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DYNAMIC MANUSCRIPT

Minimally Invasive Ivor Lewis Esophagectomy (MILE): technique and outcomes of 100 consecutive cases

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Abstract

Background Esophagectomy is the mainstay of therapy for esophageal cancer but is a complex operation that is associated with significantly high morbidity and mortality rates. The primary aim of this study is to report our perioperative outcomes, and long-term survival of Minimally Invasive Ivor Lewis Esophagectomy (MILE).

Methods IRB approved retrospective study of 100 consecutive patients who underwent elective MILE from September 2013 to November 2017 at University of Florida, Jacksonville.

Results Primary diagnosis was esophageal cancer ($n=96$) and benign esophageal disease ($n=4$). Anastomotic leak rate was observed in 6%; 30- and 90-day mortality rates were 2% and 3%, respectively. The mean length of hospital stay was 10.3 days; 87 patients were discharged to home, while 12 patients were discharged to rehabilitation facility, and there was one in-hospital mortality secondary to graft necrosis. At a mean follow-up was 37 months (2–74), the 3- and 5-year overall survivals are $63.9 \pm 5.0\%$ (95% CI 53.3–72.7%) and $60.5 \pm 5.3\%$ (95% CI 49.4–69.9%), respectively. The 3- and 5-year disease-free survival is $75.0 \pm 4.8\%$ (95% CI 64.2–83.0%) and $70.4 \pm 5.5\%$ (95% CI 58.0–80.0%).

Conclusion MILE can be performed with low perioperative mortality, and favorable long-term overall and disease-free survival.

Keywords Esophagectomy · Ivor lewis · Minimally invasive · MIE · MILE

The incidence of esophageal cancer continues to increase in the USA with a profound shift in the prevalence of adenocarcinoma [1]. The overall 5-year survival rate has improved but is still reported to be less than 30%; and even among those with limited nodal disease, 5-year survival is expected to be less than 50% [1–3]. Surgery remains the cornerstone for a multimodal approach to esophageal cancer. Despite improvements in technique and perioperative care, the reported mortality rate is 8–20% [4, 5], and anastomotic leak rates of around 11% following esophagectomy are amongst the highest of any gastrointestinal anastomosis [6]. The first description of Minimally Invasive Ivor Lewis Esophagectomy (MILE) was in the early 1990s by Cuschieri et. al. and DePaula et al. As this technique has been refined, perioperative outcomes have significantly improved while demonstrating equivalent oncologic outcomes compared to open surgery [9–14].

The primary objective of the study is to report our technique, perioperative outcomes, and long-term survival of Minimally Invasive Ivor Lewis Esophagectomy (MILE).

Methods

This is a retrospective analysis of prospectively collected data that was approved by our institutional review board and included all patients undergoing MILE performed at University of Florida, Jacksonville, by a single surgeon (ZTA) from September 2013 to November 2017 (IRB #201600651). Demographics, preoperative staging, neoadjuvant treatment and postoperative course was assessed. Intraoperative data including complete video footages of the operation was performed on all patients.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00464-020-07529-0) contains supplementary material, which is available to authorized users.

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Surgical approach

All patients underwent a subtotal esophagectomy with proximal gastrectomy using minimally invasive Ivor Lewis esophagectomy.

Abdominal portion

Five trocars are used for the abdominal portion of the operation that includes creation of a tubular gastric conduit, lymphadenectomy, and placement of a feeding jejunostomy tube, if not preformed previously. The patient is placed in slight reverse Trendelenburg position and a staging diagnostic laparoscopy is performed. The dissection commences by opening the gastrocolic omentum at the level of the pyloric antrum. Meticulous attention is paid to the origin and course of the right gastroepiploic artery (Fig. 1). The dissection then heads to the right side mobilizing the proximal transverse colon by dividing its attachments to the inferior edge of the liver and retroperitoneum to expose the second portion of the duodenum. A Kocher's maneuver is routinely performed so the pylorus can be easily brought up to the diaphragmatic hiatus. The greater curve of the stomach is mobilized by dividing the gastrocolic omentum and the short gastric vessels heading towards the base of the left crus. Difficulty in exposure can be mitigated by tilting the table in the left side up position, helping to open the space between the stomach and spleen to facilitate division of the short gastric vessels and minimize possible traction injury of the stomach. Vascularized omental flap is created to latter serve as an omental buttress for the intrathoracic anastomosis.

The gastrohepatic ligament is opened heading towards the base of the right crus. The esophagus if lifted off its bed using sharp dissection and the gastroesophageal junction is circumferentially mobilized. The right crus is routinely transected to widen the size of the hiatus. A Penrose drain is placed around the distal esophagus which helps with identification and thoracoscopic esophageal mobilization. En-bloc celiac lymphadenectomy is performed; the left gastric artery and vein are divided using a laparoscopic linear stapler (Fig. 2).

A four cm Heineke-Mikulicz pyloroplasty is performed in all cases. The gastric conduit (4–5 cm wide) is constructed 4 cm proximal to the pylorus using multiple applications of the laparoscopic linear stapler. The distal margin is determined based upon tumor location. The tip of the gastric conduit is anchored to the distal gastric staple line with 2 stitches of 0 silk to facilitate delivery of the conduit into the chest. We routinely place a 12 French feeding jejunostomy in the left upper quadrant.

