Original Article

Clinical outcomes of the robot-assisted Ivor Lewis procedure for adenocarcinoma of the esophagogastric junction with semi-instrument overlap intrathoracic anastomosis

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Background: The main difficulty of minimally invasive Ivor Lewis (IL) procedure for adenocarcinoma of the esophagogastric junction (AEGJ) is the intrathoracic esophagogastric anastomosis (IEA). We aimed to assess the safety and feasibility of the IL procedure with the da Vinci surgical system for treatment of AEGJ with semi-mechanical intrathoracic IEA.

Methods: The cohort included 72 patients with AEGJ who received treatment at the Department of Minimally Invasive Esophagus Surgery of the Tianjin Medical University Cancer Institute and Hospital from August 2020 to March 2023. Of these 72 patients, 17 received neoadjuvant chemo-immunotherapy. The robot-assisted minimally invasive IL procedure was performed using a linear stapler for overlap side-to-side intrathoracic anastomosis and the stapler defect was closed with double full-layer continuous sutures by robotic hand-sewn (semi-mechanical) IEA.

Results: Of the 72 AEGJ patients, 2 were converted to exploration, 7 were converted to laparotomy and thoracotomy for circular-stapled intrathoracic anastomosis, and 6 were converted to thoracotomy for circular-stapled anastomosis, which included 2 cases of extensive pleural adhesion and 4 cases of overlap anastomosis failure, whereas 57 underwent the robot-assisted minimally invasive IL procedure with semi-mechanical IEA. Among the 9 patients converted to laparotomy, the laparotomy rate was closely related to the Siewert classification ($P<0.005$) and preoperative use of neoadjuvant therapy ($P<0.05$). Among the 57 patients who underwent the robot-assisted minimally invasive IL procedure with semi-mechanical IEA, there were 2 cases of anastomotic leakages (2/57, 3.5%), no case of anastomotic stricture, 5 cases of postoperative pneumonia (5/57, 8.77%), 2 cases of intensive care unit admission (2/57, 3.5%), and 1 case of readmission within 30 days (1/57, 1.75%). None of the patients died within 30 days after surgery.

Conclusions: The robot-assisted minimally invasive IL procedure with semi-mechanical IEA is both safe and feasible for AEGJ. However, caution is advised for patients with Siewert type III AEGJ and those who have already received preoperative neoadjuvant therapy.

Keywords: Adenocarcinoma of the esophagogastric junction (AEGJ); da Vinci surgical system; Ivor Lewis procedure (IL procedure); anastomotic leakage

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Introduction

The Ivor Lewis (IL) procedure is commonly used for treatment of lower esophageal squamous cell carcinoma (ESCC) and adenocarcinoma of the esophagogastric junction (AEGJ). As compared to the left thoracic and abdomino-transhiatal routes, the right transthoracic route (IL procedure) can achieve greater dissection of the thoracic lymph nodes (LNs) and improve patient prognosis (1). As opposed to the open IL procedure, the minimally invasive IL procedure is favored by surgeons due to the lower risks of surgical trauma and lung complications, in addition to better quality of life and shorter hospital stays for the patients (2-4). Due to technical difficulties, equipment availability, high surgical risk, and uncertain long-term effects, the minimally invasive IL procedure is not yet widely applied (5). In addition, esophagogastric anastomosis is relatively difficult for the surgeon because of the limited space in the thoracic cavity for placement of purse-string sutures, which could increase the incidences of anastomotic leakage and other complications (4). Therefore, the video-assisted minimally invasive IL procedure is prohibitive for many surgeons.

Robot-assisted surgery has the advantages of high-definition 3-dimensional (3D) vision, 10-fold magnification, tremor filtration, and a 360° rotatable mechanical arm, which allows for convenient and accurate movements within narrow spaces (6,7). These attributes of robot-assisted surgery can overcome many deficiencies of endoscopic surgery, especially the accuracy of LN dissection (8). Hence, robot-assisted surgery is expected to replace video-assisted surgery to minimize invasiveness of the IL procedure. The main difficulty with the minimally invasive IL procedure is the intrathoracic esophagogastric anastomosis (IEA), regardless of the hand-sewn approach or the use of a stapler. Owing to the convenience for intrathoracic anastomosis, the robot-assisted hand-sewn approach is usually favored for layered anastomosis (9), but full-layer anastomosis by the hand-sewn approach for AEGJ has not been reported.

