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# Minimally Invasive Esophagectomy

Nicholas Baker, Inderpal Sarkaria, and James Luketich

## Historical Perspective

Open approaches to esophagectomy have historically been associated with elevated morbidity and mortality. A 10-year review of the Veterans Affairs' population demonstrated 50% morbidity and 10% mortality [1]. In the 1990s, the growing confidence in laparoscopic surgical techniques and instrumentation led to the introduction of various minimally invasive approaches to esophageal resection. Early minimally invasive resection techniques often hybridized more traditional open techniques with newer less invasive approaches. Collard was the first to describe a thoracoscopic technique for esophageal dissection, and DePaula was the first to describe the first entirely laparoscopic transhiatal esophagectomy in 1995. In the following year, Luketich and associates at the University of Pittsburgh began performing totally minimally invasive esophagectomy (MIE) via a McKeown approach and later published one of the first, large series with zero mortality in their first 77 patients [2].

**Electronic supplementary material** The online version of this chapter (https://doi.org/10.1007/978-3-030-18740-8_1) contains supplementary material, which is available to authorized users.

N. Baker
Department of Cardiothoracic Surgery, University of Pittsburgh Medical Center, UPMC Presbyterian-Shadyside, Pittsburgh, PA, USA

I. Sarkaria (✉)
Shadyside Medical, Pittsburgh, PA, USA
e-mail: sarkariais@upmc.edu

J. Luketich
Division of Thoracic and Foregut Surgery, UPMC Presbyterian, Pittsburgh, PA, USA

## Indications

Indications for MIE are the same as standard open esophagectomy, including end-stage achalasia, failed antireflux surgery, intractable esophageal stricture, high-grade Barrett's esophagus not amenable to ablative or endoscopic techniques, and esophageal cancer. A thorough history of previous interventions to the chest and abdomen, including endoscopic management and pre-and postoperative symptoms in failed benign esophageal surgery, is mandatory. Chemoradiotherapy history, staging, and location of tumor are also necessary in order to appropriately plan the surgical approach.

There are multiple minimally invasive techniques described throughout the literature. In our experience, Ivor Lewis esophagectomy is the surgery of choice for standard esophageal cancer resections of the gastroesophageal (GE) junction and low mid-esophageal tumors, benign strictures, and failed antireflux surgery. McKeown (three-hole) esophagectomy is indicated for high mid-esophageal tumors, extensive high-grade



J. Kim, J. Garcia-Aguilar (eds.), *Minimally Invasive Surgical Techniques for Cancers of the Gastrointestinal Tract*, https://doi.org/10.1007/978-3-030-18740-8_1

dysplasia, or end-stage achalasia. Overall, the goal is an R0 resection for malignancy and complete resection of diseased esophagus in benign cases.

## Preoperative Considerations

Anesthesia preoperative planning should focus on the need for accurate hemodynamic monitoring, adequate intravenous access, and lung isolation. Invasive arterial line placement is necessary for accurate blood pressure monitoring as perfusion pressure to the conduit is top priority to prevent postoperative complications. Most cases require central venous catheterization to ensure adequate intravenous access throughout the case. Double lumen endotracheal tube is needed for the thoracic portion of the case and is typically placed at the beginning of the operation.

Positioning planning will include a well-padded foot board for steep reverse Trendelenburg position. The patient should also be positioned on the right lateral aspect of the surgical table to allow room for the liver retractor.

## Surgical Technique for MIE

Video 1.1

### Endoscopy

Before beginning the operation, endoscopy is used to confirm the pathology of the esophagus and distance from the incisors. The decision on approach may be altered at this time based on the findings. Ivor Lewis esophagectomy would begin with laparoscopy, whereas McKeown esophagectomy would begin with right video-assisted thoracic surgery (VATS). Bronchoscopy is also performed to confirm the absence of airway involvement and confirm normal airway before dissection begins.

### Laparoscopy

The xiphoid process and the umbilicus are identified, and a ruler is used to measure 15 cm distal to the xiphoid with marks at 5 cm and 10 cm. At the 10-cm mark, the right paramedian 10-mm port is placed 2 cm to the right of the midline via a Hasson cut-down technique. The right paramedian port is the primary working hand of the surgeon. The abdomen is insufflated to 12–15 mm Hg, and the patient is placed in steep reverse Trendelenburg position. Next, under direct visualization with a 10-mm 30° laparoscopic camera, the remaining ports are placed. The camera port is placed one hand-breadth to the patient's left from the right paramedian port. Two subcostal 5-mm ports are placed, and a right lateral subcostal port is placed just inferior to the 12th rib and is used for the liver retractor. Finally, a right lower quadrant 12-mm port is placed at approximately at one-third the distance from the anterior superior iliac spine to the umbilicus (Fig. 1.1). This port will be used later for placement of the jejunostomy tube and retraction for gastric conduit creation.

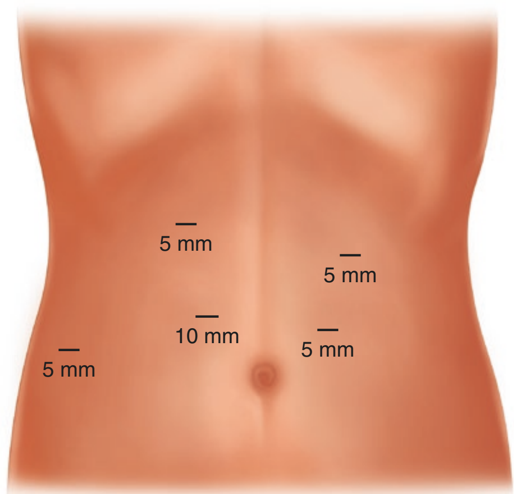


**Fig. 1.1** Port placement for laparoscopic procedures. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

## Abdominal Dissection

After all ports are placed, detailed diagnostic laparoscopy is performed to rule out metastasis in malignant cases and evaluate aberrant anatomy. A self-retaining liver retractor is positioned to elevate the left lobe of the liver to expose the hiatus. Next, the dissection begins with incising the gastrohepatic ligament. With the hiatus completely exposed, dissection continues up the right crus anteriorly and down the left crus. Circumferential exposure of the crus helps to gain access into the chest, and mediastinal dissection is carried out between the bilateral pleural, the pericardium, and the spine/aorta. This can be carried up to the inferior pulmonary veins to help with the thoracic dissection but only needs to be enough to place the specimen into this space at the end of the abdominal portion of the procedure.