Thoracic portion

The thoracic portion of the case has three primary steps which include esophageal resection, mediastinal lymphadenectomy and creation of esophagogastrostomy. The patient is placed in a left lateral decubitus position well supported and padded on the operating table. A single lung ventilation is used via a double lumen endotracheal tube. A right

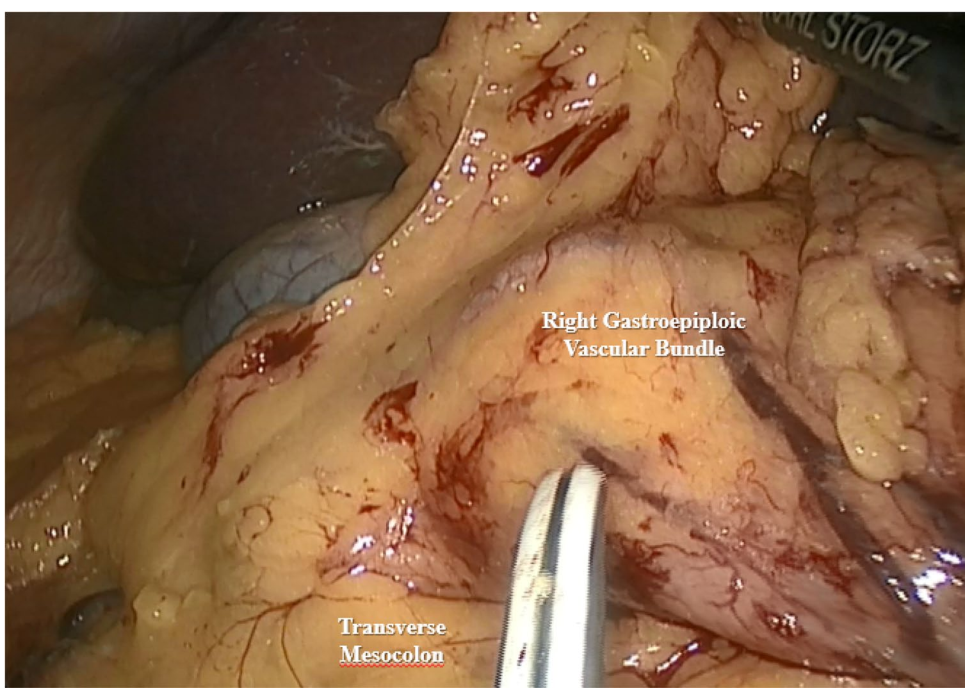

Fig. 1 Identification and Isolation of the right gastroepiploic artery

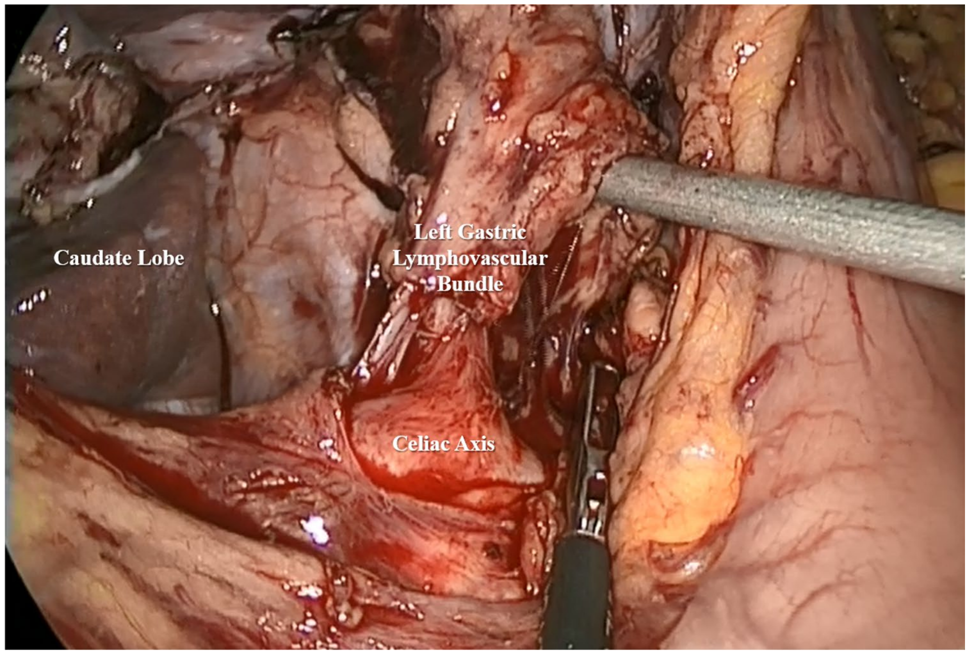

Fig. 2 Mobilization and transection of the left gastric lymphovascular bundle

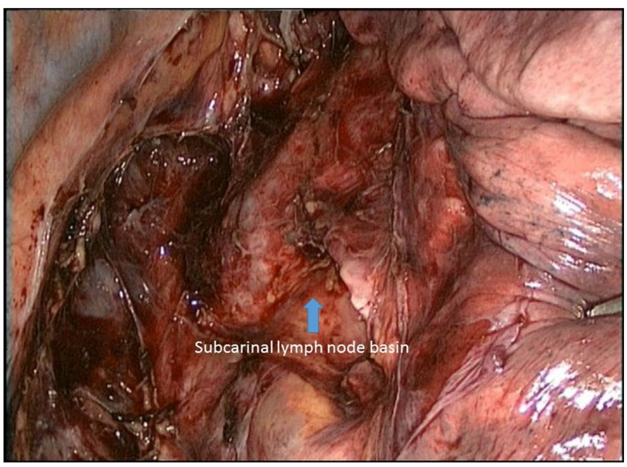

Fig. 3 Subcarinal lymph node dissection

video-assisted thoracoscopic surgery (VATS) 5-trocar approach with CO_2 insufflation at 8 mmHg is used. The inferior pulmonary ligament is incised to the level of the inferior pulmonary vein and the right lung reflected anteriorly. The mediastinal pleura is incised, and the esophagus is circumferentially mobilized together with the surrounding lymph nodes. We staple the esophagus using the superior 12 mm anteriorly placed trocar. The azygous vein is selectively divided using the laparoscopic linear stapler.