Here, we report our early experience with the robot-assisted IL procedure for AEGJ and discuss the safety and feasibility of semi-mechanical IEA. A linear stapler was used for side-to-side anastomosis and resulting defects were closed with double full-layer continuous sutures. The aim of this technique is to create a large-diameter anastomosis to minimize the incidence of anastomotic leakage and stricture. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1856/rc).

Highlight box

Key findings

- The robot-assisted minimally invasive Ivor Lewis (IL) procedure with semi-mechanical intrathoracic esophagogastric anastomosis (IEA) is both safe and feasible for adenocarcinoma of the esophagogastric junction (AEGJ). However, caution is advised for patients with Siewert type III AEGJ and those who have received preoperative neoadjuvant therapy.

What is known and what is new?

- For the minimally invasive IL procedure, the main difficulty is IEA, regardless of whether the hand-sewn approach or the use of a stapler is implemented.
- The robot-assisted hand-sewn approach is usually favored for layered anastomosis, but full-layer anastomosis by the hand-sewn approach for AEGJ has not been reported.

What is the implication, and what should change now?

- Here, we report our early experience of semi-mechanical IEA with the robot-assisted IL procedure for AEGJ. The aim of this technique is to create a large-diameter anastomosis to minimize the incidence of anastomotic leakage and stricture and discuss the safety and feasibility.

Methods

Study approval and patient consent

The study protocol was approved by the Ethics Committee of Tianjin Medical University Cancer Institute and Hospital (No. bc2020176) and conducted in accordance with the ethical principles for medical research involving human participants described in the Declaration of Helsinki (as revised in 2013). Prior to inclusion in this study, written informed consent was provided by all participants.

Patients

The study cohort consisted of 72 AEGJ patients (61 males and 11 females; average age, 65 years) who underwent the IL procedure at the Department of Minimally Invasive Esophagus Surgery of the Tianjin Medical University Cancer Institute and Hospital (Tianjin, China), from August 2020 to March 2023, retrospectively. The same group of surgeons performed all procedures. Biopsy samples were collected from all patients by gastroscopy for pathological confirmation of adenocarcinoma. Cervical ultrasound, endosonography, chest and abdomen enhanced computed

Table 1 Baseline characteristics of the patients (n=72)

Characteristics	Number (%)
Age, years	
≥65	43 (59.7)
<65	29 (40.3)
Sex	
Male	61 (84.7)
Female	11 (15.3)
Comorbidities	
Hypertension	17 (23.6)
Diabetes	8 (11.1)
Arrhythmia	8 (11.1)
Old cerebral infarction	4 (5.6)
Coronary artery disease	2 (2.8)
Appendectomy	4 (5.6)
Postoperative inguinal hernia	2 (2.8)
Neoadjuvant treatment	
Yes	17 (23.6)
No	55 (76.4)
Siewert classification	
Type I	28 (38.9)
Type II	30 (41.7)
Type III	14 (19.4)
cT stage	
T1	17 (23.6)
T2	3 (4.2)
T3	10 (13.9)
T4a	42 (33.3)
cN stage	
N0	33 (45.8)
N1	24 (33.3)
N2	10 (13.9)
N3	5 (6.9)
cTNM stage	
I	14 (19.4)
II	9 (12.5)
III	38 (52.8)
IVA	11 (15.3)
Conversion	
Exploration	2 (2.78)
Open surgery	7 (9.72)
Thoracotomy	6 (8.33)

TNM, tumor-node-metastasis.

tomography (CT), upper gastrointestinal contrast, and other examinations were routinely performed before surgery. Positron emission tomography (PET)/CT was used to exclude metastatic disease in some patients. Based on these examinations, the location, size, depth of invasion, and LN metastasis of the tumor were determined for accurate Siewert classification, preoperative clinical staging, as well as surgical resectability. Of the 72 patients, 17 (23.6%) received 2 or 3 cycles of preoperative neoadjuvant chemo-immunotherapy. Immunotherapy with checkpoint inhibitors usually consisted of pembrolizumab, whereas chemotherapy consisted of cisplatin combined with fluorouracil.

The inclusion criteria were resectable AEGJ (clinical stage cT1–4a, cN0–2, or cM0) at diagnosis or after induction therapy and good physical condition to tolerate anesthesia and surgery. The exclusion criteria were ESCC, disease stage cT4b, cN3, or cM1, inability to tolerate anesthesia and surgery, and history of right chest trauma, surgery, or tuberculosis. LNs were classified according to the Japanese Classification of Esophageal and Gastric Cancer.

