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A safe and effective anastomotic technique for robot-assisted minimally invasive oesophagectomy: Reverse-puncture anastomosis

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Abstract

Background: Oesophagogastric anastomosis is mainly complicated by its tediousness. We hope to modify an oesophagogastric anastomotic technique that simplifies anastomosis.

Methods: We conducted a retrospective analysis of 57 cases executed using reverse-puncture anastomotic (RPA) technique and 64 cases of manual purse anastomosis (MPA) technique for robot-assisted minimally invasive oesophagectomy (RAMIE). Baseline characteristics and perioperative outcomes were analysed.

Results: There were no significant differences between the 2 groups with regards to demographic data and clinical features. All patients had R0 resection. Relative to MPA, RPA group experienced significantly shorter operation times (232.5 ± 33.84 min vs. 262.3 ± 83.94 min, $p = 0.038$).RPA group patients had shorter anastomotic times relative to MPA group patients (10.5 ± 3.4 min vs. 18.3 ± 4.1 min, $p = 0.014$). No adverse events were observed.

Conclusions: Reverse-puncture anastomosis is safe, feasible in RAMIE. This approach has the potential to efficiently shorten the anastomotic time and ensure safe operation.

KEYWORDS
3D, oesophagectomy, minimal invasive surgery, oesophagus

1 | INTRODUCTION

Oesophageal cancer (EC) is the sixth most common cause of cancer-associated deaths worldwide. And its global incidence has increased significantly in the past 4 decades.[1,2] In China, EC is a burden and a strain on the health care system.[3] Radical oesophagectomy is the cornerstone of multimodal treatment aimed at curing EC.[4] Ivor Lewis[5] and McKeown[6] oesophagectomy are the main minimally invasive oesophagectomy (MIE) methods.[7]

Transthoracic oesophagectomy is associated with a considerable degree of morbidity[8] and oesophagogastric anastomosis leakage is a significant source of perioperative morbidity and occasional

oesophagectomy mortality.[9] Various techniques are currently used for oesophagogastric reconstruction but their effects on post-operative anastomotic leakage and morbidity have not been examined.[10] Cervical anastomosis is easier to execute, and convenient for treating anastomotic leakage in case of postoperative complication. Intrathoracic anastomosis after MIE is associated with a lower rate of anastomotic leakage and better functional outcomes.[11]

Multiple factors may cause anastomotic complications, including surgical technique. The most commonly used anastomotic methods following oesophagectomy are hand-sewn (HS), circular-stapled and semi-mechanical linear-stapled (LS)[12] techniques. Here, we find that no anastomotic technique is superior in terms of limiting post-operative complications or shortening anastomotic time.[13] However, with advancements in surgical instrumentation, robot-assisted minimally invasive oesophagectomy (RAMIE) has become increasingly popular. RAMIE has the potential to avoid some of the pitfalls of conventional TAMIE, especially lymph node dissection of recurrent laryngeal nerve. Robotic surgery offers better dexterity and lower surgeon fatigue. This approach aims to reduce surgical trauma and postoperative complications, thereby improving postoperative outcomes.[14] Thus, we hope to develop an ideal anastomotic technique that saves time, whilst ensuring operation safety.

Here, we describe reverse-puncture anastomotic (RPA), an improved RAMIE-based gastroesophageal anastomotic technique that aims to simplify the complex steps of manual purse. We offer suggestions on treatment options for surgeons regarding oesophagogastric reconstruction approaches using a gastric tube during oesophagectomy.

2 | MATERIALS AND METHODS

2.1 | Patients

We retrospectively analysed clinical data on 121 patients treated in Affiliated Jinling Hospital, Medical School of Nanjing University between January 2017 and August 2019. Of these, 57 underwent RPA, whilst 64 underwent Manual-Puncture Anastomotic (MPA) technique for oesophagectomy. The diagnoses and clinical information were collected by consulting medical records of the patients. All those patients routinely underwent endoscopic ultrasound examination, chest computed tomography (CT).The demographic and clinical characteristics were composed of age, sex, body mass index (BMI) and basic illness (including hypertension, diabetes and chronic obstructive pulmonary disease [COPD]). Tumour associated data, in terms of tumour histology, size and location were also collected. The surgical related data included total-operative time, anastomotic time, intraoperative bleeding, lymph-nodes removed, postoperative hospital stay, intraoperative adverse events and complications. The decision of the site of the anastomosis depended on the tumour resection margin. Passage was re-established by a gastric conduit. Anastomotic leakages were detected by endoscopy. Diagnostic criteria of anastomotic leakage accordingly to the ECCG. Ethical

approval for the study was granted by our institutional review board and written informed consent was obtained from each participant.

