which rarely occurs, LSEA is an attractive alternative for gastroesophageal anastomosis reconstruction [3, 9, 18]. In our study, the overall incidence of postoperative symptomatic dysphagia was 11.69% (5.7% in the LSEA group and 16.7% in the CEEA group, $p = 0.26$), which is better than that of the previously reported study (22–56%) [13]. Though the incidence of postoperative symptomatic dysphagia was not statistically significant between the two groups, it was three times higher in the CEEA group compared to the LSEA group. We speculated that the possible reason might be due to the small sample and lack of objective assessment for the lumen of the anastomosis of our study. In addition, our previous prospective randomized controlled trial revealed that LSEA could prevent stricture formation more effectively than CEEA without increasing gastroesophageal reflux [9].

The time to perform the anastomosis in the CEEA group was shorter than in the LSEA group ($p < 0.01$). This may be due to the total mechanical stapled esophagogastrostomy in the CEEA group, while suturing on anterior anastomotic wall was needed in the LSEA group. However, differences in the time to fashion the anastomosis are unlikely to be a major primary outcome, but rather parameters such as anastomotic leak and morbidity rate are more important. Neither of the two techniques described showed clear proof of superiority over the other for gastroesophageal anastomosis since no surgical outcome was found to be statistically different between the two groups. Surgeons can select either LSEA or CEEA based on their own preference and technical expertise.

Based on our experience and the presented results, surgical robot simplifies sutures and knots, which is essential for thoracoscopic digestive reconstruction during minimally invasive Ivor Lewis esophagectomy. However, some limitations still exist. Firstly, the lack of tactile feedback probably caused more inadvertent injury, particularly when manipulating friable tissue near the anastomosis. Secondly, the time required to dock, undock and exchange instruments is cumbersome in robotic surgery. Thirdly, most patients could not afford to the cost of robotic surgery without health insurance coverage, and finally, the surgeon is physically separated from patient and is outside of the sterile operative field, raising potential safety concerns [19]. In addition, there are also some inherent limitations of our study: (1) It was a retrospective study and lacked of long-term outcomes; (2) the number of patients was relatively small making it difficult to detect differences of anastomotic leakage and dysphagia which might reach significance if the number of patients was larger; (3) relatively few patients (20.8%) with resectable locally advanced thoracic ESCC received neoadjuvant therapy; (4) anastomotic complications are undoubtedly multifactorial and might not be solely explained by anastomotic technique. These limitations may be addressed by performing a randomized controlled trial with long-term outcomes to improve the higher level of evidence in the near future.

Conclusions

In robotic Ivor Lewis esophagectomy, both LSEA and CEEA were feasible and safe to perform. Based on their own level of technical expertise, surgeons can select the preferred technique.

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Compliance with ethical standards

Conflict of interest There is no conflict of interest for all of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

Ethical standard The study protocol was approved by the applicable institutional review board.

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