Data collection

The baseline data of all 72 patients [i.e., age, sex, preoperative comorbidities, Siewert classification, tumor-node-metastasis (TNM) stage, and surgical approach] are presented in *Table 1*. Excluding 2 patients who were converted to exploratory surgery, 7 converted to open surgery, and 6 converted to thoracotomy (*Table 1* and *Figure 1*), the intraoperative and postoperative data (i.e., pathology, total operation time, anastomosis time, estimated blood loss, post-operative length of hospital stay, morbidity, and mortality) were collected from 57 patients who underwent the robot-assisted IL procedure with semi-mechanical IEA. The numbers of harvested and positive LNs were retrieved from pathology reports. The total operation time was defined as the time from the initial

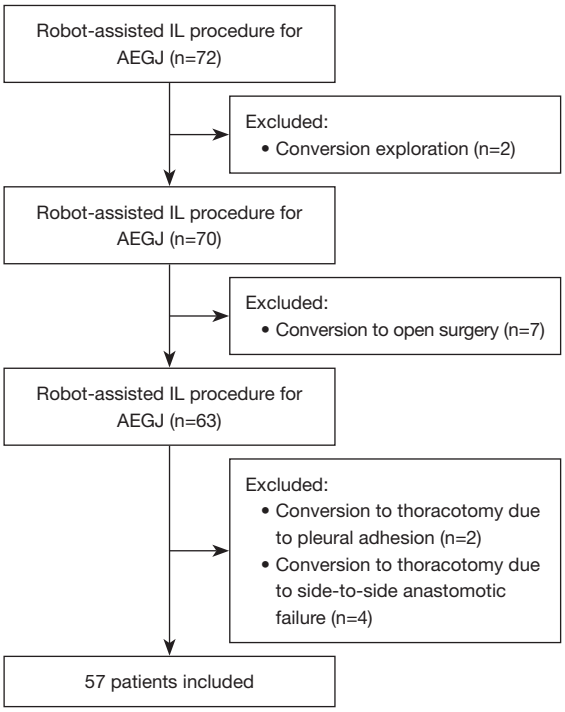

Figure 1 Flow chart of patient selection. IL, Ivor Lewis; AEGJ, adenocarcinoma of the esophagogastric junction.

incision until final closure, which included the non-robotic operation time and intraoperative conversion of body position. Anastomosis time was defined as the time from the beginning of constructing an orifice of the esophagus to the end of closure of the stapler defects with robotic hand-sewn sutures. All major complications were evaluated based on the Esophagectomy Complications Consensus Group criteria (10). Vocal cord injury (e.g., hoarseness) was evaluated by tracheoscopy.

Surgical procedures

The da Vinci Xi surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) was used in this study, along with a harmonic scalpel, monopolar cautery hook, bipolar forceps, Cadiere grasper, Hem-o-lock clips, needle drivers, 3-0 absorbable barb sutures (V-Loc^{TM} 180; Medtronic, Fridley, MN, USA), and 60 mm linear stapler (GST60D; Ethicon, Inc., Bridgewater, NJ, USA). The surgical procedures included stomach and distal esophagus mobilization, abdominal and thoracic LN dissection, gastric conduit construction, and semi-mechanical IEA, where the posterior wall of the esophagus and the anterior wall of gastric conduit were overlapped using a linear stapler and the common lumen was closed with robotic hand-sewn sutures.

Abdominal phase

The patient was placed in the supine position and artificial CO_2 pneumoperitoneum was established at a pressure of 12 mmHg. An 8-mm trocar was placed below the umbilicus for a camera, and two 8-mm trocars were placed at the junctions of the right and left midclavicular lines and umbilical line as operating ports. A 12-mm assistant port was placed at the right anterior axillary line below the costal arch. Abdominal lymphadenectomy, including the paracardial LNs, LNs along the left gastric artery, celiac trunk, splenic artery, common hepatic artery, and hepatoduodenal ligament, was performed with a harmonic scalpel. A 3 cm-wide gastric conduit was constructed using a 60-mm linear stapler. Then, a gastrostomy site was chosen on the anterior wall of the gastric conduit about 6 cm from the distal end and a suture was placed. The severed esophagogastrectomy specimen was connected to the gastric conduit by silk suture. Jejunostomy was routinely performed after the gastric conduit was constructed. Pyloroplasty, pedicled omental flap, etc., were not routinely performed.

