9 Transthoracic Esophagectomy Approach by Thoracoscopy: 3 or 2 Stage?

James D. Luketich and M.N. Jaimes Vanegas

Esophageal cancer is the eighth most common cancer worldwide and the sixth leading cause of cancer-related deaths [1]. The incidence of esophageal cancer has been increasing dramatically over the last few decades, and esophageal cancer affects more than 450,000 people worldwide. Although squamous cell carcinoma predominates worldwide, in the western world this pronounced rise has been due to an increase in the incidence of adenocarcinoma of the esophagus [2]. The number of new cases in the United States in 2016 is estimated to be 16,910 [3]. Esophagectomy is an important, potentially curative treatment for localized esophageal cancer, however it is a complex operation and the morbidity and mortality are significant.

In a systematic review of literature, including more than 1100 patients, comparing minimally invasive esophagectomy (MIE) and open esophagectomy, MIE was associated with decreased morbidity and a shorter hospital stay compared with open esophagectomy [4]. Regarding the location for the anastomosis, both cervical and intrathoracic anastomosis have potential benefits. With a cervical anastomosis the surgeon is able to reach a more proximal resection margin and, even though there is a higher cervical anastomotic leak rate, it has lower associated morbidity. On the other hand, with an intrathoracic anastomosis, there tends to be a slightly higher rate of anastomotic leak, but also a lower incidence of recurrent laryngeal nerve (RLN) injury, and the ability to remove some of the potentially ischemic gastric tip as has been described in prior publications [5].

In an attempt to lower the morbidity related to esophagectomy, in 1996 we adopted at University of Pittsburgh Medical Center (UPMC) a minimally invasive approach to esophagectomy.

Since 1996, we have performed over 2000 minimally invasive esophagectomies. We have made several refinements to the MIE procedure that we believe significantly improved our surgical outcomes. It included the minimal handling of the final gastric conduit (no touch technique), keeping the width of the gastric conduit no smaller than 3 cm, selective application of an omental flap, and conversion from routine use of minimally invasive, three-hole esophagectomy to our new routine of minimally invasive Ivor Lewis esophagectomy. The Ivor Lewis, 2 stage MIE remains the mainstay in the surgical treatment of esophageal adenocarcinoma at UPMC [6].

J.D. Luketich (✉) • M.N. Jaimes Vanegas
Department of Cardiothoracic Surgery
University of Pittsburgh Medical Center (UPMC), Health System, Pittsburgh, PA, USA
e-mail: luketichjd@upmc.edu

M.A. Cuesta (ed.), *Minimally Invasive Surgery for Upper Abdominal Cancer*,
DOI 10.1007/978-3-319-54301-7_9

9.1 Gastric Conduit Concerns

Early in the UPMC experience, a very narrow gastric tube (2–2.5 cm in diameter) was trialed and was noted to be associated with an increase in gastric tip necrosis and anastomotic leaks. By increasing the diameter of the gastric conduit to a minimum of 3 cm, a decrease in anastomotic complications has been observed. It should be noted that this finding was somewhat anecdotal relatively early in our experience and was not part of a controlled trial of observations.

9.2 Omental Flap

Regarding the details of our omental flap, we create a 3-cm wide, 8–10 cm long omental pedicle, originating from the upper greater curvature of the stomach, laparoscopically. Key steps of the laparoscopic technique are, (1) identifying 2–3 arcades that branch off at right angles from the main gastroepiploic arcade, (2) preserving these branches as they traverse away from the greater curve out onto the omentum, (3) dissecting the fine adhesions between the undersurface of this omental flap and the transverse colon, (4) preventing a colonic enterotomy and avoiding damage to the blood supply of the omental flap, (5) tacking the distal tip of your new omental flap to the proximal gastric conduit, which will be pass into the chest via the hiatal opening with the newly created conduit. The primary disadvantage of laparoscopic harvest of an omental flap is that it can be time consuming (20–30 min), especially in obese patients or those with adhesions from multiple prior surgeries. Currently, the omental flap technique is utilized selectively, most commonly in high-risk patients who have undergone neo-adjuvant chemoradiation.

9.3 Three Hole Considerations

A neck dissection and subsequent creation of a cervical anastomosis has been associated with a higher rate of complications such as anastomotic leak, stricture, and injury to the RLN. This is particularly of concern in the setting of injury to RLN, which may have a profound impact on the risk of aspiration pneumonia due to poor clearance of pulmonary secretions. Another disadvantage of the neck anastomosis is the additional length of conduit needed to reach this area resulting in a potential increase in anastomotic tension, a marginal blood supply to the gastric tip and subsequent ischemia at the tip of the gastric conduit, resulting in a higher incidence of anastomotic leaks.

9.4 Ivor Lewis Considerations

Due to the concerns enumerated above, and the fact that we were seeing an increase in tumors of the lower third of the esophagus, we began to perform minimally invasive, Ivor Lewis esophagectomy more frequently in 2002, and reported our initial experience of 50 patients in 2006. In that report, we showed that a minimally invasive Ivor Lewis esophagectomy was feasible and that the technique was reproducible.