The subcarinal nodal tissue is taken en-bloc with the specimen when technically feasible or is otherwise taken separately (Fig. 3). The inferolateral incision is extended to a 4-cm incision and a wound protector is placed. The gastric conduit is pulled into the right thoracic cavity maintain the right orientation. The specimen is removed and sent for pathologic confirmation of a negative margin.

The 25-mm OrVil™ (Covidien, Minneapolis, MN, USA) is introduced orally and passed through the esophageal stump via a small opening that is made at or just next to the staple line, leaving the anvil in place. The staples line at the tip of the gastric conduit is excised using Harmonic Shears (Ethicon, Somerville, NJ, USA). A mechanical circular stapler 25 mm DST XL EEA (Covidien, Minneapolis, MN, USA) is passed through the gastrotomy, and an end-to-side esophagogastrostomy is constructed (Fig. 4). Prior to closure of the gastrotomy a nasogastric tube is passed to the anastomosis under direct vision. The gastrotomy is closed using the laparoscopic linear stapler. A leak test is performed via the nasogastric tube, and the nasogastric tube is gently advanced several centimeters passed the anastomosis. The previously mentioned omental flap is then delivered into the chest and is laid over the anastomosis and the lesser curvature staple line (Fig. 5). Two sutures area placed to anchor the conduit to the paraspinal pleura as to prevent torsion of the conduit.

Postoperative course

All patients are admitted to the Surgical Intensive Care Unit (ICU), with a dedicated surgical intensivist participating in the management. A standardized postoperative protocol is used (Fig. 6). Patients are discharged with jejunostomy tube feeding and close follow-up with the MILE team. Close outpatient monitoring with routine telephone calls and clinic visits with regards to perioperative surgical symptoms (i.e.,

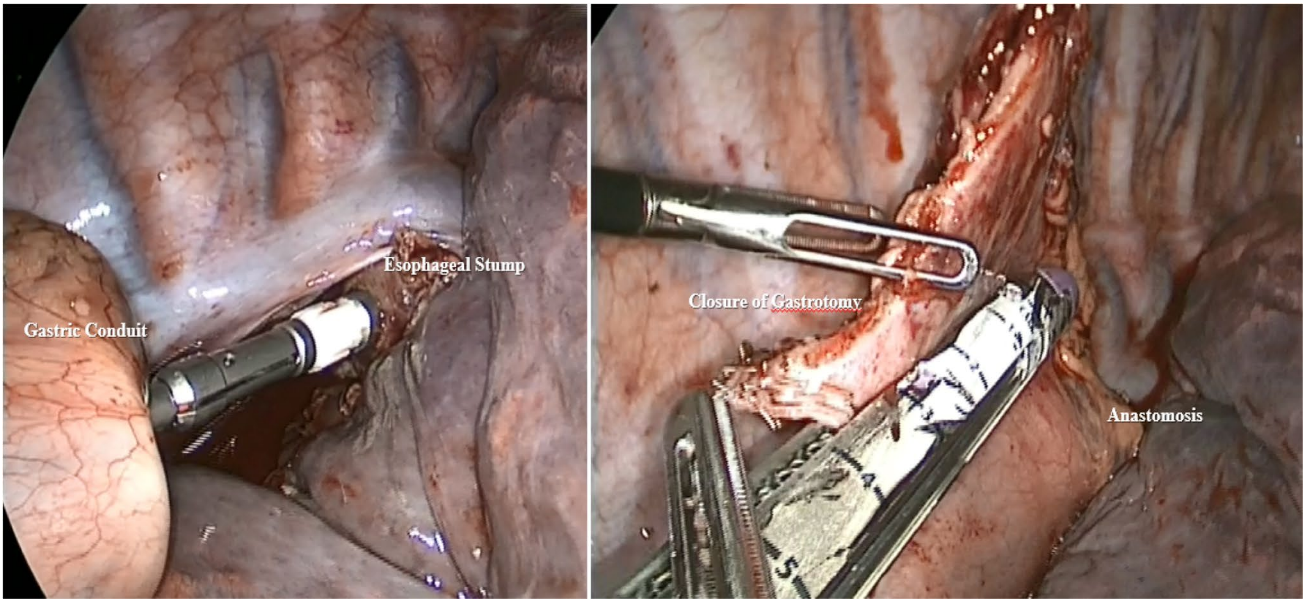

Fig. 4 Esophagogastric anastomosis

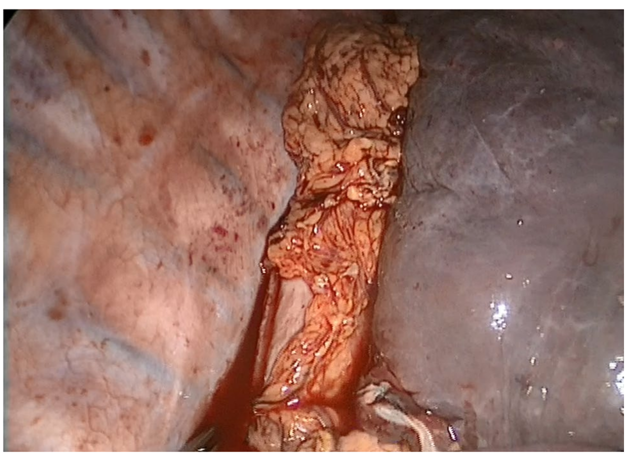

Fig. 5 Placement of omental flap

hydration, enteral nutrition tolerance), and activities of daily living, are the primary goals of therapy. Oral intake is initiated on the 1st postoperative visit and gradually advanced as tolerated.