The left gastric pedicle is approached to identify the base, and lymph node tissues are dissected from the base toward the specimen to remove all nodal tissue associated with the celiac axis. The dissection is carried out laterally on top of the splenic artery and pancreas over to the splenic hilum. All the lymph node tissues are again pushed up toward the specimen, and using an endovascular stapling device, the left gastric artery is taken at its base.

Next, using a "no touch" technique, the short gastric arteries are divided and the left gastroepiploic artery is identified. The omental arteries are now identified and divided leaving a couple of centimeters of tissue on the lateral aspect of the right gastroepiploic artery to ensure it is not damaged. An omental flap can be created at this step using approximately two to three of these omental branches creating a 3–4-cm-wide omental flap to be used later to buttress the anastomosis. We routinely do this on induction cases where radiation is used. Complete mobilization of the entire gastroepiploic artery is necessary for full mobility (Fig. 1.2). A Kocher maneuver is performed, and retrogastric and duodenal attachments are incised as well to help with mobilization. At this step, the pylorus should reach to above the caudate lobe of the liver. This indicates adequate mobilization. After full mobilization of the stomach, the three remaining portions of the abdomen include conduit formation, pyloroplasty, and jejunostomy tube placement.

## Laparoscopic Pyloroplasty

A Heineke-Mikulicz pyloroplasty is performed laparoscopically with an endoscopic suturing device (Endo Stitch 2.0, Medtronic) with 2-0

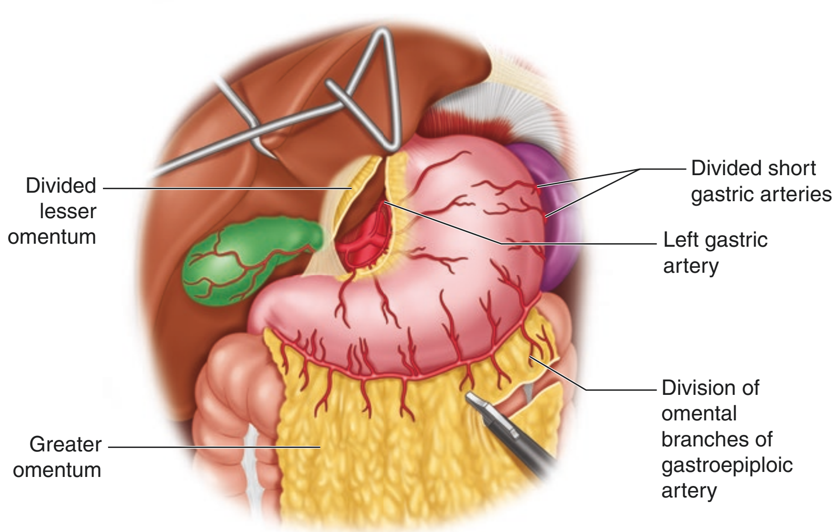


**Fig. 1.2** Mobilization of gastroepiploic arcade. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

sutures placed at the most superior and inferior aspect of the pylorus. The pylorus is incised using ultrasonic shears (Harmonic Scalpel, Ethicon Inc.) in the midline horizontally with care to ensure complete full thickness incision. The pylorus is then closed in a vertical fashion with the Endo Stitch incorporating mucosa with each suture (Fig. 1.3). Routinely, omentum is placed over the pyloroplasty prior to completing the abdominal portion of the procedure.

## Laparoscopic Jejunostomy Tube

The patient is placed back in level supine position and the insufflation of the abdomen is reduced to 8–10 mm Hg. The omentum is retracted cephalad and the ligament of Treitz is identified. Approximately 40 cm distal to the ligament of Treitz, a portion of mobile jejunum is chosen and tacked to the anterior abdominal wall. Using a 12-Fr needle jejunostomy kit, a needle is passed into the jejunum and a wire is passed. Serial dilators are passed in a Seldinger technique until the introducer is passed. Next the jejunostomy tube is inserted into the jejunum. Two 2-0 Witzel sutures are placed around the J-tube, and then a purse-string suture is placed around the jejunostomy tube tacking it to the anterior abdominal wall. One single interrupted 2-0 suture is placed approximately 2 cm distal to the feeding tube as an anti-torsion suture (Fig. 1.4).

## Creation of Gastric Conduit

The gastric conduit is formed by retracting the fundus of the stomach into the left upper quadrant as far as possible, and the antrum is retracted toward the patient's right foot. The surgeon gently retracts the gastric conduit. The stapler is passed though the right paramedian port. This begins with a 2.5-mm endovascular staple to divide the lesser curve vessels. These steps should form the desired diameter of the tube. We prefer