Thoracic phase

The patient was tilted 45° towards the prone position (semi-prone) and artificial CO_2 pneumothorax was used to collapse the lung with a pressure of 8 mmHg, while discharging the residual gas from the lung. An 8-mm trocar was placed on the middle axillary line of the fifth intercostal space for a camera. An 8-mm trocar was placed on the anterior axillary line of the third intercostal space and another on the posterior axillary line of the ninth intercostal space as operating ports. A 12-mm assistant port was placed on the anterior axillary line of the seventh intercostal space. The distal esophagus was dissociated from the hiatus of the diaphragm to the level of the azygos arch with a harmonic scalpel or monopolar cautery hook. The azygos arch was transected, if necessary, and the mediastinal LNs were dissected. Mediastinal lymphadenectomy included the lower paratracheal right, subcarinal, paraesophageal, and pulmonary ligament LNs. The No. 106recR LNs located along the right recurrent laryngeal nerve and the aortopulmonary window were dissected with bipolar forceps to protect the nerve when LN metastasis was suspected at these stations. The gastric conduit was then pulled up

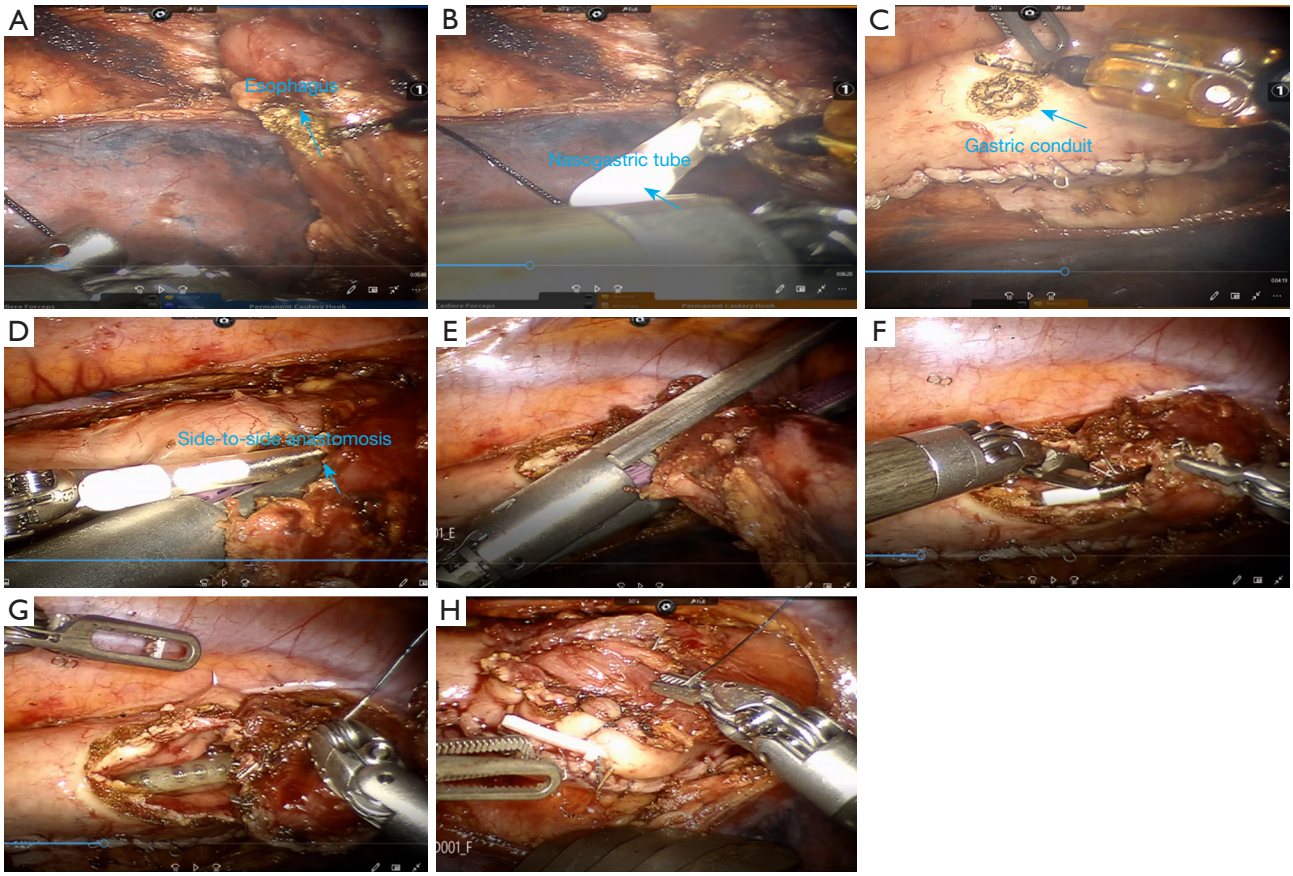

Figure 2 The steps of robot-assisted semi-mechanical IEA. (A) A 1 cm orifice about 6 cm from the proximal mobilized esophagus was constructed with an electric hook; (B) the nasogastric tube was drawn out through the orifice of the esophagus; (C) an orifice (~1 cm) for gastrostomy was made with an electric hook on the anterior wall of gastric conduit; (D) side-to-side anastomosis of the posterior wall of the esophagus and the anterior wall of gastric conduit using a 60-mm linear stapler; (E) the esophagus was transected with a 6-mm linear stapler; (F) a nasogastric tube was inserted into the gastric conduit through the anastomosis; (G) the stapler defect was closed with full-layer continuous sutures by robotic hand-sewn; (H) the anastomosis was reinforced with full-layer continuous sutures. IEA, intrathoracic esophagogastric anastomosis.

into the thoracic cavity through the hiatus. The posterior wall of the esophagus and anterior wall of the gastric tube were anastomosed via the side-to-side approach using a 60-mm linear stapler. In China, there are no robotic staplers, relying mainly on assistants. All stapler defects were robotic hand-closed with double full-layer continuous sutures (semi-mechanical IEA). The esophagogastrectomy specimen was removed through a wound protector via the enlarged assistant port and a thoracic drainage tube was placed. A week after surgery, upper gastrointestinal contrast with meglumine diatrizoate was routinely performed to assess healing of the anastomosis.