Esophagectomy Outcomes

A standardized surgical outcomes database was prospectively created to collect data for a retrospective chart review. Demographics, laboratory and radiographic studies, operative details, and tumor-related variables were recorded. Intraoperative and postoperative outcomes were extracted, including postoperative morbidities, length of stay, and mortality. Descriptive data were collected with all measured parameters. Quantitative data were expressed as mean and with min–max range, if applicable. Also, the data set is built in chronological order and presented in four quartiles (25 patients each) for comparison and better highlight stages of possible improvement. Kaplan–Meier survival analyses were used to calculate overall and disease-free survival.

Follow-up

After discharge all patients were regularly evaluated at the clinic. In the first year, follow-up consisted of evaluations every 3 months. In the second and third year, follow-up took place every 6 months and annual visits were held during the fourth and fifth year.

Results

Demographics and comorbidities are demonstrated in Tables 1 and 2, respectively. One-way ANOVA analysis revealed no significant differences across the four quartiles with respect to age [F (3,96) = 0.144, p = 0.934], weight [F (3,96) = 0.318, p = 0.813], or BMI [F (3,96) = 1.184, p = 0.320]. Chi-square analysis revealed no significant differences across the four quartiles with respect to sex [χ^2 (3,100) = 1.50, p = 0.682], race [χ^2 (3,100) = 2.17, p = 0.537], or BMI over 30 [χ^2 (3,100) = 0.213, p = 0.976].

Fig. 6 Esophageal resection standardized clinical pathway

Esophageal Resection Standardized Clinical Pathway

Postoperative Day 0

1. Admit to Intensive Care Unit
2. Post-op Patient Controlled Anesthesia
3. Perioperative antibiotics
4. Deep Venous Thrombosis prophylaxis
5. Stress ulcer prophylaxis
6. Beta-Blocker
7. Tight blood sugar control
8. Patient mobilized to chair
9. Nasogastric tube to low-intermittent suction
10. Water at 10 cc/hr via jejunostomy tube
11. Nutritional Consultation
12. Aspiration precautions
13. Incentive spirometer 10x/hour, respiratory exercise
14. Case Management Consultation: discharge planning and home health needs

Postoperative Day 1

1. Foley catheter removal
2. Physical Therapy consultation: Walk 3-4 times per day; sit in the chair for 3 hours twice daily
3. Mineral oil 30 cc/day via jejunostomy tube

Postoperative Day 2

1. Nasogastric tube removed
2. Jejunostomy tube analgesics
3. Ice chips-5 cc/hour

Postoperative Day 3

Jejunostomy tube nutrition initiated at 10 cc/h and advance to goal

Postoperative Day 4-5

1. Gastrografin and thin barium swallow study
2. Removal of tube thoracostomy

Postoperative Day 6

1. Discharge Planning

Table 1 Demographics

	All patients	Patient #1–25	Patients #26–50	Patients #51–75	Patients #76–100
Age	65.12 (36–80)	64.88 (45–77)	64.76 (36–77)	64.68 (44–74)	66.16 (45–80)
Sex	80M/20F	19M/6F	20M/5F	22M/3F	19M/6F
Race	92C/8AA	22C/3AA	22C/3AA	24C/1AA	24C/1AA
Weight (lbs)	175.88 (114–287)	175.52 (114–264)	171.04 (117–220)	176.24 (126–273)	180.72 (135–287)
BMI	26.36 (16.70–41.72)	27.07 (17.30–41.00)	26.19 (20.19–35.55)	24.97 (16.70–37.10)	27.23 (22.20–41.72)
BMI > 30:	17	5	4	4	4

C Caucasian, *AA* African American, *BMI* body mass index

Disease characteristics

Ninety-six patients underwent MILE for esophageal cancer (Adenocarcinoma, $n = 75$; Squamous Cell Carcinoma, $n = 21$), while 4 patients underwent resection for benign disease (End Stage Achalasia, $n = 3$; Large Leiomyoma, $n = 1$). Thirty-six patients had an enteral feeding access, while one patient had an esophageal stent placed prior to the esophagectomy (Table 3).

Intraoperative findings

There was no conversion to exploratory laparotomy for the abdominal part of the procedure. Four patients were