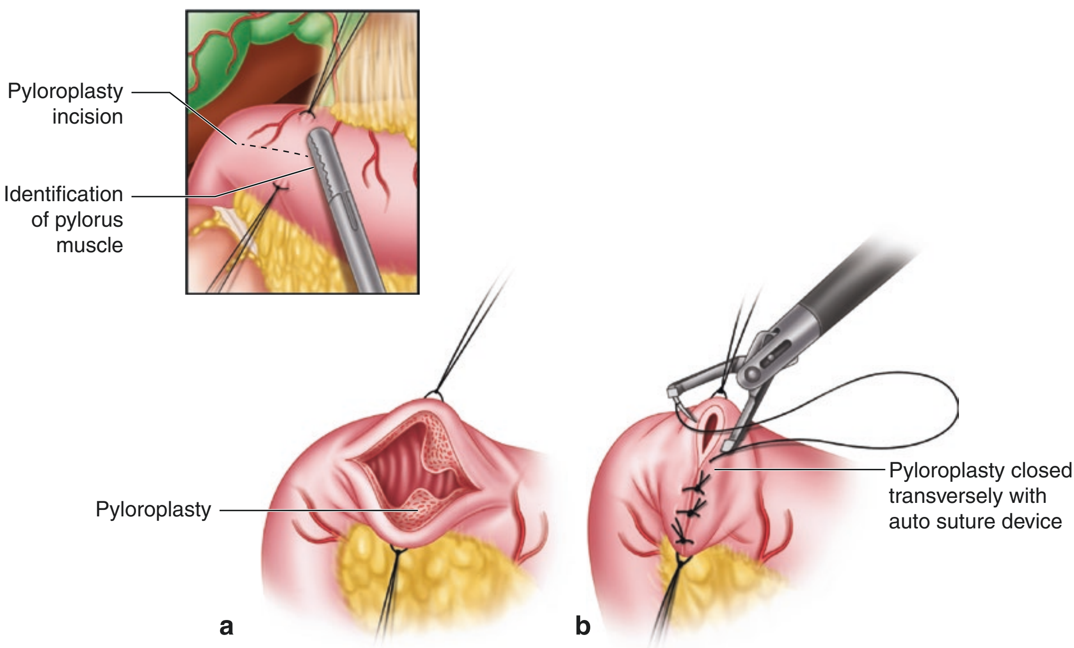


**Fig. 1.3** Laparoscopic pyloroplasty is performed by (**a**) creating a longitudinal incision across the pylorus. (**b**) An Endo Stitch is used to close the pyloroplasty with a transverse incision

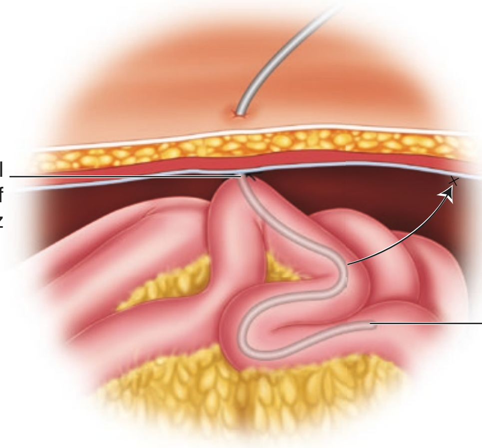


**Fig. 1.4** Laparoscopic jejunostomy tube is placed approximately 30 cm distal to the ligament of Treitz. One additional suture is placed distal to the catheter insertion to prevent torsion of the jejunal limb. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

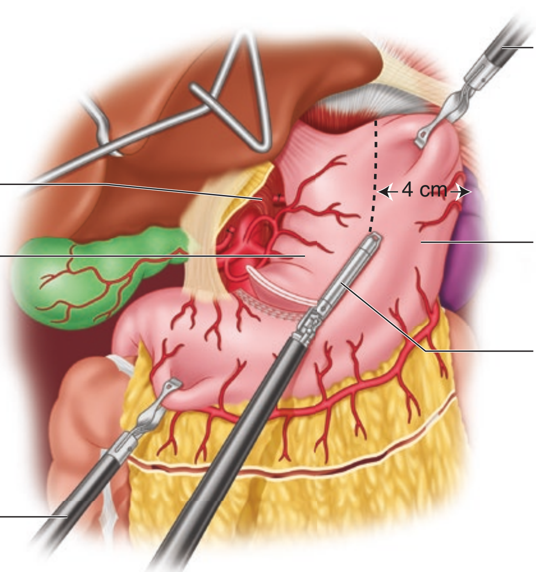


**Fig. 1.5** Creation of the gastric conduit with a linear stapler. The assistant provides gentle traction and counter-traction of the stomach. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

a 3–4-cm-wide gastric tube (Fig. 1.5). Gastric staple loads usually begin with a 5-mm endovascular staple load and subsequently progress to 4 mm. The staple line should parallel the greater curve in the desired width to ensure not spiraling the conduit. After the conduit has been fully created, the specimen is placed into the hiatus and the conduit is sutured to the specimen maintaining proper orientation with the specimen staple line sewn and attached from the lesser curve to the greater curve of the conduit (Fig. 1.6).

## Thoracoscopy

A nasogastric tube (NGT) is placed at this time, and double-lumen endotracheal tube is placed if not already done. The patient is placed in a left lateral decubitus position, and with the double-lumen tube confirmed in appropriate position, the right lung should be isolated immediately to provide adequate time for decompression. The operating table is flexed to move the iliac crest away from the costal margin and

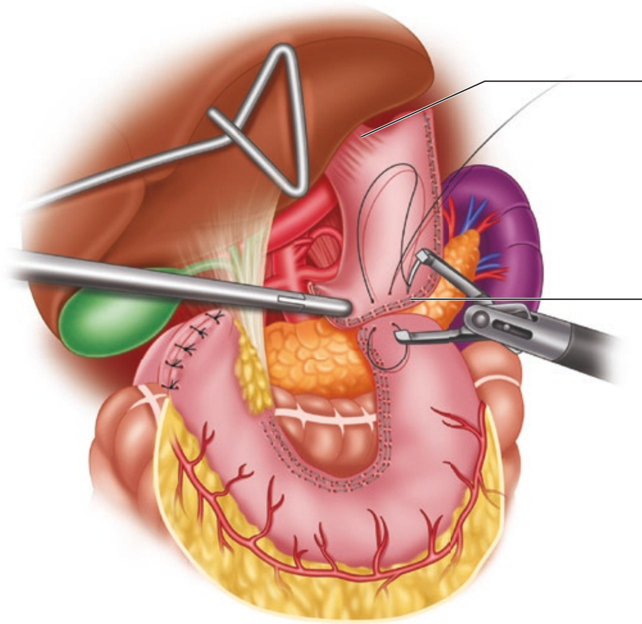


**Fig. 1.6** Attachment of the specimen to the gastric conduit with the Endo Stitch and maintaining proper orientation. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

expand the intercostal spaces, and the position of the right scapula is marked.

