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ORIGINAL ARTICLE

Robot-assisted esophagectomy with robot-sewn intrathoracic anastomosis (Ivor Lewis): surgical technique and early results

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Abstract

Esophagectomy is the selected treatment for nonmetastatic esophageal and esophagogastric junction cancer, although high perioperative morbidity and mortality incur. Robot-assisted minimally invasive esophagectomy (RAMIE) effectively reduces cardiopulmonary complications compared to open esophagectomy and offers a technical advantage, especially for lymph node dissection and intrathoracic anastomosis. This article aims at describing our initial experience of Ivor Lewis RAMIE, focusing on the technique's main steps and robotic-sewn esophagogastrostomy. Prospectively collected data from all consecutive patients who underwent Ivor Lewis RAMIE for cancer was reviewed. Reconstruction was performed with a gastric conduit pull-up and a robotic-sewn intrathoracic anastomosis. Intraoperative and postoperative complications were recorded as prescribed by the Esophagectomy Complications Consensus Group (ECCG). Thirty patients underwent Ivor Lewis RAMIE with complete mediastinal lymph node dissection and robot-sewn anastomosis. No intraoperative complications nor conversion occurred. Pulmonary complications totaled 26.7%. Anastomotic leakage (ECCG, type III) and conduit necrosis (ECCG, type III) both occurred in one patient (3.3%). Chylothorax appeared in 2 patients (6.7%) (ECCG, Type IIA). Anastomotic stricture, successfully treated with endoscopic dilatations, occurred in 8 cases (26.7%). Median overall postoperative stay was 11 days (range, 6–51 days). 30 day and 90 day mortality was 0%. R0 resection was performed in 96.7% of patients with a median number of 47 retrieved lymph nodes. RAMIE with robot-sewn intrathoracic anastomosis appears to be feasible, safe and effective, with favorable perioperative results. Nevertheless, further high-quality studies are needed to define the best anastomotic technique for Ivor Lewis RAMIE.

Keywords Intrathoracic anastomosis · RAMIE · Ivor-Lewis · Robotic · Esophageal cancer

Introduction

Esophagectomy with radical lymphadenectomy combined with multimodal therapy is the main form of curative treatment for patients with nonmetastatic esophageal or gastroesophageal junction (EGJ) cancer [1]. Although several improvements have been achieved in the last decades to enhance recovery and decrease postoperative complications, transthoracic esophagectomy is still an invasive surgical procedure associated with a relatively high morbidity rate even in high-volume centers, mostly in terms of cardiopulmonary complications and anastomotic failure [2]. Moreover, this latter condition is associated with an increased risk of anastomotic stricture, a mortality rate of up to 16% and decreased long-term survival rate [3].

One of the most recent improvements has been the adoption of laparoscopic minimally invasive esophagectomy (MIE). MIE has been shown to be superior compared to open esophagectomy with regards to postoperative outcomes, especially in terms of pulmonary complications, without compromising oncologic safety [4, 5]. In addition, in a thoracoscopic setting, current, sound scientific evidence indicates that intrathoracic anastomosis is associated with

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a clinically relevant lower leakage rate and improved functional results compared to cervical anastomosis [6].

The creation of an intrathoracic anastomosis is considered quite challenging even during MIE owing to the intrinsic limitations of this technique and so far, no general consensus exists on the optimal anastomosis [7]. Recently, a robotic approach has been implemented to facilitate complex minimally invasive (MI) procedures by combining the optimal advantage of its ergonomics [8]. This technology might be particularly useful for the thoracic stage of Ivor Lewis en-bloc esophagectomy (ILE), especially when a hand-sewn esophagogastrostomy is planned. Indeed, although few studies have reported about hand-sewn intrathoracic anastomosis during Ivor Lewis robot-assisted minimally invasive esophagectomy (RAMIE) using widely varying techniques [9–17], all experiences underlined that the robotic technology provided increased suturing capacity, more precise construction and highly controlled anastomosis in a narrow space.

Ivor Lewis RAMIE was implemented by our surgical team in 2019 based on our foregoing experience of traditional open ILE. The aim of this study is to describe the main steps of our technique especially focusing on robot-sewn esophagogastrostomy. Postoperative complications and short-term oncologic outcomes of our initial experience are also analyzed. The following article is presented in accordance with the criteria set out in the Preferred Reporting of Case Series in Surgery (PROCESS) checklist [18].

Materials and methods

From April 2019 to February 2022, all consecutive patients with distal esophageal cancer or EGJ cancer who were scheduled for an intent to treat ILE with robot-sewn esophagogastrostomy were included in the study. Preoperative workup included esophagogastroduodenoscopy with biopsy, thoracoabdominal computed tomography (CT), endoscopic ultrasonography, fluorodeoxyglucose-18 positron emission tomography (FDG-PET)/CT in selected cases, cardiopulmonary function examination and assessment of nutritional status. The exclusion criteria ruled out patients with evidence of distant metastasis and prior thoracic surgery.