Steps of robot-assisted semi-mechanical IEA

(I) A 1-cm orifice about 6 cm from the proximal mobilized esophagus was made with a monopolar cautery hook on the posterior wall of the mobilized esophagus. The length of the proximal esophageal stump was determined based on the location of the tumors at the esophagogastric junction (*Figure 2A*).

(II) The nasogastric tube was drawn out through the orifice of the mobilized esophagus and disinfected with iodophor (*Figure 2B*).

(III) The gastric conduit was pulled up into the thoracic

Table 2 Relationship between the Siewert classification and the laparotomy conversion rate of the robot-assisted minimally invasive IL procedure

Siewert classification	Conversion, n	No conversion, n
Type I	2	26
Type II	1	29
Type III	6	8

P<0.005 (χ^2=14.9687). IL, Ivor Lewis.

Table 3 Relationship between the use of neoadjuvant treatment and the laparotomy conversion rate of the robot-assisted minimally invasive IL procedure

Neoadjuvant treatment	Conversion, n	No conversion, n
Yes	5	12
No	4	51

P<0.05 (χ^2=3.97). IL, Ivor Lewis.

cavity with atraumatic forceps and a Cardiere grasper. Gastrostomy (approximately 1 cm orifice) about 6 cm distal of the anterior wall of the gastric conduit was performed with a monopolar cautery hook and the stomach fluid was aspirated to avoid contamination of the thoracic cavity (*Figure 2C*).

(IV) The posterior wall of the mobilized esophagus and the anterior wall of the gastric conduit were anastomosed via the side-to-side approach using a 60 mm linear stapler. The jaw of the linear stapler was inserted into the esophageal lumen along the nasogastric tube to prevent insertion between the mucosal and muscular layers of the esophagus. The nasogastric tube was retracted through the anastomosis before the linear stapler was fired to avoid attaching the nasogastric tube to the tissues (*Figure 2D*).

(V) The esophagus was transected with a 60-mm linear stapler (*Figure 2E*). Notably, side-to-side anastomosis should be performed before esophagotomy because if the esophagus is transected before side-to-side anastomosis, the esophagus will retract, thereby complicating the anastomosis and possibly injuring the esophagus.

(VI) Prior to closure of the stapler defects, a nasogastric tube was inserted into the gastric conduit through the anastomosis under direct vision (*Figure 2F*).