2.2 | Inclusion criteria

(1) Patients were preoperatively diagnosed with distal esophagus and oesophagogastric junction squamous cell carcinoma of esophagus. (2) No enlargement of cervical lymph nodes based on preoperative CT. (3) Head CT, bone scan and PET-CT suggest that there is no distant metastasis of cancer, poor cardiac, lung function or severe arrhythmia.

2.3 | Exclusion criteria

(1) Patients with severe comorbidities, such as impaired cardiac, kidney, liver and/or lung function. (2) Patients with severe chest adhesions, history of right chest trauma, surgery and tuberculosis. (3) The tumour involved a large proportion of the stomach and the patient required total or subtotal gastrectomy and oesophagojejunostomy. (4) Patients refused to undergo this modified surgical approach.

2.4 | Surgical procedure

2.4.1 | Preoperative preparation

Preoperative preparation was same as for conventional surgery. Intubation can be done via double-lumen endotracheal intubation or single lumen with a bronchial occluder. After intubation, intravenous-inhalation combined anaesthesia was given and an artificial pneumothorax applied on the lung, on the side of the operation to ensure its complete collapse.

2.5 | Abdominal operation

The patient was in a supine position. About 12 mm trocar under the umbilicus was placed into an robotic observation hole. An incision with a length of about 1 cm was taken from the left upper part of the umbilicus, the right upper part of the umbilicus and 2 cm below the bilateral ribs. Artificial pneumoperitoneum was performed, and the lens was placed under the umbilicus for exploration. The exploration results are as shown above. Lift the colon, cut the gastrocolic ligament, free the great curvature of the stomach to the secluded entrance and keep the right blood vessel of the gastric omentum. Free the left side of the greater curvature of stomach to below the gastric ligament. Cut off the short gastric artery, free the bottom of the stomach to the cardia, turn up the stomach, expose the left gastric artery, separate the left gastric artery, clean the surrounding lymph nodes by skeletal ligation and ligate the left gastric artery at the distal end and proximal end, respectively. Cut off the left artery

from the middle with ultrasonic knife, and cut off the hepatogastric ligament and its lymph nodes from the right side of the cardia down to the toughness of the hepatoduodenum, enlarge the muscle hole, remove the device, and take a 5-cm incision along the midline under the xiphoid process.

2.6 | Thoracic operation

With help of the robot, we tried to free the thoracic oesophagus and execute lymph node dissections. For this, the patient is usually in the left lateral position, slightly leaning forward if necessary to expose the oesophagus (Figure 1). Four ports were then positioned as shown in Figure 1. A 12-mm camera port was then inserted in the sixth intercostal space (ICS) at the anterior axillary line. Two 8-mm ports were inserted in the ninth ICS at the posterior axillary line and in the fourth ICS at the anterior axillary line, respectively, for the first and second working ports. Finally, a 12-mm assistant port was created in the seventh ICS of anterior axillary line. This port allows the assistant to pull the lung and expose the oesophagus better. Thus, the oesophagus can be successfully separated using the two robotic arms. The oesophagus was mobilised en bloc from the thoracic inlet to the gastroesophageal junction. Next, the corresponding lymph node parts were dissected and the conduit pulled up through the hiatus. MPA and RPA were used for RAMIE.

2.7 | RPA technique

Firstly, a knot was made through the small hole at the tip of the puncture head. This knot should not be too tight, as this would make it difficult to pull out the circular stapler. The length of the oesophageal hemi-transection should be kept at between 2 and 3 cm. Next, we inserted a 60 mm × 38 mm circular stapler into the oesophagus (Figure 2A). We then used an endoscopic stapler to close the oesophageal stump (Figure 2B). Next, we slowly, vertically pulled out the circular stapler which was tied with a knot (Figure 2C) with the tubular stomach pulled into the chest through the enlarged hiatus. After that, the circular staple was used to pierce the centre rod of the completed tubular stomach and docked with an anvil (Figure 2D). An endoscopic stapler was then used to close the incision on the tubular-stomach and purse-string suture used to reinforce the anastomotic stoma. Finally, integrity of the anastomosis was examined (Figure 3).