Table 2 Comorbidities

	All patients	Patient #1–25	Patients #26–50	Patients #51–75	Patients #76–100
History of smoking	79/100	17/25	21/25	21/25	20/25
Current smoker	37	9/25	6/25	17/25	5/25
Avg pkyrs	35	39	27.4	43	32
Drugs use	0/100	0/25	0/25	0/25	2/25
EtOH use	58/100	16/25	14/25	16/25	12/25
DM	17/100	5/25	4/25	3/25	5/25
Respiratory disease	39/100	5/25	12/25	10/25	12/25
COPD	22/100	3/25	6/25	6/25	7/25
OSA	14/100	1/25	4/25	4/25	5/25
Asthma	4/100	1/25	3/25	0/25	0/25
Other	3/100	1/25	1/25	0/25	1/25
Cardiac disease	23/100	4/25	8/25	3/25	8/25
CAD	16	3	5	3	5
Atrial fibrillation	6	1	2	0	3
Mitral valve prolapse	1	0	1	0	0
Hyperlipidemia	33/100	7/25	9/25	10/25	7/25
Hypertension	34/100	13/25	17/25	12/25	12/25
Liver disease	1/100	0/25	1/25	0/25	1/25
Esophageal reflux	52/100	9/25	16/25	16/25	11/25
Renal disease	4/100	1/25	1/25	1/25	1/25
Chronic anemia	64/100	16/25	10/25	17/25	21/25
Other malignancies					
Breast	1	1	0	0	0
Lymphoma	1	1	0	0	0
Prostate	5	1	1	2	1
Skin cancer	2	0	0	2	0
Renal cancer	1	0	1	0	0
Melanoma	1	1	0	0	0
Thyroid	1	1	0	0	0
Previous abdominal surgery	69/100	15/25	18/25	16/25	21/25

Avg Pk Yrs Average pack years, *DM* diabetes mellitus, *COPD* Chronic Obstructive Pulmonary Disease, *OSA* Obstructive Sleep Apnea, *CAD* Coronary Artery Disease

Table 3 Disease characteristics

Disease characteristics	All patients	Patient #1–25	Patients #26–50	Patients #51–75	Patients #76–100
Disease					
Adenocarcinoma	75	19	20	19	18
Benign disease	4	1	0	1	1
SCC	21	5	5	5	6
Neoadjuvant therapy	88/96	22/25	25/25	24/25	21/25
Preoperative enteral nutritional procedures					
Jejunostomy	28	6	8	6	8
Gastrostomy	8	1	2	3	2
Esophageal stent	1	0	1	0	0

converted to thoracotomy. One patient had an emergent thoracotomy for bleeding from an aberrant pulmonary vein branch which was controlled, and the esophagogastric anastomosis was delayed until 2 days later. This was the only patient in the series to receive intra operative blood transfusion. Other reasons for conversion were dense mediastinal adhesions ($n=1$), loss of thoracic domain in morbidly obese patient ($n=1$), and inability to align the EEA with the anvil is an obese male patient with thick chest wall (more than 15 cm) ($n=1$). One-way ANOVA analysis revealed a significant difference across the four quartiles with respect to operative time [F (3,96) = 3.963, $p=0.01$]. A post hoc Tukey analysis revealed operative time for patients in quartile 1 were significantly greater than operative times for quartile 2 ($p=0.020$) and quartile 3 ($p=0.019$).), but no significant difference was found between quartile 1 and quartile 4 ($p=0.336$). One-way ANOVA analysis revealed no significant difference across the four quartiles with respect to blood loss [F (3,96) = 1.245, $p=0.298$] (Table 4).

Postoperative morbidity and mortality

There was no intraoperative mortality. The 30-day overall mortality was 2% (2/100). One patient developed graft necrosis necessitating thoracotomy for resection of the necrotic graft and creation of spit fistula. He expired 3 days later. The 2nd patient developed cardiac arrest at home two weeks after hospital discharge. There were six anastomotic leaks, and all were manged with endoscopic stent placement. Six patients required reoperation within the same admission: conduit volvulus, $n=2$; compression of the conduit at the diaphragmatic hiatus by excess omental flap, $n=1$; redundant sigmoid conduit causing outlet obstruction, $n=1$; reoperation for delayed reconstruction of the esophagogastric anastomosis in patient with bleeding; and reoperation for the patient with graft necrosis. All reoperations with the exception for the last two patients were done using the minimally invasive approach. Postoperative complications were observed in 44 patients. Chi-square analysis revealed no significant differences across the four quartiles with respect to hospital complications [χ^2 (6,100) = 8.36, $p=0.213$]. There was no case of chyle leak or recurrent laryngeal nerve palsy (Table 5).

The 30-day readmission rate was 8% (8/100). Reasons for readmission include aspiration pneumonia ($n=1$), jejunostomy tube malfunction and pulmonary embolism ($n=1$), pneumonia ($n=1$), shortness of breath ($n=1$), large bowel obstruction due to cecal volvulus necessitating an exploratory laparotomy and right hemicolectomy ($n=1$), exacerbation of COPD ($n=1$), atrial fibrillation ($n=1$), and wound infection at the jejunostomy and chest tube sites needed debridement and vacuum assisted closure of the wound ($n=1$), and atrial fibrillation ($n=1$). There was one 90 days readmission and reoperation for post esophagectomy hernia. The 90 days mortality was 3%. The patient died from respiratory failure at the rehab facility. Pathological outcomes are shown in Table 6. One patient had a positive proximal margin despite 3 proximal resections, while one patient had T4b (involving the aorta).

Follow-up

Mean follow-up was 37 months (2–74). Five patients were excluded from overall survival analysis; three patients were excluded for being lost to follow-up and two patients were excluded for perioperative deaths. Ninety-five patients were analyzed for overall and disease-free survival by the Kaplan Meier method (Figs. 7 and 8). The 3- and 5-year overall survivals are 63.9 ± 5.0% (95% CI 53.3–72.7%) and 60.5 ± 5.3% (95% CI 49.4–69.9%), respectively. The 3- and 5-year disease-free survival is 75.0 ± 4.8% (95% CI 64.2–83.0%) and 70.4 ± 5.5% (95% CI 58.0–80.0%).