Before treatment, all patients were assessed by an upper gastrointestinal multidisciplinary tumor board to determine optimal treatment, according to the NCCN [1] and National Guidelines [19]. The standard neoadjuvant treatment for patients with esophageal adenocarcinoma was perioperative chemotherapy with FLOT or chemoradiotherapy with CROSS according to primary cancer site [20, 21]. All patients were reassessed 1 month after the completion of treatment with CT scan (and FDG-PET if necessary): in case of objective radiological response patients were scheduled for ILE with curative intent 4–6 weeks after FLOT and 10–12 weeks after CROSS regimen, respectively.

All surgical procedures were performed by a single surgeon (F.B.) with long-standing experience in laparoscopic and robotic surgery. The reconstruction was carried out with a gastric conduit pull-up and a robot-sewn intrathoracic anastomosis [14]. The abdominal stage of the surgery was performed using an open, 3D laparoscopic, or a robotic approach.

From April 2019 to February 2021 all procedures have been carried out at Santa Croce e Carle Hospital, Cuneo, Italy (a tertiary referral center). In 2020, January the dV®Si™ system in the hospital was replaced by the dV®Xi™ (Intuitive Surgical Inc., Sunnyvale, USA). Prior to this change, the abdominal step of ILE according to our standardized technique (which includes a complete Kocher maneuver, pyloroplasty and feeding jejunostomy creation) would have been quite complex to accomplish with the dV®Si™ system. For this reason, an open or laparoscopic approach was selected taking into consideration the patient's characteristics (i.e., open approach in case of previous abdominal surgeries) and surgeon's preference.

From May 2021 to February 2022 all surgeries have been performed using the same technique with dV® Xi™ system at Candiolo Cancer Institute, FPO–IRCCS (Candiolo, Torino, Italy), a tertiary referral center where F.B moved.

After the Institutional Review Board approval and the signing of a data use agreement, a database of prospectively collected data was created. Patient and treatment-related data were recorded. Intraoperative data included operative time (OT) of the abdominal and thoracic surgical phase and conversion rate. Length of stay (LOS) including the intensive care unit (ICU) hospitalization, reasons for readmission, and 30-day and 90-day mortality were also analyzed. Intraoperative and postoperative complications were recorded according to definitions set by the Esophagectomy Complications Consensus Group (ECCG) [2].

All the patients were treated according to the ERAS program for esophagectomy [22] that can be briefly summarized as follows:

– Preoperative phase: incentive spirometer 10x/hour and respiratory exercises are prescribed 7 days before surgery, immunonutrition is administered starting 7 days and up to 3 h before surgery, a thoracic epidural catheter is inserted the day before the surgery, thromboprophylaxis and cephazoline 2 g i.v. are administered 12 h and 1 h before surgery, respectively.
– Intraoperative phase: the patient is intubated with a double-lumen tube, the anesthetic protocol is standardized using a careful goal-directed fluid therapy aimed at avoiding an excessive positive fluid balance, maintenance of normothermia is ensured; pyloroplasty and feeding

jejunostomy are always performed, a nasogastric tube (NGT) as well as an active-suction drain in the chest are regularly put in place, while an abdominal passive drain is not routinely positioned.

- Postoperative phase: the patient is usually extubated in the operating room and transferred to the surgical ward after an observation period in the postoperative recovery room (unless surgery ends in late afternoon in which case the patient is transferred to ICU where extubation is carried out within 12 h), the urinary catheter is removed on postoperative day (POD) 2, NGT is removed at a threshold of about 100–200 mL per day after passing of first flatus, abdominal drain (if present) is removed on POD 2, chest drain is set up without suction (provided pneumothorax is absent) on POD day 2 and removed after diet starts at a threshold of 200 mL per day, enteral nutrition starts on POD day 1 initiated at 10 cc/h and increased to goal, a fluid oral intake is allowed after NGT removal, early mobilization, starting 12 h after surgery, is strongly encouraged. Conduit emptying is generally checked on POD 4–5 with gastrografin swallow and, if guaranteed, a fractional semi-liquid diet starts from the same day.