2.8 | MPA technique

The first three stitches of purse string in turn were at 3, 12 and 9 O'clock positions of the oesophageal wall. Especially the final stitch was used to assist the oesophagus to rotate 90° clockwise, which facilitate placement. Then we rotated the oesophagus 90° counterclockwise to facilitate placement of the fourth stitch at the 3 o'clock position. After that, a transverse incision was made in the anterior oesophageal wall, 2–3 cm distal to the purse-string suture. The incision was held open at the 3 and 9 o'clock positions, straighten the oesophagus inferiorly and posteriorly and the anvil of a 25-mm circular stapler was inserted. The purse string is tied tight and knotted with a knot pusher. After the first knot was finished, one end of the string was re-circled through back wall of oesophagus and tied to complete the second knot. The distal oesophagus was transected 0.5 cm from the purse string. The gastric conduit was pulled into the thoracic cavity, and the circular stapler was inserted through the main port to construct an oesophagogastric end-to-side anastomosis. At last, the gastric conduit was stapled with a linear stapler.
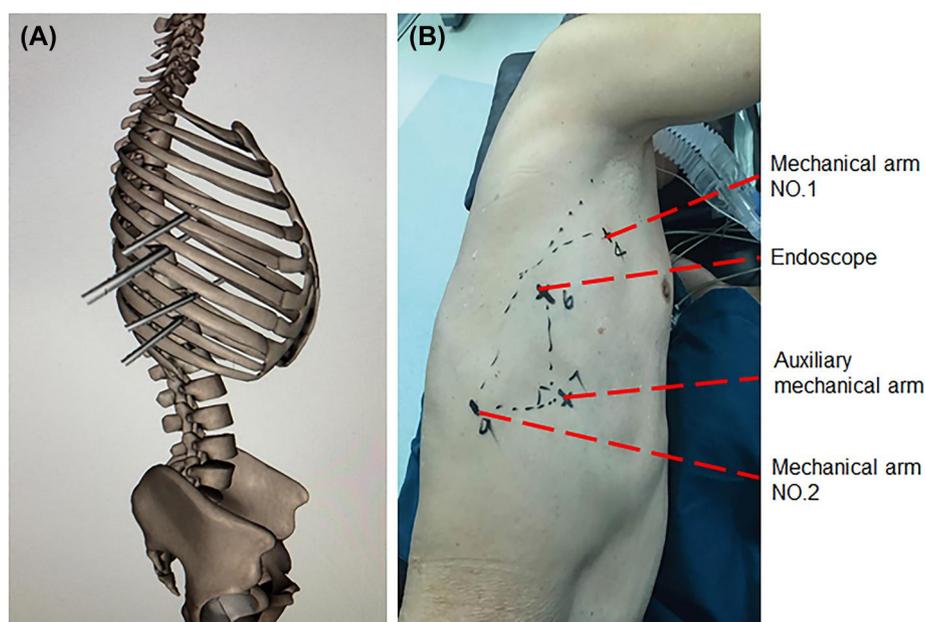
FIGURE 1 Port positions for minimally invasive oesophagectomy
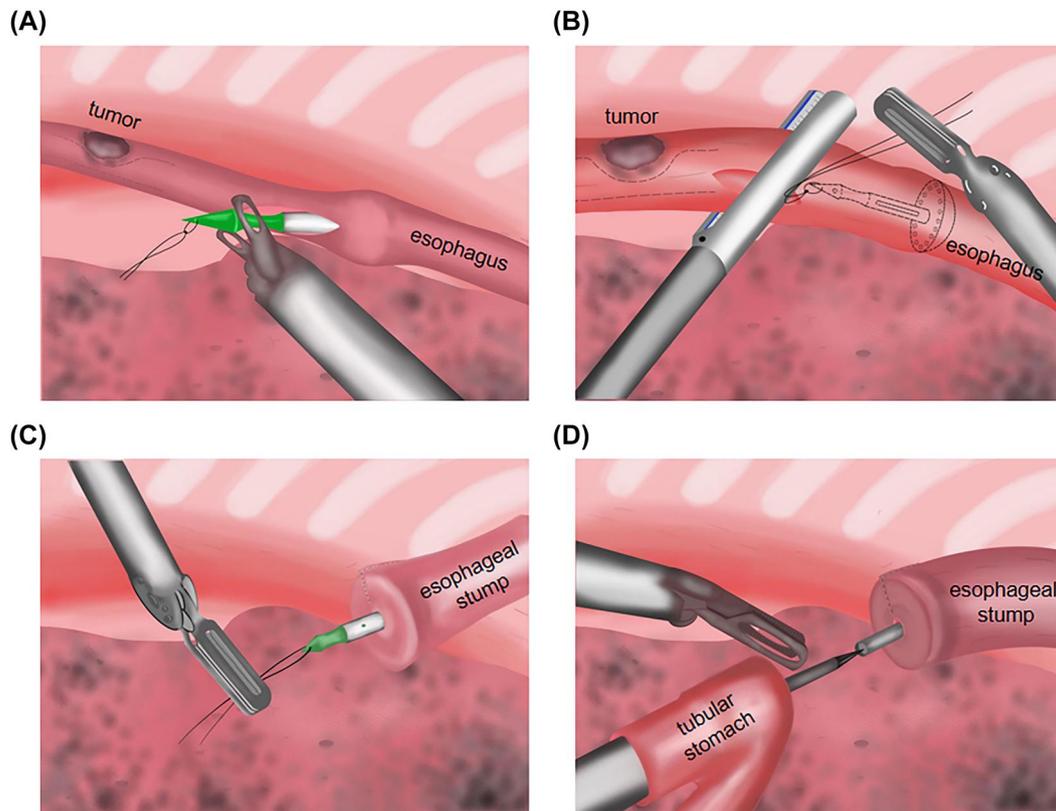
FIGURE 2 A) Circular stapler inserted into the oesophagus. (B) Use an endoscopic stapler to close an oesophageal stump. (C) Slowly, vertically pull out the circular stapler that was tied with a knot. (D) Let the circular staple pierce the centre rod of the completed tubular stomach and docked with an anvil
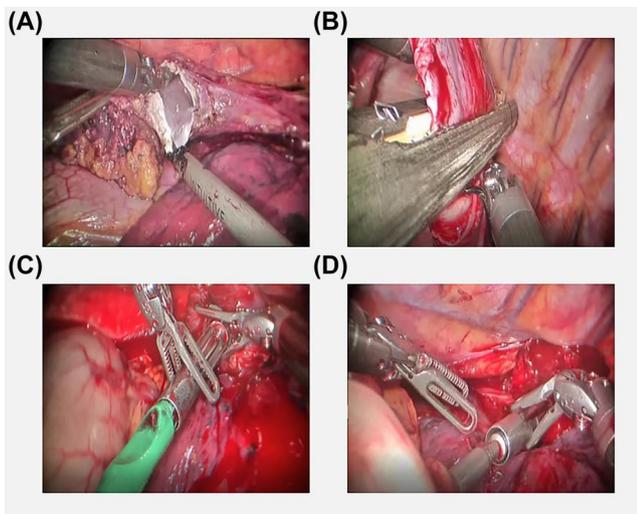
FIGURE 3 Pictures of the operation