Five patients are alive with cancer recurrence; mediastinal, $n=4$, retroperitoneal, $n=1$, and are currently undergoing treatment. The recurrence occurred 6–48 months after surgical resection. Thirty- five patients are dead at a mean 16.3 months (range 4–42) after surgery. In 16 patients, the death was non-cancer related, while in 19 patients it was related to cancer progression (one patient with T4b disease) or cancer recurrence. The recurrence occurred at a mean of 12.4 months (range 3–34) after surgery, while death occurred 16.6 months (range 6–39) after surgery.

Table 4 Intraoperative findings

Intraoperative findings	All patients	Patient #1–25	Patients #26–50	Patients #51–75	Patients #76–100
Operative time (min)	384.56 (236–827)	432.48 (300–600)	358.16 (236–550)	357.52 (290–501)	390.08 (244–827)
Blood loss (mL)	186.1 (5–3300)	190.6 (10–500)	294.8(5–3300)	150.6 (10–1000)	108.5 (15–500)
ASA	2.9 (2–4)	2.9 (2–3)	3 (2–4)	2.9 (2–3)	2.9 (2–4)
Converted to thoracotomy	4	0	2	0	2

Table 5 Postoperative morbidity and mortality

PostOp hospital course:	All patients	Patient #1–25	Patients #26–50	Patients #51–75	Patients #76–100
Mean length of hospital stay	10.3 (5–42)	12.2 (6–42)	9.5 (5–18)	9.2 (6–16)	10.2 (6–30)
Leak	6/100	0/25	2/25	3/25	1/25
Graft necrosis	1	0	1	0	0
Hospital complications	40/100	11/25	10/25	10/25	7/25
Atrial fibrillation	20	3	9	6	2
C Difficle Colitis	2	2	0	0	0
Acute kidney injury	5	4	0	0	1
Colonic pseudo-obstruction	3	1	0	0	2
Ventricular tachycardia	1	0	0	0	1
Supraventricular tachycardia	1	1	0	0	0
Ileus	1	0	0	1	0
Urinary retention	1	0	1	0	0
Aspiration	2	0	0	1	1
Pneumothorax	1	0	0	1	0
Pleural effusion	2	0	0	1	1
Fever	3	2	0	1	0
Pneumonia	4	2	0	0	2
Respiratory failure	5	4	0	0	1
Pulmonary embolism	1	1	0	0	0
Confusion	4	2	0	2	2
Discharge disposition					
Home	27	21	23	20	23
Rehabilitation facility	12	4	1	5	2
Hospital mortality	1	1	1	0	0
30 day mortality	2	1	1	0	0
30 day readmission	8	4	2	0	2
30 day reoperation	8	2	4	0	2
90 day readmission	9	4	3	0	2
90 day reoperation	9	2	5	0	2
90 day mortality	3	1	1	1	0

Discussion

Our experience has shown that MILE can be performed with an acceptable morbidity and mortality that is comparable to most recent published series [15, 19–37]. The 3 and 5-year overall and disease-free survival rate observed in our present study is similar or exceeds the results of most recent open or minimally invasive esophagectomy series [32, 33, 38–40]. Recent publication from our institute comparing outcomes for patients who underwent Ivor Lewis esophagectomy with the National Surgical Quality Improvement Program (NSQIP) database showed no differences between groups for mortality, readmission, discharge destination, or mean operative time. We had significantly fewer complications (16.7% vs 33.3%; $p = 0.003$), fewer reoperations (6.4% vs 14.5%; $p = 0.046$), and shorter hospital length of stay (10.3 vs 13.1 days; $p = 0.001$) [41]. The four quartiles in our series were evenly matched with regards to age, sex, race, weight, BMI and comorbidities. There was no significant difference in the complication rates including anastomotic leak and blood loss across the 4 quartiles. The operative time often considered a benchmark of proficiency was significantly longer in the quartile 1 compared to the quartile 2 and 3 but to difference to quartile 4. The fundamental reasons for increased operative time are illusive but could include multiple issues such as increased set-up time, patient's body mass index, abdominal adiposity, previous abdominal surgeries necessitating lysis of adhesions, tumor location or adherence to vital structures, delays in reporting pathological frozen section analysis, patient's inability to tolerate single lung ventilation, unexperienced nursing and surgical technician team, PGY level of resident participating in the case, fellow participation, or an intrinsic inefficiency of the surgeon's technique. Lorimer et al. in a retrospective review of 200 minimally invasive esophagectomy cases found that operative time was significantly longer with conversion to open

Table 6 Pathological outcomes

Pathology	All patients	Patient #1–25	Patients #26–50	Patients #51–75	Patients #76–100
Mean lymph node resection	20 (9–34)	16 (9–29)	23 (11–34)	19 (10–32)	18 (10–31)
Postoperative stage					
1	50	13	14	12	11
2	10	3	0	5	2
3a	10	3	5	0	2
3b	18	3	3	6	6
4a	7	1	3	1	2
4b	0	0	0	0	0
Benign disease	4	2	0	1	1
Leiomyoma	1	0	0	0	1
Positive margins	1/100	0/23	1/25	0/25	0/25
Lymphovascular invasion					
Unknown	37	24	7	1	5
Present	21	1	5	7	8
Absent	38	0	13	17	12

Staging in Accordance with AJCC Cancer Staging Manual, Eight Edition (2017)