A 10-mm camera port is inserted in the eighth intercostal space just anterior to the mid-axillary line. This typically places the port just above the costophrenic recess. Another 10-mm port is placed in the scapular tip line in the eighth intercostal space. This is the surgeon's working port. Next a 5-mm port is placed at the scapula tip, and 5-mm port is placed in the sixth intercostal space at the anterior axillary line. The fifth and final 10-mm port is placed in the fourth intercostal space anterior axillary line, and a fan retractor is passed through this port to retract the lung. A full-length Endo Stitch is placed in the central tendon of the diaphragm and retracted through the costophrenic recess via an Endo-close device (Medtronic) and is secured to the outside of the chest wall to retract the diaphragm inferiorly, allowing full visualization of the distal esophagus and hiatus.

The chest dissection begins with taking the inferior pulmonary ligament down and identifying the pericardium. This usually connects with the hiatal dissection that was carried out in the abdomen. The dissection is carried up the pericardium to level 7 lymph nodes and the right bronchus intermedius. This is a critical dissection point, and care must be taken not to injure the posterior membrane of the airway. The anterior dissection is continued up the mediastinum to the azygos vein that is taken with a 2.5-mm endovascular staple load. The dissection above the azygos vein should be carried out directly on the esophageal wall, and this can be carried safely up to the level of the thoracic inlet and beyond if needed.

The posterior dissection is performed in a similar fashion, but clips are deployed in an attempt to prevent thoracic duct injury. This is carried up to the thoracic inlet as well. The last remaining plane is the deep plane along the left pleural and aorta. After all the periesophageal tissue, esophagus, and level 7 lymph nodes have been successfully mobilized up to the thoracic inlet, the conduit is delivered into the mediastinum with care to ensure appropriate orientation with the staple line facing toward the operators.

The access incision is created for passage of the end-to-end anastomosis stapler (EEA) and removal of the specimen. This is one rib space above the surgeon's working port and is <4 cm in length. A wound protector (Applied Medical) is placed to protect the wound from spillage and tumor implants. The specimen is incised above the level of the azygos vein and passed out of the chest via the access incision.

Assessment of the proximal esophagus is then performed and the decision on which EEA stapler to use is made. Most commonly, a 28-mm EEA stapler is used, and the esophagus can be dilated with a Foley catheter if needed. The anvil is passed into the chest and placed into the proximal end of the esophagus. Two purse-string 2-0 sutures are placed around the anvil with each stitch ensuring incorporation of mucosa (Fig. 1.7). The conduit is completely delivered into the chest and the stapler is passed into the chest. It is placed into the conduit in a "sock over foot" type fashion (Fig. 1.8). After the stapler is inserted, it is progressed up to the anvil, and an assessment of length is again made. The staple line should be facing the operator and the spike can be brought out of the conduit in line with the gastroepiploic artery. The stapler is locked and fired (Fig. 1.9a, b). The rings of the stapler must be examined to confirm they are complete. The excess conduit is resected with a 3.5-mm endovascular stapler, and this is the final gastric margin (Fig. 1.10).

Lastly the omental flap should be placed around the anastomosis making sure there is flap between the airway and the anastomosis. A 10-mm flat Jackson-Pratt drain is placed posterior to the conduit with the tip adjacent to the anastomosis. The chest is irrigated with copious antibiotic solution. One 28-Fr chest tube is placed in an apicoposterior position. After wound closure, the patient is placed back in a supine position and the oropharynx is irrigated and suctioned. The double lumen tube is exchanged for a single lumen tube and repeat bronchoscopy is carried out to inspect and clear the airway. The final reconstruction is depicted in Fig. 1.11.

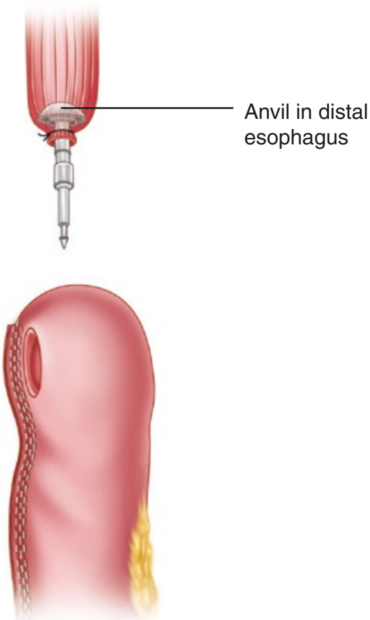


**Fig. 1.7** The anvil has been placed in the esophagus. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

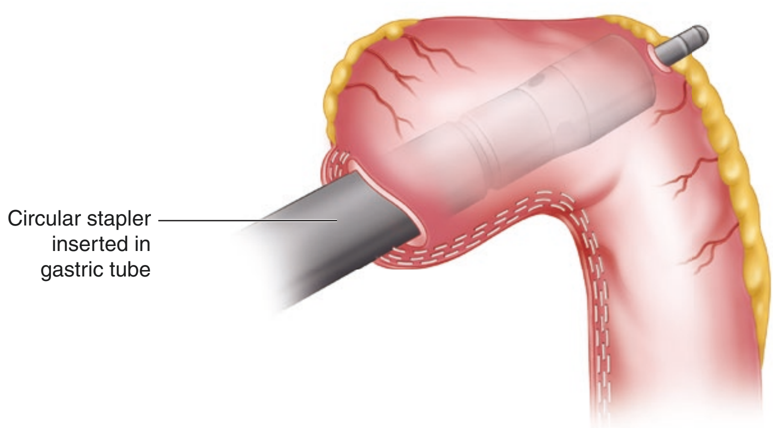


**Fig. 1.8** Insertion of the EEA stapler into the conduit in a "sock over foot" fashion. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