Surgical technique: Ivor Lewis Esophagectomy with intrathoracic robot-sewn anastomosis

Abdominal phase

The patient is in a supine position with the arms along the body and split legs. To perform the laparoscopy, three 10 mm ports (one sub umbilical for the 3D camera, one along the right and one along the left mid-clavicular line as operating ports) as well as two 5 mm ports (one epigastric and one on the right flank at the anterior axillary line, both for the assistants) are put in place under direct vision (Fig. 1A). dV® Xi™ port layout is shown in Fig. 1B. Four robotic trocars (R1-4, 8 mm) are placed in a horizontal line above or below the umbilicus within 6 cm of each other and an additional 12 mm trocar for the assistant is inserted in the right or left mesogastrium according to patient habitus. A 15° reverse Trendelenburg position is established. The robotic cart is docked from the right side of the patient and the targeting area is identified along the pars flaccida of the lesser omentum. A xifo-supra umbilical incision is performed in the case of an open approach. For the robotic abdominal phase, the dissection is usually performed using an endowristed monopolar cautery hook and bipolar forceps, sometimes we employed a bipolar vessel sealer device (Intuitive Vessel Sealer). In the case of a laparoscopic and open approach an ultrasound device is used.

Irrespective of the type of surgical approach selected, the abdominal stage of ILE includes the following steps.

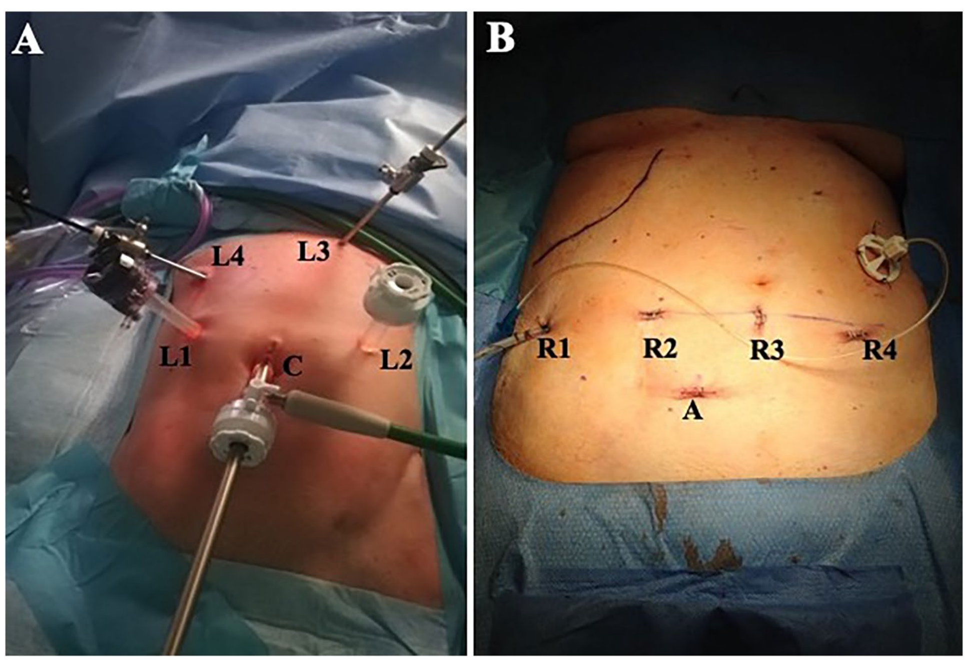

Fig. 1 Trocar placement of the laparoscopic (**A**) and robotic (**B**) abdominal phase of the procedure. C camera port, A assistant port, R robot arm

First, the greater gastric curvature is dissected along the gastrocolic ligament. Next the stomach is mobilized using a medial to lateral approach up to the left crura, carefully sparing the right gastroepiploic arcade. The retrogastric adhesions as well as the short gastric arteries can be dissected and ligated safely. Then a full Kocher maneuver is performed as a rule. The gastro-hepatic ligament is cut open close to the liver, preserving the right gastric artery, and then upwards to the right crus of the diaphragm. A lymph node dissection along the upper margin of the common hepatic artery (#8a) is subsequently performed up to the celiac axis. The left gastric artery and vein are sectioned at their origins and the lymphadenectomy of station #7, 9 and 11p is completed. Next, the hiatus is slightly enlarged by transecting the right crus of the diaphragm. A 4 cm-wide gastric tube is created on the site of the greater curvature with a 60 mm smart articulating stapler (Signia™, Medtronic, USA), starting at the level of the incisura angularis. After the gastric tube has been prepared, an assessment of its perfusion is performed with indocyanine green (ICG) fluorescence [23]. Hence, the divided stomach is sewn to the end of the divided esophagus and the end of the first stapling line is tagged with a stay suture as a marker. Pyloroplasty is routinely performed digitally in the open approach and with interrupted 4-0 polyglactin 910 (Ethicon Inc. USA) sutures in the MI technique (extramucosal Heineke–Mikulicz pyloroplasty).

At the end of the abdominal phase a percutaneous jejunostomy is created and a drain is placed.