(VII) The common lumen was closed with 2 robotic hand-sewn full-layer continuous 3-0 absorbable barb sutures. A second full-layer continuous suture was placed to reinforce the anastomosis. Due to the complicated nature of placement of a layered suture, a full-layer continuous suture was used to simplify the procedure (*Figure 2G,2H*).

Statistical analysis

All statistical analyses were performed using SPSS 13.0 software (SPSS, Inc., Chicago, IL, USA). The chi-square test and Fisher's exact test were used to compare counted data and the *t*-test was used to compare measured data. Statistical significance was considered when P<0.05.

Results

Of the 72 patients, AEGJ was classified as Siewert type I in 28 cases, type 2 in 30 cases, and type 3 in 14 cases. In accordance with the TNM staging criteria of esophagogastric junction carcinoma [American Joint Committee on Cancer (AJCC) 8th edition], 14 cases were stage cI, 9 cases were stage cII, 38 cases were stage cIII, and 11 cases were stage cIVA (*Table 1*).

All 72 patients with AEGJ underwent the robot-assisted minimally invasive IL procedure. Among them, 2 participants were converted to open exploration due to tumor invasion of the pancreas and splenic hilum, 7 were converted to laparotomy due to difficulty with radical dissection of the left gastric LNs, followed by conversion to thoracotomy for circular-stapled anastomosis, 6 were converted to thoracotomy with circular-stapled anastomosis (2 due to extensive pleural adhesion and 4 due to failure of overlap side-to-side anastomosis), and 57 underwent the robot-assisted minimally invasive IL procedure with semi-mechanical IEA. R0 resection was achieved in all but 2 cases of exploration. No hybridization operation was performed (*Table 1* and *Figure 1*). All failures of semi-mechanical IEA occurred in the first 20 cases.

Of the 72 patients, 9 were converted to laparotomy. Among the 17 patients who received neoadjuvant therapy, 5 were converted to open surgery, accounting for more than half of those converted to open surgery (5/9, 55.56%). Of the 14 cases of Siewert type III AEGJ, 6 were converted to laparotomy, accounting for 66.67% (6/9). The rate of conversion to laparotomy was closely related to the Siewert classification and preoperative neoadjuvant therapy (all P<0.05) (*Tables 2,3*).

Table 4 Summary of different anastomosis methods used with robot-assisted IL reported in the literature

Author	Year of publication	No. of cases	Anastomotic method	Total operation time†, min	Anastomotic leakage, n (%)	Anastomotic stricture, n (%)
Wang *et al.* (11)	2019	31	Circular stapler	387.4±68.2	2 (6.5)	6 (19.4)
Marano *et al.* (12)	2023	30	Hand-sewn	NR	1 (3.3)	8 (26.7)
Wang *et al.* (13)	2019	37	Linear stapler + layered suture	340	3 (8.1)	0 (0.0)
Angehrn *et al.* (14)	2022	21	Linear stapler + layered suture	453	2 (9.5)	NR
This study	2024	57	Linear stapler + full-layer suture	274±44	2 (3.5)	0 (0.0)

†, the total operation time was defined as the time from the initial incision until final closure. NR, not reported.

Table 5 Intraoperative characteristics and surgical outcomes (n=57)

Variables	Values
Total operation time, min, mean ± SD	274±44
Anastomotic time, min, mean ± SD	32±6
Estimated blood loss, mL, mean ± SD	122±45
Harvested LNs, n, mean ± SD	21±8
Positive LNs, n, mean ± SD	3.75±5.18
Postoperative hospital stay, days, mean ± SD	10.7±2.4
30-day readmission, n (%)	1 (1.75)
30-day mortality, n (%)	0 (0.0)
ICU admission, n (%)	2 (3.5)
Postoperative complications, n (%)	
Anastomotic leakage	2 (3.5)
Anastomotic stricture	0 (0.0)
Hoarseness	0 (0.0)
Pneumonia	5 (8.77)
Chylothorax	0 (0.0)

SD, standard deviation; LNs, lymph nodes; ICU, intensive care unit.