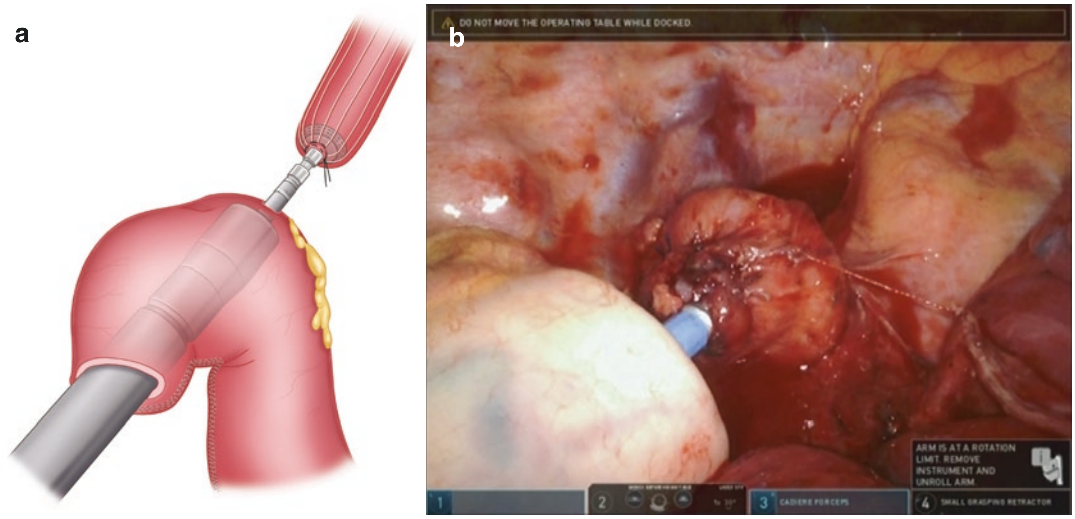


**Fig. 1.9** (**a**) Illustration of the alignment of the EEA stapler pin/trocar with the anvil. (**b**) Intraoperative image of the stapler alignment. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

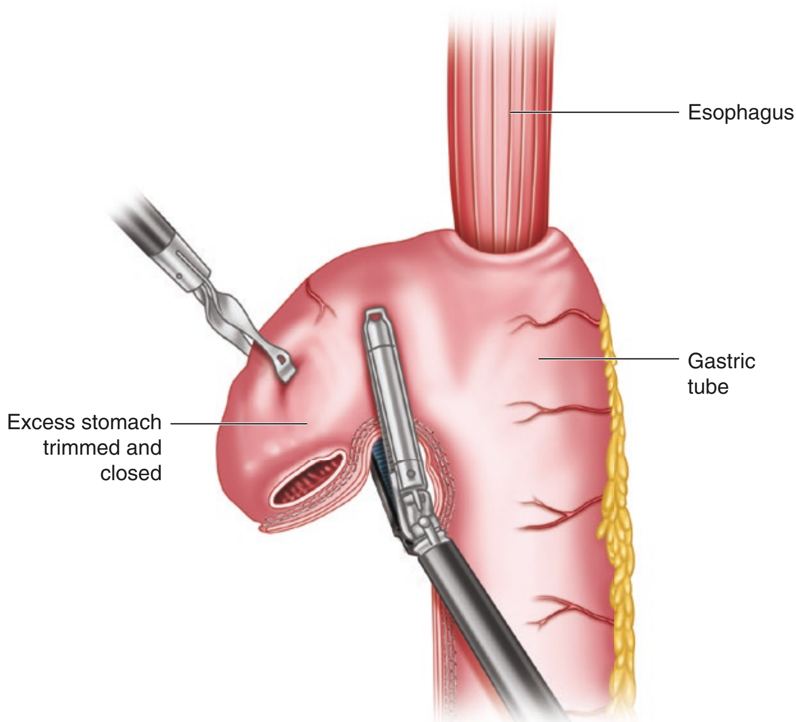


**Fig. 1.10** Resection of proximal gastric conduit with a linear stapler. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

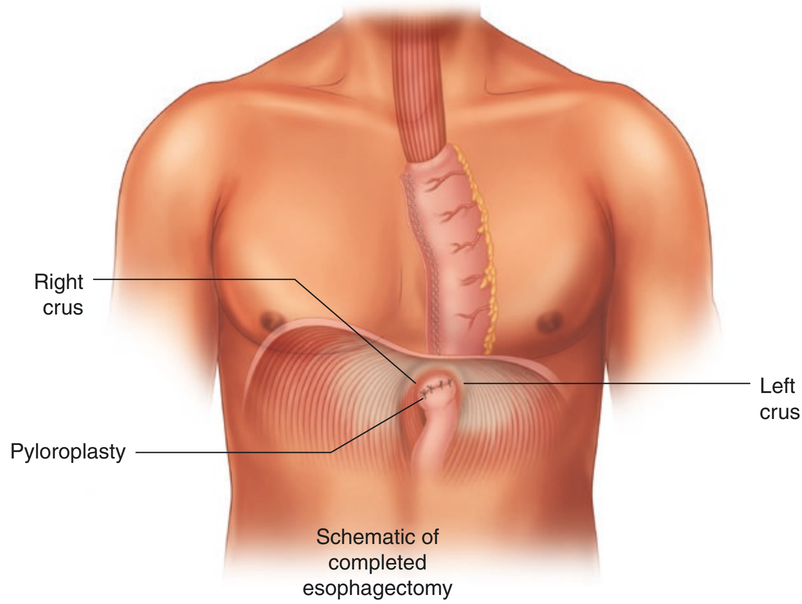


**Fig. 1.11** The finished reconstruction with the gastric conduit in the chest and the pyloroplasty near the hiatus. (© Heart, Lung, and Esophageal Surgery Institute University of Pittsburgh Medical Center)

## Postoperative Care and Complications

### Thoracic Complications

Bleeding and transfusion requirements were less with the minimally invasive approach, but it is important to note that even small amounts of bleeding can obscure the operative field, making progress difficult and requiring conversion to an open procedure. Hence, the aorto-esophageal vessels must be identified and clipped and bleeding from the azygos vein and peribronchial arteries avoided. Injury to the posterior membranes of the bronchus and trachea must be carefully avoided, especially during mediastinal lymph node dissection. Cautery, auto-sonic, or harmonic scalpel use in close proximity to the posterior membranous airway can lead to tissue damage resulting in an air leak, local ischemia, and subsequent development of a tracheogastric conduit fistula.