Thoracic phase

Single-lung ventilation is introduced, and the patient is placed in the left lateral decubitus position, tilted 45° compared to the prone position. For both robotic systems, the cart is docked from the right side of the patient. In addition, three robotic ports are put in place as well as two thoracoscopic ports for the assistant.

dV®Si™ port layout for this stage has previously been described [24]. It's worthy of mention that an additional 5 mm port for the assistant is placed between the intercostal spaces (ICS) 6 and 10, along the posterior axillary line. Figure 2 shows the dV®Xi™ trocar position (three-arms technique) in a slight U shape: robotic arm#1(R1) for the grasper or the bipolar forceps at the ICS 9, robotic arm#2 (R2) for the 30° down scope at the ICS 6, posterior to the posterior axillary line and robotic arm#3 (R3) for the monopolar cautery hook, the needle driver or the clip applier at the ICS 4, anterior to the scapular rim. Furthermore assistant port #1(A1, 12-mm) is located in the ILC 8, and assistant port #2 (A2, 5 mm) between R2 and R3 at the posterior axillary line. The targeting area is identified at the level of the Azygos arch.

A 7–8 mmHg pneumothorax is then induced. Starting at the anterior side of the esophagus, the parietal pleura is cut from the level of the azygos arch down to the diaphragm where the pulmonary ligament is divided. The azygos arch is then sectioned with robotic Weck Hem-o-lok clips (Teleflex, Morrisville, NC, USA) and a right paratracheal lymphadenectomy is performed. Next, the dissection of the parietal pleura is deepened towards the esophageal hiatus until the aorta becomes exposed.

Subsequently, the right vagus nerve is sectioned just below the carina, preserving its bronchial branches. The dissection of the esophagus is extended below the tracheal bifurcation and a Penrose drain is placed around the esophagus to facilitate traction.

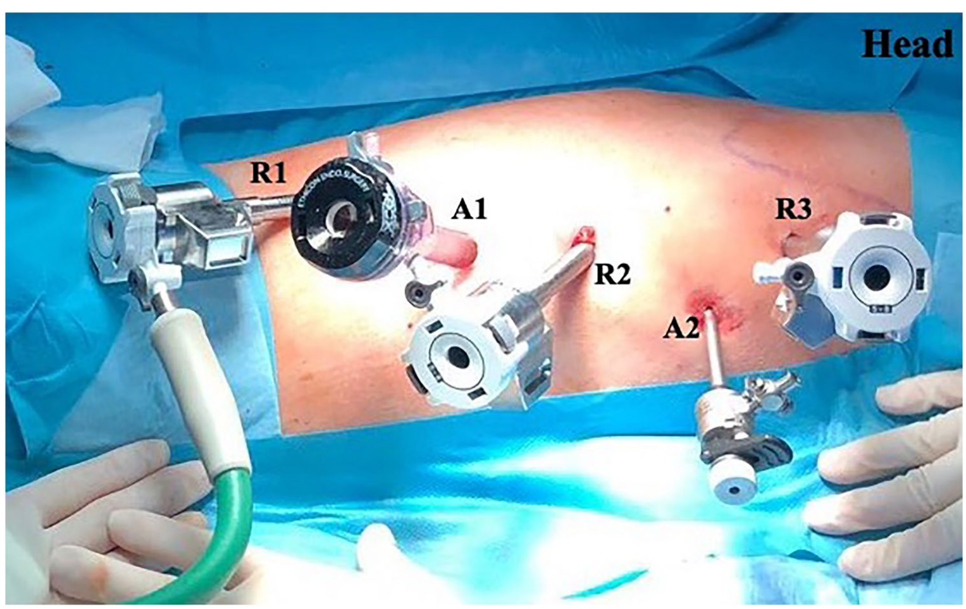

Fig. 2 Trocar placement of the thoracic phase of the procedure. R robot arm, A assistant port

The dissection of the esophagus is then continued along the pericardium down to the diaphragm and the thoracic duct is clipped with robotic clips. The resection of the esophagus en-bloc with periesophageal, bronchial and subcarinal nodes (stations # 107–111) and the thoracic duct is fully completed from the diaphragm up to the azygos arch.

The proximal esophagus is divided using a robotic cautery hook above the level of the azygos vein. At this point, the instruments in R1 and R3 are reversed to be able to carefully pull the esophago-gastric bloc and the gastric conduit up through the hiatus until the marker suture becomes visible. The specimen and conduit thus are disconnected, and the specimen is placed in a plastic bag which will be removed through the enlarged incision of the assistant port.