2.9 | Statistical analysis

This is a safety and feasibility study of a modified surgical technique. Categorical data are expressed as values and percentage. Continuous data are reported as mean ± SD. Data were prospectively recorded on Microsoft Office Excel 2003. Data were analysed using SPSS (IBM). Student's t-test or Wilcoxon rank-sum test was used to compare continuous variables between groups. Chi-squared test or Fisher's exact test was used to compare categorical data. A 2-sided $p < 0.05$ indicates statistical significance.

3 | RESULTS

3.1 | Patient characteristics and anastomotic techniques

We retrospectively analysed clinical data on 121 patients with a mean age of 65 years (range 45–77 years) treated at our hospital between January 2017 and August 2019. A total of 57 patients underwent RPA and 64 with traditional technique for RAMIE. Demographic and clinical features are shown in Table 1. No significant differences were observed between the RPA and MPA-treated patients with regards to age, sex, body mass index, basic illness and neoadjuvant therapy.

3.2 | Cancer outcome

Detailed results on tumour associated data are listed in Table 2. All patients had R0 resection, including the distal oesophagus and cardia, Most of the cardia were adenocarcinomas. Thus, there were no

TABLE 1 Demographic and clinical characteristics

	RPA n (%) (N = 57)	MPA n (%) (N = 64)	p-value
Age, years			
Median (range)	64.7 (45–79)	65.6 (50–77)	0.737
≥60	41 (71.9)	47 (73.4)	0.933
<60	16 (28.1)	17 (26.6)	
Gender			
Male	47 (82.5)	52 (81.3)	0.678
Female	10 (17.5)	12 (18.7)	
BMI, kg/m^2			
≤25	21 (36.8)	25 (39.1)	0.944
>25	36 (63.2)	39 (60.9)	
Basic illness			
Hypertension	15 (26.3)	21 (32.8)	0.350
Diabetes	4(7.0)	5(7.8)	
COPD	3(5.3)	5(7.8)	
Neoadjuvant therapy			
Radio-therapy only	2(3.5)	3(4.7)	0.287
Chemo-therapy only	0(0.0)	1(1.6)	
Chemo-radio therapy	1(1.8)	1(1 .6)	

Abbreviations: BMI, Body mass index; COPD, chronic obstructive pulmonary disease; MPA, manual purse anastomosis; RPA, reverse-puncture anastomosis.

TABLE 2 Tumour associated data

	RPA n (%) (N = 57)	MPA n (%) (N = 64)	p-value
Tumour histology			
Squamous-cell carcinoma	30 (52.6)	37 (57.8)	0.837
Adenocarcinoma	26 (45.6)	26 (40.6)	
Small-cell carcinoma	1 (1.8)	1 (1.6)	
Tumour size			
T1	18 (31.6)	19 (29.7)	0.313
T2	25 (43.9)	12 (18.7)	
T3	13 (22.8)	29 (45.3)	
T4	1 (1.7)	4 (6.3)	
Tumour location			
Distal oesophagus	35 (61.4)	33 (51.6)	0.681
Cardia	22 (38.6)	31 (48.4)	
TNM classification			
I	16 (28.1)	26 (40.6)	0.749
II	15 (26.3)	13 (20.3)	
III	25 (43.9)	24 (37.5)	
IV	1 (1.7)	1 (1.6)	

Abbreviations: MPA, manual purse anastomosis; RPA, reverse-puncture anastomosis.

TABLE 3 Perioperative period related information

Characteristics[a]	RPA n (%) (N = 57)	MPA n (%) (N = 64)	p-value
Total operative time, min	232.5 ± 33.84	262.3 ± 83.94	0.038
Anastomotic time, min	10.5 ± 3.4	18.3 ± 4.1	0.014
Intraoperative bleeding, ml	204.729 ± 52.220	297.60 ± 89.748	0.029
Lymph-nodes removed, pcs	22.351 ± 7.609	25.252 ± 8.381	0.805
Postoperative hospital – stay, day	9.486 ± 1.968	17.76 ± 5.297	0.031
Major complications			
Anastomotic leakage	2 (3.1)	3 (5.3)	0.294
Pulmonary embolism	0 (0.0)	1 (1.8)	
ARDS	1 (1.6)	2 (3.5)	
Minor complications pneumonia			
Pneumonia	1 (1.6)	2 (3.5)	0.261
Wound infection	0 (0.0)	1 (1.8)	
Pneumothorax	1 (1.6)	0 (0.0)	
Postoperative urinary retention	1 (1.6)	0 (0.0)	
Chylothorax	0 (0.0)	0 (0.0)	
Vocal cord paralysis	0 (0.0)	0 (0.0)	
Atrial fibrillation	1 (1.6)	2 (3.5)	

Abbreviations: ARDS, acute respiratory distress syndrome; MPA, manual purse anastomosis; RPA, reverse-puncture anastomosis.

[a]Categoric data are expressed as number (%) and continuous data as mean ± SD or median (interquartile range).

statistically significant differences between the groups with regards to tumour histology ($p = 0.837$), size ($p = 0.313$), location ($p = 0.681$) and TNM classification ($p = 0.749$)