The thoracic duct is at risk for subtle injuries leading to the development of a chylothorax. Early in our experience with our initial 77 patients undergoing MIE, we noted 3 patients with delayed chylothorax, leading us to become more cautious in this area and transitioning to the liberal use of metal clips on thoracic duct branches. Vocal cord paralysis from injury to the recurrent laryngeal nerve is minimized by dividing the vagus nerve just above the azygos vein and dissecting this away from the esophagus. We generally do not perform a lymph node dissection above this level in an effort to avoid injury to the recurrent laryngeal nerves and the lack of definitive evidence that lymph node clearance in the upper chest is essential for gastroesophageal junction tumors.

### Abdominal Complications

Disruption of the main gastroepiploic arcade can be devastating to the viability of the gastric conduit. Likewise, one must be certain that there is adequate room at the hiatus for the conduit to lie without strangulation. In our series, there was an incidence of gastric tip necrosis of 3.2%. Delayed hiatal herniation of abdominal viscera is also a possibility if the gastric conduit is not properly tacked to the hiatus. Kent et al. reported approximately 2% incidence of diaphragmatic hernias and 2% risk of redundant gastric conduit leading to delayed gastric emptying, reflux, and obstruction. Eighty-five percent of patients with such anatomical complications benefited from reoperative revisional surgery [3].

### Other Major Complications

Cardiopulmonary complications, including atrial fibrillation (2.9%), Acute Respiratory Distress Syndrome (ARDS) (5.7%), and pneumonitis (3.8%), were the most frequently encountered complications following MIE in the multi-institution E2202 trial [4]. Our overall anastomotic leak rate requiring surgery with the McKeown approach was 5% and decreased to 4% with the Ivor Lewis approach. The reported leak rate for the open procedure is approximately 9.1%. Other MIE series demonstrate similar leak rates. Moderate strictures at the gastroesophageal cervical anastomosis are common and generally can be managed with one or two outpatient dilations. Using the Ivor Lewis approach and a 28-mm EEA stapler, strictures still occur but generally are less clinically important and respond favorably to dilations.

## Robot-Assisted Minimally Invasive Esophagectomy

Robot-assisted minimally invasive esophagectomy (RAMIE) approach is largely adapted from our MIE approach as described earlier. There are several selected differences that we will expand on below.

### RAMIE Preoperative Planning

The robotic platform uses four arms with two operating consoles with the operating surgeon and trainee at the controls and an assistant at the bedside. The tower is to the patient's right and the robotic cart is to the left of the patient. Bedside positioning is similar to MIE except the left arm may be tucked to avoid collision.

### RAMIE Surgical Technique

Setup for the abdominal portion of RAMIE involves docking the robotic cart (Da Vinci Surgical Robot) and arms directly over the midline of the patient with the patient in steep reverse Trendelenburg position (Fig. 1.12). The camera port is placed in the midline just above the umbilicus. A 5-mm left lateral subcostal port is placed and is used for an atraumatic grasper. An 8-mm left midclavicular port is placed and is used for the harmonic scalpel (Ethicon). An additional 5-mm right lateral subcostal port is placed and is used for placement of the liver retractor, and an 8-mm right midclavicular port is used for a bipolar atraumatic grasper. An additional 12-mm assistant port is placed by triangulating between the umbilicus and the right midclavicular port and is used for suction by the assistant as well as jejunostomy tube placement. It is important to maintain a minimal distance of 9–10 mm between robotic ports to minimize collisions (Fig. 1.13).

The thoracic portion of the case setup begins with placement of the camera port in the eighth intercostal space in the mid to posterior axillary line under direct video guidance (Fig. 1.14). Carbon dioxide insufflation at 8 mm Hg is used for better visualization. A 5-mm robotic port is placed in the third intercostal space in the mid to posterior axillary line, and an 8-mm robotic port is placed in the fifth intercostal space. An additional 8-mm port is placed laterally in approximately the eighth or ninth interspace. A 12-mm assistant port is placed under direct vision at the diaphragmatic insertion midway between the camera port and the lateral 8-mm robotic port (Fig. 1.13). The robot is docked to the ports, and the robotic camera is placed within the chest at a 30° downward orientation.

RAMIE operative components are the same as MIE. RAMIE allows the surgeon to perform all exposures without the need for an assistant, allowing the surgeon to be in complete control. The camera offers better visualization with three-dimensional optics. Wristed instruments offer greater precision while suturing. Potential disadvantages of the RAMIE approach include reduced versatility in large operative fields such as the thorax with a large area between the hiatus and the inlet. This can lead to multiple collisions and decreased range of motion. Also, the robot has to be undocked to change positions of the operative