Thereafter, four supportive 4-0 polyglactin 910 (Ethicon Inc. USA) stitches are put in between the mucosae and the muscularis externa layer of the esophagus at the four cardinal points to evert the esophageal mucosae. Next, the proximal esophagus is dilatated using a Foley catheter inflated with 10 cc of sterile water for approximately 2–3 min. After having assessed both gastric conduit and esophageal perfusion with ICG fluorescence, a gastrotomy is performed at the most proximal portion of the conduit, maintaining at least 2 cm of distance from the stapler line.

A single-layer robot-sewn esophagogastric anastomosis is performed above the level of the azygos arch with two separate running self-locking barbed sutures (Filbloc® 3/0, Assut Europe, Italy or alternatively V-Loc™ 3/0, Medtronic, USA) that run in the same direction from 3 to 9 o'clock. Of note is the fact that, after having applied the first stitch on the posterior wall we customarily pass the needle back below the first stitch to evert the posterior esophageal and gastric layer and improve their visualization. Once the posterior aspect of the anastomosis is complete, a NGT is placed under direct vision inside the stomach distally to the anastomosis, thus accomplishing the closure of anterior surface. Finally, a few tension release stitches are put in between the mediastinal pleura and seromuscular layer of the gastric tube.

The anastomosis is checked for intraoperative leaks with methylene blue and a 28-Fr chest drain is inserted via the R1 robotic trocar, posteriorly to anastomosis, with the apex in the upper chest (Video).

Table 1 Patient demographics and tumor characteristics

n = 30	
Age, year median [range]	68 [33–89]
Gender, n (%)	
M/F	26 (86.7)/4 (13.3)
cTNM stage, *n (%)*	
I	1 (3.3)
IIB	2 (6.7)
III	10 (33.3)
IVA	16 (53.3)
IVB	1 (3.3)
Physical status of ASA, *n* (%)	
II	15 (50)
III	14 (46.7)
IV	1 (3.3)
Tumor location, *n (%)*	
EGJ/Lower esophageal	23 (76.7)/7 (23.3)
Histology, *n (%)*	
Adenocarcinoma	27 (90)
Squamous cell carcinoma	1 (3.3)
Mixed Type	2 (6.7)
Neoadjuvant therapy, *n* (%)	
Chemotherapy	20 (66.7)
Chemo-radiotherapy	5 (16.7)

cTNM stage, Clinical stage according to TNM staging AJCC UICC 8th edition;*ASA* American Society of Anesthesiologists; *EGJ* esophagogastric junction

Results

Between April 2019 and February 2022, 30 patients with resectable esophageal cancer or cancer at the EGJ level underwent curative ILE with mediastinal lymph node dissection and robot-sewn esophagogastrostomy. Baseline characteristics are listed in Table 1. Most of the patients (73.67%) were affected by tumors localized at the EGJ and received neoadjuvant chemotherapy (66.67%). Planned treatment was completed in 27 patients (90%).

Surgical and postoperative data are highlighted in Table 2. A robot-sewn esophagogastrostomy with self-locking barbed 3/0 suture was carried out in all patients. Both dV®Si™and dV®Xi™ systems were used in 9 and 21 patients, respectively. However, all the candidates are considered together because the only difference is related to the type of robotic platform used. The abdominal phase was mostly carried out using a robotic approach (70%). No conversion to open or laparoscopic approach were needed and no intraoperative complications occurred.

Postoperative complications of some grade occurred in 16 (53.3%) patients. The most commonly observed ones were pulmonary complications (26.7%). Anastomotic leakage occurred in 1 patient (3.3%) (ECCG, Type III) who was primarily treated with endoscopically placed clips (Instinct® Endoscopic Clip, Cook® Medical, USA) and who later required reoperation for repair and drainage. Chylothorax was observed in 2 patients (6.7%) (ECCG, Type IIA). One patient (3.3%) experienced a gastric conduit necrosis on POD 14 (ECCG, Type III) and underwent gastric tube excision and esophagostomy. This was the

Table 2 Surgical and postoperative outcomes

$n = 30$	
Abdominal approach *n* (%)	
Open/3D laparoscopy/robotic	6 (20)/3 (10)/21 (70)
Operative time (min), *mean* ± *sd*	
Total/thoracic phase	481 ± 49/217 ± 44
Intraoperative complications, *n* (%)	0 (0)
Conversion, *n* (%)	
Thoracic/abdominal phase	0 (0)
Overall complications, *n* (%)	16 (53.3)
Cardiac complications, *n* (%)	
Atrial dysrhythmia requiring treatment	2 (6.7)
Pulmonary complications, *n* (%)	8 (26.7)
Pneumonia	3 (10)
Pleural effusion requiring additional draining procedure	3 (10)
Pneumothorax requiring treatment	2 (6.7)
Anastomotic leak, *n* (%)	
Type III	1 (3.3)
Chyle leak, *n* (%)	
Type IIA	2 (6.7)
Gastric conduit necrosis, *n* (%)	
Type III	1 (3.3)
Acute delirium, *n* (%)	1 (3.3)
Delayed conduit emptying (NGT drainage > 7 days), *n* (%)	1 (3.3)
Thoracic wound dehiscence, *n* (%)	1 (3.3)
Feeding J-tube complications, *n* (%)	3 (10)
Intrathoracic abscess, *n* (%)	2 (6.7)
Other infections requiring antibiotics, *n* (%)	1 (3.3)
LOS (days) median [range]	11 [6–51]
ICU stay (days) median [range]	1 [0–8]
Mortality, *n* (%)	
In-Hospital/30 day/ 90 day	0 (0)/0 (0)/0 (0)
30 day hospital re-admission, *n* (%)	1 (3.3)
Anastomotic strictures, *n* (%)	8 (26.7)