Of the 57 patients who underwent the robot-assisted minimally invasive IL procedure with semi-mechanical IEA, there were 2 cases of anastomotic leakage (2/57, 3.5%), 0 cases of anastomotic stricture, 2 cases of intensive care unit (ICU) admission (2/57, 3.5%), 5 cases of postoperative pneumonia (5/57, 8.77%), and 1 case of hospital readmission within 30 days (1/57, 1.75%) (*Table 4*). None of the patients died within 30 days after surgery and there was no incidence of chylothorax or hoarseness after surgery. The mean total operation time was 274±44 minutes, the mean anastomosis time was 32±6 minutes, the mean estimated blood loss was 122±45 mL, the mean postoperative hospital stay was 10.7±2.4 days, the mean number of harvested LNs was 21±8, and the mean number of positive LNs was 3.75±5.18 (*Tables 4*,*5*).

Discussion

Squamous cell carcinoma is the most common histotype of ESCC in China. As ESCC is characterized by jump metastasis and IEA is a complicated technique, most minimally invasive esophagectomy procedures in China are performed via McKeown esophagectomy with cervical anastomosis. For esophageal adenocarcinoma or AEGJ, the IL procedure is typically used. Due to the low incidence in China, esophageal adenocarcinoma is usually classified as AEGJ. In fact, the IL procedure is standard for Siewert type I AEGJ, while there is no consensus for Siewert type II AEGJ. In addition, the IL procedure is recommended for Siewert type II AEGJ invaded the esophagus ≥3 cm with dissection of the No. 106recR and 108 LNs (15). The IL procedure is also recommended for Siewert type III AEGJ with suspected mediastinal LN metastasis before surgery. Mitchell *et al.* reported that 23% of patients with Siewert type II and III AEGJ had clinically suspected mediastinal LN metastasis before surgery (16). In the present study, 14 patients were diagnosed with Siewert type III AEGJ and the IL procedure was mainly used because of suspected mediastinal LN metastasis before surgery. Of the 9 AEGJ patients converted to laparotomy, 6 were Siewert type III. Notably, the rate of conversion from the robot-assisted minimally invasive IL procedure to laparotomy was closely related to the Siewert classification (P<0.005). As a possible explanation, Siewert type III AEGJ is more likely to invade the pancreas and splenic hilum, resulting in greater

risks for metastasis to the abdominal LNs and inaccurate preoperative diagnoses for resectability. As compared to a previous report (9), the conversion rate in the present study was relatively high because all cases were AEGJ rather than ESCC.

Most of the patients in this study had stage cIII or cIVA AEGJ and only 17 patients who received preoperative neoadjuvant therapy were considered eligible for resection. The main reasons for ineligibility for resection were the lack of neoadjuvant therapy for locally advanced AEGJ, late diagnosis, poor compliance with neoadjuvant therapy, poor response to neoadjuvant therapy for locally advanced AEGJ, inaccurate T staging of AEGJ by endoscopic ultrasound, and stage cT3 misdiagnosed as stage cT4a. In fact, neoadjuvant therapy is recommended for patients with stage cT1N+ or cT2–4Nx AEGJ to improve prognosis (17,18). In general, neoadjuvant chemoimmunotherapy is both safe and effective for locally advanced AEGJ (19), although further studies are needed to clarify an expected endpoint of a pathologic complete response (20). Among the 17 patients who received neoadjuvant therapy, 5 were converted to laparotomy. Hence, there was a significant difference in the conversion rate for patients who did not receive neoadjuvant therapy ($P<0.05$). Possible reasons for this difference include inaccurate preoperative assessment of resectability and limited dissociation of degenerated LNs adhered to vessels after neoadjuvant therapy.

The difficulty of minimally invasive IL esophagectomy is due to IEA, especially circular-stapled anastomosis, because this procedure is very complicated and requires mini-thoracotomy (21). Also, the incidence of stricture of circular-stapled anastomosis is very high (22). The best way to avoid anastomosis stricture is to establish a large anastomosis diameter by side-to-side anastomosis. Even with side-to-side anastomosis with a linear stapler (23), it is difficult to close the common lumen because placement of hand-sewn sutures is inconvenient and anastomotic stricture easily occurs when closing with a linear stapler along the longitudinal axis of the esophagus and gastric conduit. In contrast, robot-assisted minimally invasive IL esophagectomy allows for convenient and reliable suture placement to close stapler defects along the transverse axis of the esophagus and gastric conduit for avoiding anastomosis stricture. Therefore, the robot-assisted minimally invasive IL procedure with semi-mechanical IEA can reduce anastomosis stricture, while also simplifying the procedure.