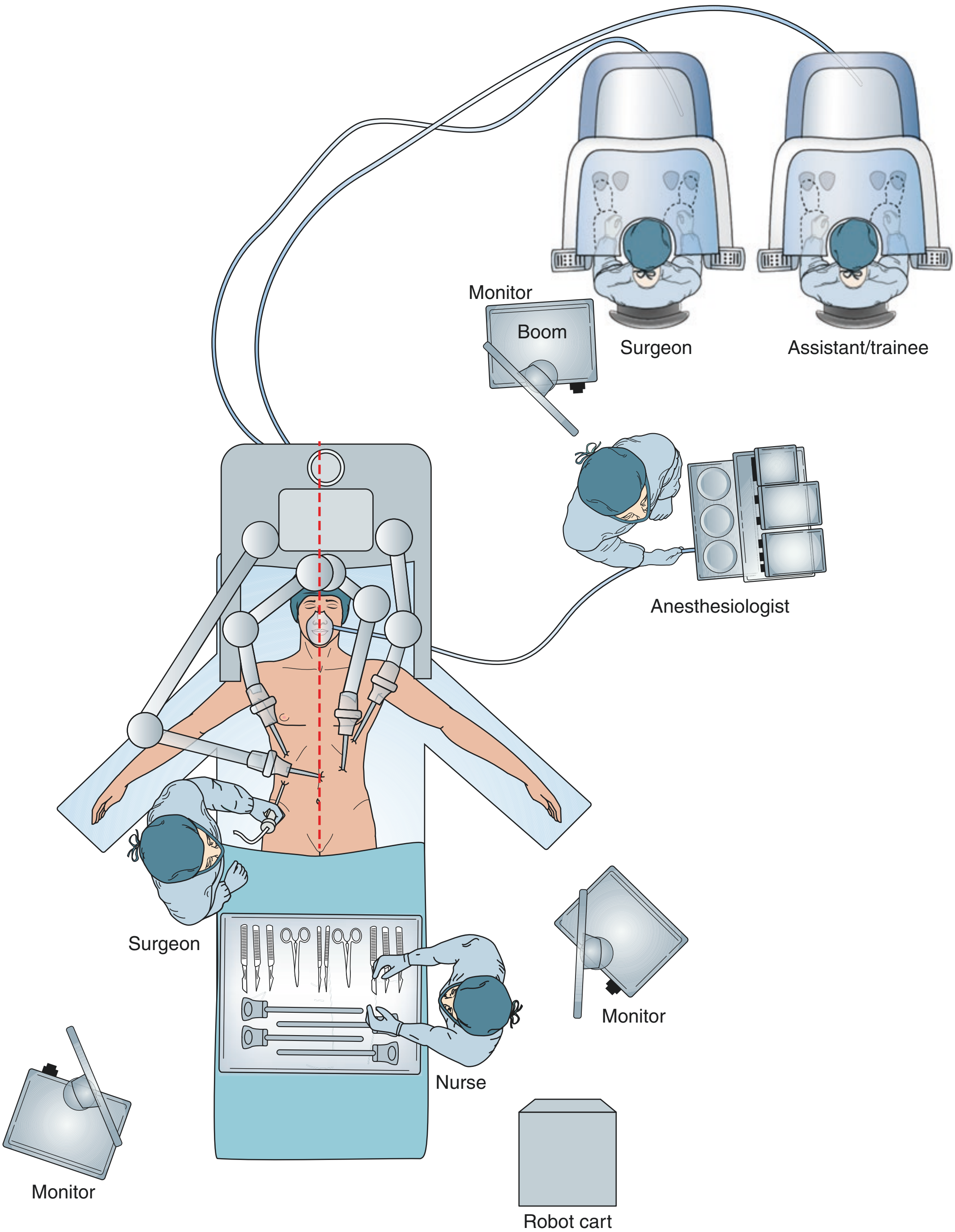


**Fig. 1.12** Robotic setup for the abdominal steps of RAMIE

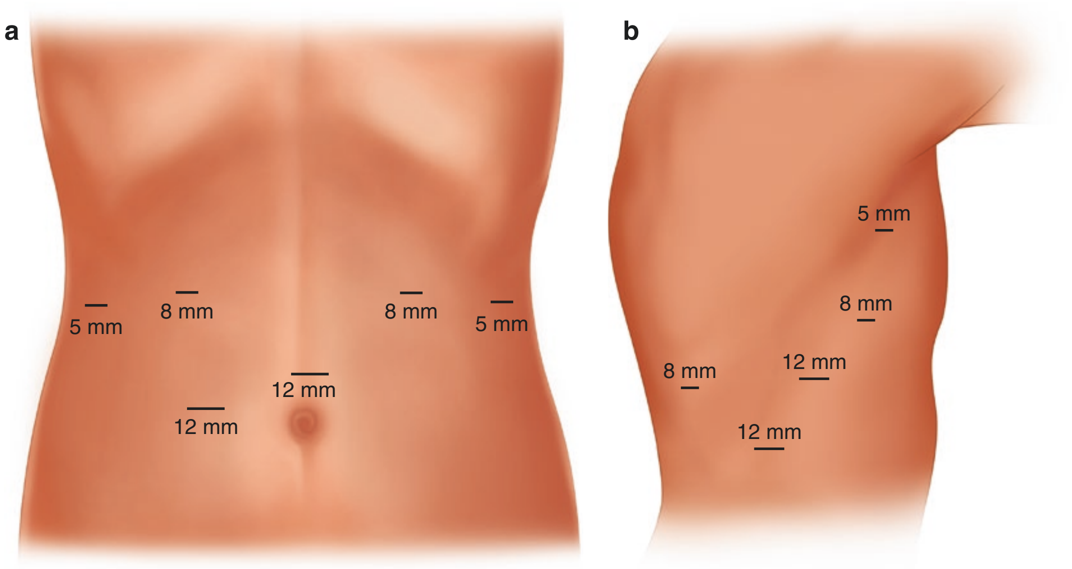


**Fig. 1.13** (**a**) Port placement for abdominal steps of robotic RAMIE. (**b**) Port placement for thoracic steps of robotic AMIE

table. These disadvantages have been somewhat reduced with newer technologies such as Da Vinci Xi with an integrated operating room table (Intuitive Surgical Inc.).

## Conclusions

Our institutional approach at the University of Pittsburgh Medical Center has evolved over time, initially developed as a modified McKeown (three-hole) technique with a cervical anastomosis, and transitioned to a primarily Ivor Lewis approach with intrathoracic anastomosis. In an initial series of 222 patients, 8 initial cases were performed as laparoscopic transhiatal operations, with quick adaptation thereafter to a modified McKeown approach with thoracoscopic mobilization and cervical anastomosis. Results from this early experience yielded a median hospital stay of 7 days and an operative mortality of 1.4%, which is equivalent or better to the majority of open series. An anastomotic leak rate of 11.7% and stage-specific survival were similar to open series. In a follow-up institutional series of 1011 patients undergoing elective MIE, including 530 patients operated via the currently preferred Ivor Lewis MIE approach, operative mortality in this cohort was 0.9% and median length of hospital stay was 8 days [2].