Complications are reported according to ECCG (Esophagectomy Complications Consensus Group) Classification

LOS Length of stay, *ICU* Intensive care unit, *NGT* Nasogastric tube

only case of readmission after patient discharge on POD 7. Intrathoracic abscesses were found in 2 patients without any clinical and radiological evidence of anastomotic leakage. A clinical diagnosis of anastomotic stricture was observed in 8 patients (26.7%) who were successfully treated with endoscopic dilatations.

In total, complications requiring reoperation under general anesthesia occurred in 2 patients (6.7%) owing to anastomotic leaks ($n = 1$) and conduit necrosis ($n = 1$). The first patient recovered uneventfully while the second died a few months after discharge from SARS-CoV-2 pneumonia. Median LOS was 11 days (range 6–51 days), and median ICU stay was 1 days (range 0–8 days). No mortality either in-hospital or within 90-days postoperatively occurred in this series.

The pathologic outcomes are summarized in Table 3. A median of 47 lymph nodes (range 20—81) were harvested. A R0 resection was achieved in all cases but one (96.7%) which presented a potentially positive gastric resection margin. This patient who was affected by an ypT3N3 adenocarcinoma underwent additional systemic chemotherapy. All patients had at least 6 months of follow-up with a median follow-up of 12 months. Median overall survival has not been reached yet.

Table 3 Histopathological data

	n = 30
Oncological Radicality, n (%)	
R0/R1	29 (96.7)/1 (3.3)
Harvested lymph nodes, median [range]	47 [20–81]
pTNM, n (%)	
T0N0	1 (3.3)
T0N1	1 (3.3)
T1bN0	2 (6.7)
T2N0	2 (6.7)
T2N3	1 (3.3)
T3N0	4 (13.3)
T3N2	8 (26.7)
T3N3	8 (26.7)
T4N3	3 (10)

pTNM, Pathological stage according to TNM staging AJCC UICC 8th edition

Discussion

In this single-surgeon study report, we present the technical details and initial results of ILE with two field lymph node dissection and robot-sewn intrathoracic anastomosis. This reconstruction proved to be technically feasible and safe. Moreover, the short-term outcomes are promising.

Nowadays, the adoption of MI techniques for ILE is becoming more and more widespread. However, to date, a considerable number of intrathoracic reconstructions have been described and there is still no general consensus on the best esophagogastric anastomosis in terms of postoperative complications [7, 25]. This is partly due to the technical challenges encountered when the anastomosis is performed thoracoscopically. Indeed, this approach has some intrinsic disadvantages mainly caused by the mirrored intracorporeal movements of the rigid instruments working in a narrow space, which increase the difficulty in creating the anastomosis itself.

Robotic systems have been introduced to further overcome the limitations of thoracoscopy [13]. The wrist-like range of movements provided by this new technology, together with its magnified visualization and precision control may be particularly helpful during ILE, especially for lymph node dissection and intrathoracic anastomosis. With regard to the latter, no standardized technique has been implemented so far but, even though the evidence regarding surgical outcomes is limited, robot-sewn techniques and circular or linear stapling techniques have all proven to be effective options [26].

In our surgical team, the Ivor Lewis procedure with single layer robot-sewn anastomosis is the preferred surgical option for patients undergoing esophagectomy. The well-known robotic benefits together with the adoption of some technical refinements (i.e., supportive stitches) make the hand sewing easier to perform. Nine previous studies [9–17] have reported on widely varying techniques to construct a robot-sewn intrathoracic anastomosis during ILE (Table 4). Differences include patient position, number of robotic arms adopted and especially the anastomosis fashioning in terms of the configuration, method, and type of suture. Therefore, a comparison of these experiences is quite difficult because of the heterogeneity in surgical techniques.