In this study, overlap linear-stapled anastomosis failed in 4 cases, all of which occurred within the first 20 cases. The reason for these failures was that the jaw of the linear stapler was mistakenly inserted between the mucosal and muscular layers of the esophagus during anastomosis of the esophageal muscular layer and the anterior wall of the gastric conduit. However, the nasogastric tube must be drawn out from the orifice of the esophagus before placing the jaw of the linear stapler into the esophageal lumen along the nasogastric tube. Finally, the robot-assisted minimally invasive IL procedure with semi-mechanical IEA was successfully completed in 57 cases. Overall, the mean total operation time was 274±44 minutes, the mean anastomosis time was 32±6 minutes, and the mean estimated blood loss was 122±45 mL. According to previous studies (11-14), the fastest reported mean operation time was 340 min, indicating that the robot-assisted surgical procedure is highly accurate and our technique is skilled. To date, our group have completed more than 400 robot-assisted minimally invasive McKeown esophagectomy procedures (24). Among the 57 patients in the present study who underwent the robot-assisted minimally invasive IL procedure, the mean number of harvested LNs was 21±8, the mean number of positive LNs was 3.75±5.18, and the mean postoperative hospital stay was 10.7±2.4 days (about 11 days), similar to a previous report (25).

For closure of the common lumen, layered sutures between the mucosal layers or muscular layers of the esophagus and stomach are recommended (9). The robot can be used for double, full-layer, continuously sutured anastomosis to simplify the procedure and this technique is easier to master. Nonetheless, safety is the primary concern of the surgeon regardless of the procedure. Of the 57 patients who underwent the robot-assisted minimally invasive IL procedure, there were 2 cases of anastomotic leakage (2/57, 3.5%), no case of anastomotic stricture, 5 cases of postoperative pneumonia (5/57, 8.77%), and 2 cases of ICU admission (2/57, 3.5%). As compared to previous reports of linear stapler combined layered suture (13,14), the present study with linear stapler combined full-layer suture achieved the lowest incidence of anastomotic leakage. In the multicenter German da Vinci Xi registry trial, the incidences of anastomotic leakage and pulmonary complications were 13.2% and 19.5%, respectively (26). In the present study, anastomotic leakage occurred in 2 patients, which included 1 complicated with diabetes. With this patient, continuous sutures with only 1 barbed thread were placed for closure of the common lumen, despite sewing two layers, but failed to achieve reinforcement.

In the second case, the esophagus was cut obliquely with the linear stapler, which could affect the blood flow of the esophagus. Our experience has clarified that stapler defects must be closed with double full-layer sutures with 2 barbed threads and the esophagus must be transected as much as possible. Among the 57 patients, only 1 (1.75%) was readmitted to the hospital within 30 days, which was due to pneumonia caused by aspiration after discharge and no deaths occurred. In contrast, Awad *et al.* reported readmission and mortality rates within 30 days of 12% and 2%, respectively, in 100 patients who underwent minimally invasive IL intrathoracic circular-stapled anastomosis (27). In terms of anastomotic stricture, circular stapler or hand-sewn anastomosis has a high incidence (11,12). In the present studies, there was no instance of anastomotic stricture, which is typically related to side-to-side anastomosis with a large diameter and sutures placed along the transverse axis of the esophagus (13,14). Also, there was no postoperative instance of chylothorax or hoarseness, as the use of a robotic bipolar low-energy instrument allows for accurate dissociation of LNs, while avoiding injury to the recurrent laryngeal nerve. Therefore, as compared to reports of related postoperative complications in the literature (11-14,26,27), our procedure is relatively safer.

Conclusions

In summary, the robot-assisted minimally invasive IL procedure with semi-mechanical IEA is both safe and feasible for AEGJ after adequate preoperative evaluation of surgical indications. However, multi-center studies with large samples are needed to confirm the long-term effects and outcomes of this procedure. Lastly, caution is advised when applying this procedure for Siewert type III AEGJ and patients who have undergone preoperative neoadjuvant therapy.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1856/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1856/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1856/coif). B.K. serves as the advisory boards/speaker for AstraZeneca, Merck, BMS, and Roche. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study protocol was approved by the Ethics Committee of Tianjin Medical University Cancer Institute and Hospital (No. bc2020176) and conducted in accordance with the ethical principles for medical research involving human participants described in the Declaration of Helsinki (as revised in 2013). Prior to inclusion in this study, written informed consent was provided by all participants.

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