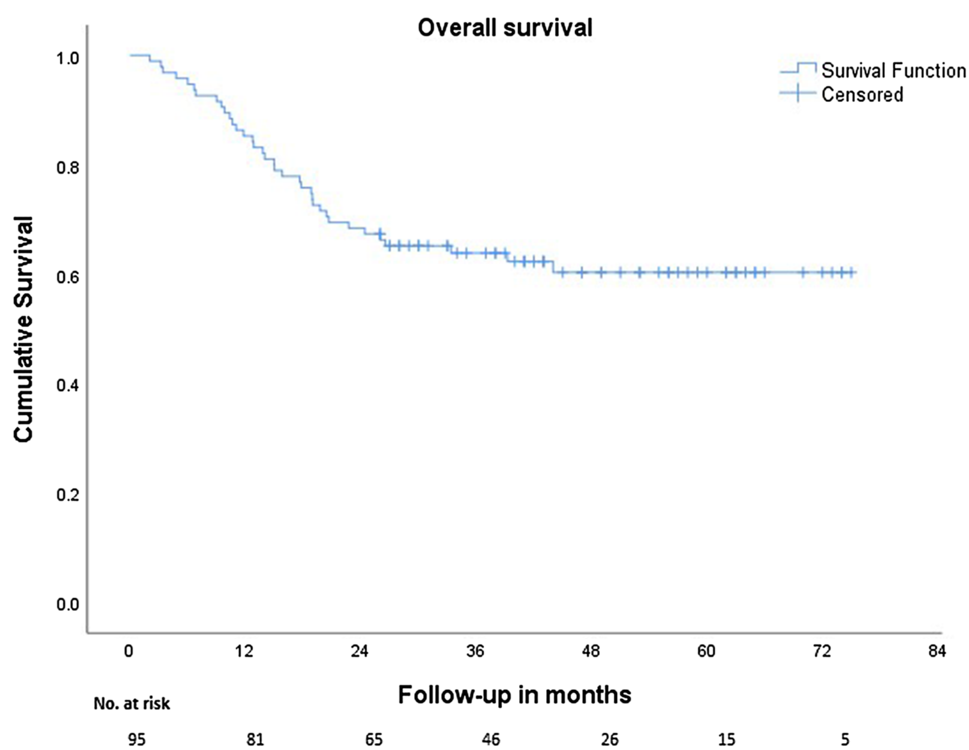

Fig. 7 Kaplan–Meier survival curve

surgery and total esophagectomy with cervical anastomosis [42]. Increased BMI was associated with longer operative time. After accounting for other factors, operative experience was still significantly associated with shorter operative time [42].

The mean number of lymph nodes retrieved was 20 (9–34) with no significant difference across the quartiles. Our standard lymphadenectomy results is comparable to other groups who performed MIE [32, 33, 43], and it surpasses the median number of 14 lymph nodes yielded in the CROSS study [40].We have been able to achieve excellent oncological results in terms of R0 resections, and our long-term follow-up yields a meaningful data regarding the long-term oncological outcomes after MIE.

Pyloric drainage after esophagectomy is a controversial topic. We routinely perform pyloroplasty and had no