In our experience no intraoperative complications occurred, and the 30-day overall complication rate was 53.3%. Pulmonary complications were observed in 26.7% of patients, 10% of whom had pneumonia. These rates are consistent with the ESODATA results of 27.8% published by the ECCG [2]. Moreover, our data supports the low rate of respiratory complications in the prone position during MIE versus open esophagectomies [27].

In this study, robot-sewn anastomosis provided an anastomotic leak rate of 3.3% (n = 1, ECCG, Type III). This finding is consistent with that reported by other similar studies ranging from 0 to 32% (Table 4) and with the average anastomotic insufficiency rate (up to 5.6%) reported by other experiences of Ivor Lewis RAMIE with mechanical intrathoracic anastomosis [8]. Of note is the fact that the ICAN randomized controlled study (in agreement with other not randomized studies [28–30]) has recently shown that in the setting of a MI approach, intrathoracic anastomosis is associated with a clinically relevant lower leakage rate compared to cervical anastomosis. In particular, the overall anastomotic leak rate (ECCG grades 1, 2, and 3) was 12.3% after MIE with intrathoracic anastomosis and 34.1% after MIE with cervical anastomosis [6].

Although routine use of thoracic duct resection remains controversial, it has been recently advocated to extend the thoracic lymphadenectomy with resection of the thoracic duct and its surroundings nodes. This dissection can increase the oncological radicality of esophagectomy since metastatic tumor cells have been detected with an incidence up to 11%. However, the most common complication that has been associated with this procedure is chyle leak [31] that represents one of the challenging problems with regards to esophagectomy with an incidence of 2–10% [2].

A recently published international consensus on RAMIE states that in terms of surgical techniques the thoracic duct resection can indeed be more easily completed thanks to RAMIE [32]. In our study chyle leaks were observed in 6.7% of patients (n = 2, ECCG-Type 2 A) even though the thoracic

Table 4 Literature review

Authors, year	Study design, *n*	Type of da Vinci® System	Patient position (thoracic step)	Number of robotic arms employed (thoracic step)	Anastomotic configuration	Layered suture	Suture type	Anastomotic leak Grade[a], *n* (%)	Cardio-pulmonary complication, *n* (%)	Harvested LNs, mean ± sd or median (range)	30 days mortality, *n* (%)	Anastomotic strictures, *n* (%)
Cerfolio et al. [17], 2013	Retrospective $n=16$	Si	Left lateral and slightly prone	4	ETS	DL: PW (IS and RS) AW: (RS and IS)	IS: 3-0 Silk RS: 3-0 PDS	0 (0)	1 (6,3)	18 (15–28)	0 (0)	NA
Trugeda et al.[18], 2014	Prospective $n=14$	Si	Prone	3	ETE	DL: PW (IS and RS) SL: AW (RS)	IS: 2-0 Silk RS: 2-0 V-Loc (Medtronic)	4 (28,5) Grade II, 3 (21,4) Grade III, 1 (7,1)	0 (0)	18 (2–33)	0 (0)	0 (0)
Bongiolatti et al.[19], 2016	Retrospective $n=8$	Si	Prone	3	ETS	SL: PW (RS) and AW (IS)	IS: ND RS: 3-0 PDS	2 (25) Grade III, 2 (25)	0 (0)	37.6 ± 14.7	0 (0)	0 (0)
Egberts et al. [20], 2017	Retrospective $n=52$	Si	Left lateral tilted 45° to the prone position	4	ETE	DL: PW (RS and RS) and AW (RS and IS)	IS: Vicryl (Ethicon) RS: Stratafix (Ethicon)	5 (9,6) Grade II, 4 (7,7) Grade III, 1 (1,9)	NA	29 (22–65)	3 (5,7)	NA
Zhanget al.[21], 2018	Prospective $n=26$	S	Left lateral and slightly prone	4	ETE	DL: PW (RS and IS) and AW (RS and RS)	IS: 3-0 Vicryl (Ethicon) RS: 3-0 V-loc (Medtronic)	2 (7,7) Grade II, 2 (7,7)	4 (15,4)	19,3 ± 9,2	0 (0)	NA
De Groot et al.[22], 2020	Prospective $n=68$	Si	Left lateral tilted 45° to the prone position	3	ETE/ETS	SL: PW (RS) and AW (RS)	RS: 3-0 V-loc (Medtronic)/3-0 Stratafix (Ethicon)	22 (32) Grade I, 5 (7) Grade II, 7 (10) Grade III, 10 (15)	NA	NA	NA	NA
Xu et al.[23], 2021	Retrospective $n=43$	Si	Full lateral position	4	ETS	DL: PW (RS) AW (RS)	RS: 3-0 Stratafix (Ethicon) and 4-0 Vicryl (Ethicon)	0 (0)	3 (7,0)[δ]	17,4 ± 6,9	0 (0)	2 (4,7)
Peri et al. [24], 2022	Retrospective $n=12$	Si	Semi-prone position	3	ETE	DL: PW (RS) AW (RS and IS)	RS: 3-0 V-loc (Medtronic) IS: 3-0 V-loc (Medtronic)	0 (0)	NA	32,5 ± 18,3	NA	1 (11,1)