3.3 | Surgery-related information

There were no intraoperative complications or conversions to open surgery during surgery. Perioperative period related information is shown in Table 3. Median operation time was 252 min (range 144–378 min). Relative to the MPA group, the RPA group experienced a significantly shorter operative time (232.5 ± 33.84 min vs. 262.3 ± 83.94 min, $p = 0.038$). RPA group had shorter anastomotic time relative to MPA group (10.5 ± 3.4 min vs. 18.3 ± 4.1 min $p = 0.014$). Intraoperative blood in the RPA group was lower than in the MPA group (297.60 ± 89.748 min vs. 204.729 ± 52.220 min, $p = 0.029$). The removed lymph nodes were similar between the 2 groups (25.252 ± 8.381 min vs. 22.351 ± 7.609 min, $p = 0.805$). Anastomotic leakage were similar between the 2 groups (3.1% vs. 5.3%, $p = 0.294$). Detailed complications, including pulmonary embolism, acute respiratory distress syndrome, pneumonia, wound infection, pneumothorax, postoperative urinary retention chylothorax and vocal cord paralysis, atrial fibrillation, were similar between the 2 groups. Postoperative hospital stay was shorter in the RPA group relative to the MPA group (9.486 ± 1.968 min vs. 17.76 ± 2.297 min, $p = 0.031$).

4 | DISCUSSION

RAMIE has the potential to avoid some of the pitfalls of conventional thoracoscopic-assisted minimally invasive oesophagectomy (TAMIE), especially lymph node dissection. Robotic surgery offers better dexterity and lower surgeon fatigue. With a surgeon-controlled stable 3D camera, an ergonomic operating position, and EndoWristed instruments with 7 degrees of freedom, this system is better suited to train beginners.[15,16] We find that with regards to cancer outcomes, there were no significant differences in terms of clear resection margins, tumour histology, size and location, when using robotic versus thoracoscopic procedures. Stapled intrathoracic anastomosis is mainly used when the tumour is located at the distal oesophagus and oesophagogastric junction and includes transthoracic or transoral placement of the anvil and introduction of the circular stapler through a small thoracotomy.[17] The OrVil technique is too expensive to be popular, whilst transoral insertion of the anvil raises the chance of thoracic infection and throat injury.[18] In our group, we usually use MPA for oesophagogastric anastomosis during intrathoracic anastomosis because it does not require specialised devices. However, the technique is tedious and difficult to master.

RPA omits the manual purse anastomosis (MPA) step. Anastomotic time (from oesophageal wall incision to oesophageal transection) was 10.5 ± 3.4 min, which compares well with the 10–18 min reported before,[19] indicating that RPT saves time whilst ensuring operation safety. Here, we find the total operative time in RPA and MPA was 232.5 ± 33.8 and 262.3 ± 83.94 min, respectively, which compares well with the 5.03 ± 1.04 h reported before.[14] We shortened the total operative time through increased experience and standardisation at each step. The number of lymph node dissection in RPA and MPA group was 25.252 ± 8.381 and 22.351 ± 7.609 pcs, respectively. Lymph node dissection is critical for patient survival after a radical oesophagectomy,[20] which is prone to a high metastatic rate. However, lymph node dissection is technically challenging due to a narrow operative space.[21] The feasibility and safety of the robot-assisted lymphadenectomy were demonstrated in a previous study.[22] One of main postoperative complications of EC resection is anastomotic leakage, whose incidence using various anastomosis approaches in the minimally invasive Ivor-Lewis oesophagectomy ranges from 0% to 10%, without statistically significant differences[17,18,23] Here, the anastomotic leakage rate was 3.1% in the RPA group, which is consistent with past studies. According to the doctor's personal experience and intraoperative situation. Relative to the RPA group, the MPA group will observe for a few more days in hospital. So, the postoperative hospital stay was shorter in the RPA group relative to the MPA group ($p = 0.031$), Additionally, a fixed configuration for a conventional circular stapler and puncture head can be used to lower hospital costs.

Our approach has the following characteristics: (1) Anvil placement is simple as the MPA step is omitted. (2) It can efficiently remove large tumours that cannot be pulled out and then anastomosed at the neck. (3) A knot is made through the small hole at the tip of the puncture head. The knot should be tied to the side to avoid forming an angle that would make it hard to pull out. (4) This method is modified circular-stapled end-to-side (CEEA) anastomosis. Past studies show that CEEA effectively reduces leakage rate following esophagogastrostomy.[24]

This study had some constraints. It was conducted in a nonrandomised, retrospective manner. Additionally, the technical procedure used depended on surgeon and patient preferences. The small sample size in our study could result in selection bias. This is still an early experience for RAILE.

In conclusion, our data show that this technique is feasible and reliable, and offer suggestions on treatment options for surgeons performing oesophagogastric reconstruction using a gastric tube during oesophagectomy.

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CONFLICT OF INTEREST

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