The safety and feasibility of MIE has been demonstrated in several single-institution studies and meta-analyses, yet the results from a large, prospective, multicenter trial investigating MIE has only recently emerged. The eastern oncology cooperative group study (E2202) examined the outcomes of 17 credentialed sites in the USA that performed MIE on patients with biopsy-proven high-grade dysplasia or esophageal cancer of the mid-esophagus or distal esophagus. Esophagectomy was performed using either modified McKeown MIE or Ivor Lewis MIE technique. Protocol surgery was completed in 95 out of 104 patients (91.3%). Median ICU and hospital stay were 2 days and 9 days, respectively. The 30-day mortality for patients who underwent MIE was 2.1%. Adverse events included anastomotic leak (8.6%), acute respiratory distress syndrome (5.7%), and atrial fibrillation (2.9%). At a median follow-up of 35.8 months, the estimated 3-year overall survival was 58.4%. Locoregional recurrence occurred in only seven patients (6.7%). This trial demonstrated that MIE is safe and feasible and has low perioperative morbidity and mortality and good oncologic results and suggests that

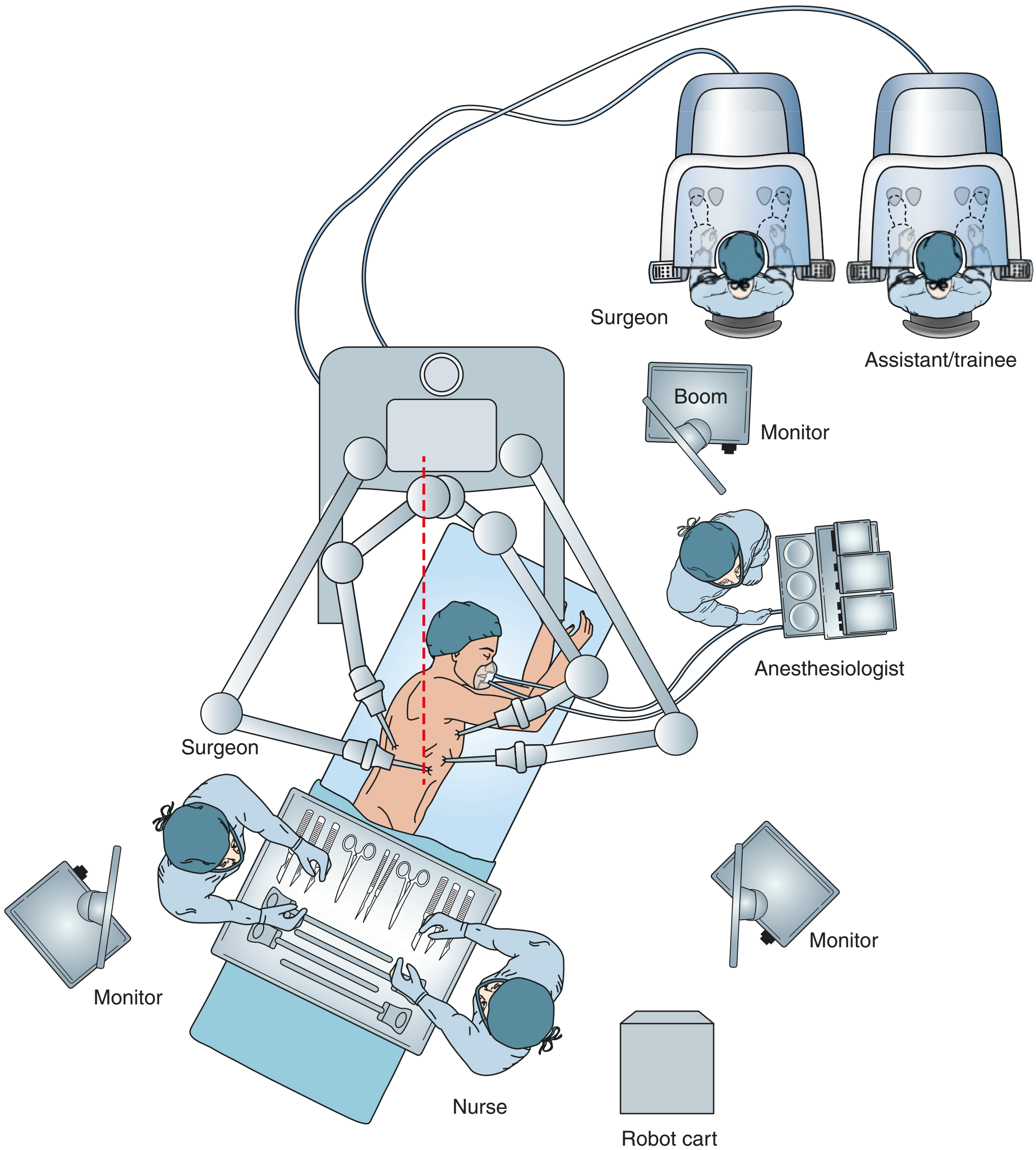


**Fig. 1.14** Robotic setup for the thoracic steps of RAMIE

MIE can be adopted by other centers with appropriate expertise in open esophagectomy and minimally invasive surgery [4].

## References

1. Bailey SH, et al. Outcomes after esophagectomy: a ten-year prospective cohort. Ann Thorac Surg. 2003;75(1):217; discussion 222.
2. Luketich JD, Pennathur A, Awais O, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg. 2012;256(1):95–103.
3. Kent MS, Luketich JD, Tsai W, Churilla P, Federle M, et al. Revisional surgery after esophagectomy: an analysis of 43 patients. Ann Thorac Surg. 2008;86: 975–83.
4. Luketich JD, Pennathur A, Franchetti Y, et al. Minimally invasive esophagectomy: results of a prospective phase II multicenter trial-the eastern cooperative oncology group (E2202) study. Ann Surg. 2015;261(4):702–7.