Table 4 (continued)

Authors, year	Study design, *n*	Type of da Vinci® System	Patient position (thoracic step)	Number of robotic arms employed (thoracic step)	Anastomotic configuration	Layered suture	Suture type	Anastomotic leak Grade[a], *n* (%)	Cardio-pulmonary complication, *n* (%)	Harvested LNs, mean ± sd or median (range)	30 days mortality, *n* (%)	Anastomotic strictures, *n* (%)
Angerhrn et al.[25], 2022	Prospective *n* = 76	Xi	Left semi-prone position	4	ETS	SL: PW (RS) AW (RS)	RS: Barbed suture	6 (7.9)	65 (85.5)	24.5 (18.5–32)	2 (2.6)	NA
Our series, 2022	Retrospective *n* = 30	Si and Xi	Left lateral tilted 45° to prone position	3	ETS	SL: PW (RS) and AW (RS)	RS: 3-0 Filbloc (Assut Europe) or 3-0 V-Loc (Medtronic)	1 (3,3) Grade III, 1 (3,3)	10 (33, 3)	47 (20–81)	0 (0)	8 (26,7)

AW anterior wall anastomosis, *DL* double layer, *ETS* end-to-side, *ETE* end-to-end, *ETS* end-to-side, *IS* interrupted suture, *NA* not available, *ND* not declared, *PDS* polydiaxone, *PW* posterior wall anastomosis, *RS* running suture, *SL* single layer suture

[a]Anastomosis leak grade according to ECCG (Esophagectomy Complications Consensus Group) Classification

duct was identified and clipped in 100% of cases. We believe that the presence of secondary thoracic duct lymph flow might be a possible cause. Hence the ligation of the main thoracic duct could be considered effective but only a preventative measure to reduce the incidence of postoperative chylothorax that has a multifactorial etiology. This complication might be reduced by adopting of appropriate energy devices for the mesogastric excision or using an omental flap as well as by performing the abdominal step of the surgery with MI techniques [33]. Moreover, near-infrared fluorescence imaging (NIR-FI) using ICG has been recently proved to be effective in displaying both thoracic duct and its anatomical variations and detecting chyle leakage, which could contribute to narrowing the incidence of postoperative chylothorax [34].

In our series, 26.7% of patients developed a stricture that required at least one dilatation within 90 days of operation. None of those occurred immediately after surgery meaning that it was not a late sequela of apparent or inapparent anastomotic leakage. However, this data is higher than that reported in four similar robotic series [10, 11, 15, 16] although comparison of these results is difficult because of the heterogeneity in surgical techniques. In addition, our result is slightly higher than the stricture rates reaching 18% reported in a meta-analysis of MI ILE including both end-to-end and side-to-side techniques [35].

The robotic system offers some unique advantages in performing a hand-sewn anastomosis by leading to a more precise and controlled reconstruction as confirmed by some groups who are promoting a return to this type of anastomoses [17, 36]. However, the lack of tactile feedback and prolonged tensile effect of the barbed sutures may have contributed to the development of postoperative stricture that occurred especially in the first cases of our series. While a recent network meta-analysis has demonstrated that hand-sewn anastomosis is associated with a higher rate of anastomotic stricture compared to linear-stapled anastomosis (though superior to the circular-stapled one [37]), large, high-quality studies are needed to provide evidence about the anastomotic stricture rate among different anastomosis techniques.

Short-term oncological outcomes are listed in Table 3. An R0 resection was achieved in 96.7% of patients with a median number of 47 lymph nodes which is greater than the minimum number of 15 lymph nodes mentioned in NCCN Guidelines [1]. Moreover, the number of harvested lymph nodes in our series supports recent, sound evidence which demonstrates that RAMIE yields more dissected lymph nodes than conventional MIE in patients who received neo-adjuvant therapy [38].

Our study had some drawbacks. First, it had a retrospective design. Furthermore, a more consistent series of patients with a longer follow-up period would likely better confirm the oncologic and functional benefits of our technique. Despite these limitations, this article revolves mainly around the current clinical demand for details on how to do a robotic Ivor Lewis esophagogastrectomy. The outcomes of our study suggest that robotic-sewn esophagogastrostomy during ILE seems to be safe and effective, with favorable perioperative results. Nevertheless further evaluation through high quality studies is required to establish the best anastomosis reconstruction for robotic ILE [39].

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Declarations

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