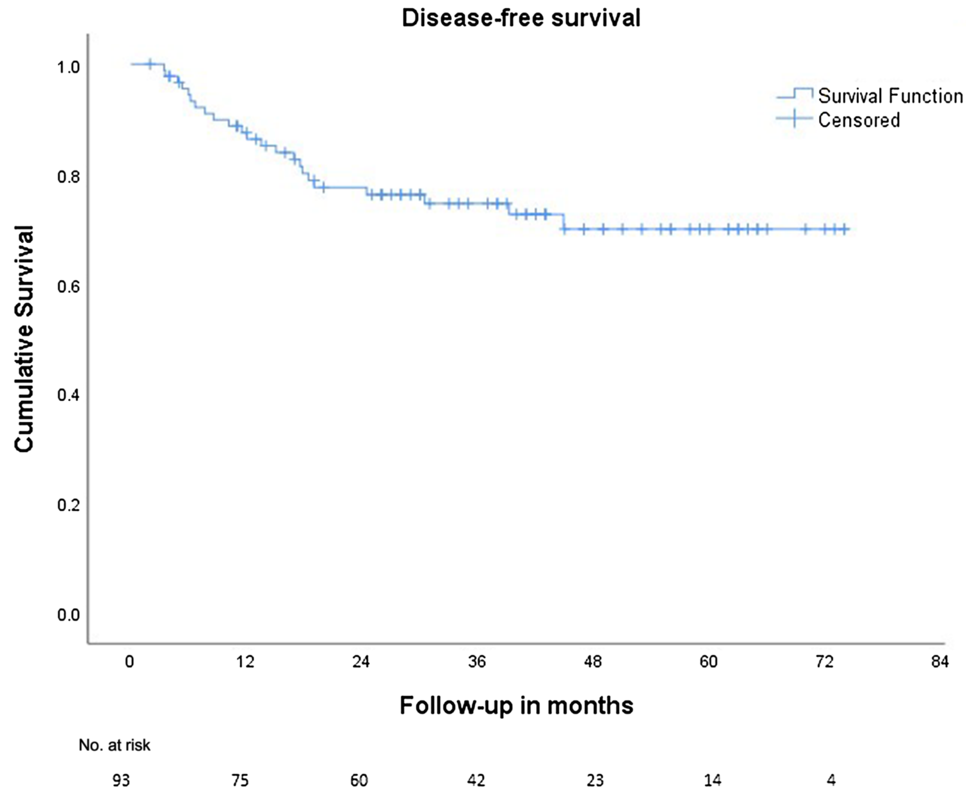

Fig. 8 Kaplan–Meier survival curve

technical complications related to the procedure mainly leaks or stricture formation. Nobel et al. in a retrospective review of 283 MIE performed between 2011 and 2017; of these, 126 (45%) had drainage (53 Botulinum injection and 73 surgical) [44]. No significant difference in the rate of postoperative complications, pneumonia, or anastomotic leak was observed between groups. At 6 and 12 months, patients that received Botulinum injection and surgical drainage had significantly more symptoms than no drainage ($p < 0.0001$) and higher need for pyloric dilation at 6 months ($p = 0.007$). They concluded that pyloric drainage was not significantly associated with lower postoperative complications or long-term symptoms [44]. Two recent systematic reviews addressing the role of pyloric drainage after esophagectomy were inconclusive. However, both recommended large multi-institutional, prospective studies are required to definitively answer this question [45, 46]

Minimally invasive Ivor Lewis esophagectomy has a fairly steep learning curve, even for surgeons already skilled in minimally invasive techniques. The existence of such learning curve has been described previously and appears to affect several aspects of the procedure. Tapias et al. reported that the operation and perioperative care of at least 35–40 patients is necessary before significant improvement in parameters such as operative time and length of stay is achieved [47]. The learning curve affects also the performance of a complete lymphadenectomy during MILE, with optimal lymph node retrieval plateauing after the first 25 cases [48].

The TIME trial is the only published randomized controlled trial, which compared MILE to open transthoracic esophagectomy [12]. In this trial, a reduced incidence of pulmonary infections, reduced hospital stay, and better short-term quality of life were observed. A meta-analysis, which compared MIE with open surgery for esophageal cancer concluded that MIE was superior in reducing in-hospital mortality and incidence of complications like arrhythmias and pulmonary complications [49]. Recent systematic review and meta-analysis provided evidence for long-term survival benefits (18% lower 5-year all-cause mortality) after MIE compared to open esophagectomy in patients with esophageal cancer [50].

Technical points

We favor the Ivor Lewis esophagectomy as it allows extending the resection for adequate proximal and distal margins with minimal concerns regarding the length of the conduit to reach the neck for the anastomosis especially among patients with short conduit, high riding clavicle, or those with short, thick neck. The Ivor Lewis approach also allows for direct esophageal visualization and dissection, secure hemostasis, precise lymph node dissection, radial margin clearance, and the ability to wrap the omental flap around the anastomosis under direct visualization. Avoiding the cervical approach reduces the risk of recurrent laryngeal nerve injury and postoperative aspiration risk. There are few technical steps aspects that we consider important:

1. Easy and rapid identification of the right gastroepiploic bundle is done by dissecting the pre-pyloric gastrocolic ligament. Anatomically, this area is the shortest distance between the gastric and colonic border. Using this technique, identification of the vascular bundle and access to the lesser sac can quickly be performed without variability even in patients with high BMI. We believe this technique protects the vascular bundle with no touch technique as we mobilize the greater curvature of the stomach by anterior and downward gentle retraction of the posterior wall of the stomach.
2. We routinely create a healthy wide omental flap that will wrap around the esophagogastric anastomosis and cover the gastric conduit staple line. Many studies have demonstrated the use of pedicled omental flap for reinforcing the anastomotic suture line significantly reduces the incidence of anastomotic leak after esophagogastrectomy [51, 52]. We recommend delivering the omental flap to the chest only after the anastomosis is completed to avoid overcrowding, allowing for better visualization and minimize the risk of soft tissue interposition when performing the esophagogastric anastomosis.
3. The overall incidence of post esophagectomy hiatal hernia (HH) is 7%-10% and is similar between the open and MIE group [53]. Since patient #45 presented with an incarcerated colon into the left chest cavity, we changed our technique and currently we do not incise the left curs as it is possible that maintenance of this muscle might reduce the risk of post esophagectomy hernia formation.
4. Marking the anterior gastric conduit with a suture helps to maintain orientation while delivering the conduit into the chest.
5. Care is taken to avoid delivery of excess conduit to the chest to minimize congestion at the hiatus and possible redundancy of the conduit in the chest and outlet obstruction.
6. Volvulus of the conduit is a known complication after esophagectomy [54] as the minimally invasive approach generally is associated with less adhesion formation. We had 2 patients (#8 and #86) with posterior volvulus of the conduit. Since then, we place 2 sutures to anchor the gastric conduit to the paraspinal pleura. The maneuver allows for stabilization of the conduit and preventing volvulus. It remains to be seen as we are add more patients to our database and long-term follow-up whether technique would reduce the incidence of volvulus of the conduit.
7. In order to avoid twisting of the anastomosis, we routinely reposition the camera to the more anterior caudal trocar to allow for better visualization of the EEA-Anvil locking mechanism, proper alignment of the anastomosis and the conduit staple line

The main limitation of our study is its retrospective nature without a control open esophagectomy arm or randomization. The strength of our study is the length of follow-up, excellent 3- and 5-year disease-free and overall survival, and technical details related to the procedure.

Conclusion

In conclusion, MIE can be performed safely with low postoperative mortality rate and favorable overall and disease-free survival.

Author contributions All authors contributed to the design of work, data acquisition and analysis. All authors worked in conjunction for drafting and critically revising the manuscript. The final manuscript was submitted after review from all the above listed authors. All the authors are in agreement to be 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.

Compliance with ethical standards

Disclosures The authors Ziad T. Awad, Syed Abbas, Ruchir Puri, Brian Dalton and David J. Chesire declare that they have nothing to disclose.

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