In an attempt to lower the morbidity related to the three hole esophagectomy, we adopted at our institution a minimally invasive Ivor Lewis approach. When we reviewed our experience with MIE in 2012, we reported on over 1000 patients. We evaluated the general outcomes after MIE, and also were able to compare the modified McKeown minimally invasive approach to the MIE Ivor Lewis. At that time our McKeown approach included thoracoscopic esophageal mobilization and dissection, laparoscopic abdominal portion and a neck anastomosis [MIE-neck]. Our Ivor Lewis approach included a laparoscopic approach first followed by thoracoscopic surgery, and a chest anastomosis [MIE-chest]. The MIE-neck was performed in 481 patients (48%) and MIE-Ivor Lewis in 530 patients (52%). The operative mortality was 1.68%. The median length of stay (8 days) and ICU stay (2 days) were similar between the two approaches. Mortality rate was 0.9%, and recurrent nerve injury was less frequent (1%) in the Ivor Lewis MIE group ($P < 0.001$).

Both approaches to MIE allowed an adequate lymph node resection (greater than 20), good postoperative outcomes, and low mortality regardless of the site of the anastomosis.

However, the MIE Ivor Lewis approach was associated with a reduced RLN injury and slight decrease in mortality to 0.9% [7].

9.5 Open Support of the Ivor Lewis Approach

One meta-analysis of more than 5000 patients comparing open Transhiatal versus open Ivor Lewis esophagectomy also found an increase in RLN injuries and anastomotic leak with a transhiatal approach with a neck anastomosis [8]. Initially, while starting our institutional MIE experience, we performed the MIE with a transhiatal approach but given the fact that complete mediastinal lymph node dissection was not possible in our hands, we rapidly adopted the addition of the VATS approach to a minimally invasive McKeown-type approach to perform the MIE [9]. However, as our experience grew, we were able to reduce the morbidity associated with RLN dysfunction by avoiding the neck dissection, and also noted the need for less length of our new gastric conduit and evolved to the minimally invasive Ivor Lewis approach.

9.6 Transhiatal Limitations

Orringer et al., in an important study of transhiatal esophagectomy (THE), reported the results in more than 2000 patients with an operative mortality rate that had steadily decreased with increasing hospital volume and surgeon experience, from 10 to 1%. Similarly, he demonstrated that complications, such as RLN injury, decreased with increased volume from 32% in the period of 1978 to 1982 to 1% to 2% in current era. These data point to the steep learning curve that many surgeons may experience if the neck approach is chosen [10]. Another factor to take into account in the current era of surgical training, is that many residents get minimal neck surgery experience during their general surgical and thoracic surgical training. All of these factors have led us to a greater degree of comfort in performing and teaching esophagectomy as an Ivor Lewis MIE at UPMC [7].

9.7 Epidemiology of Esophageal Cancer

Now a days, the vast majority of esophageal tumors that we encounter in the U.S.A and the Western world, are located in the distal esophagus and gastroesophageal junction, which makes high intrathoracic anastomosis usually adequate in regards to the proximal esophageal resection margin. For the purpose of this chapter, we will review in detail the surgical technique for MIE-neck anastomosis and MIE-thoracic anastomosis at UPMC, since on occasion a higher anastomosis is required depending on the nature of the esophageal tumor or proximal extent of Barrett's mucosa.

9.8 Operative Technique for MIE-Neck as Described in 2003 Outcomes Report of 222 Patients at Our Institution [9]

9.8.1 VATS Steps

The surgery starts with an esophagogastroduodenoscopy (EGD) to make a final assessment of the tumor's location and the gastric conduit's suitability for reconstruction. If the EGD, endoscopic ultrasound (EUS), or computerized tomography (CT) scan findings suggest gastric extension, T4 local extension or possible metastases, we perform a staging laparoscopy or a thoracoscopy or both. Patients are then intubated with a double-lumen tube and positioned in the left lateral decubitus position. The surgeon stands on the right and the assistant on the left. Four to Five thoracoscopic ports are used (Fig. 9.1). A 10-mm camera port is placed at the seventh to eighth intercostal space, just anterior to the midaxillary line. A 5-mm port is placed at the eighth or nineth intercostal space, posterior to the posterior axillary line, for the ultrasonic coagulating shears. A 10-mm port is placed in the anterior axillary line at the fourth intercostal space; this port is used to pass a fan shaped retractor to retract the lung anteriorly and allow exposure of the esophagus. The last 5-mm port is placed just posterior to

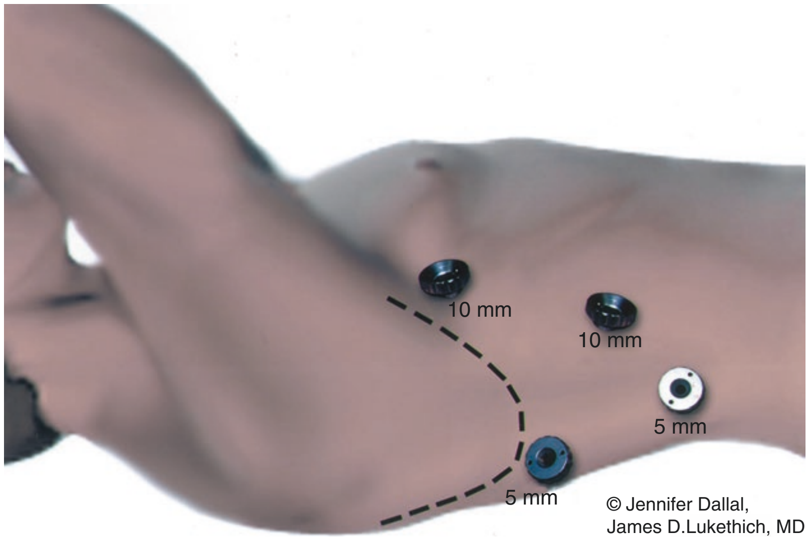

Fig. 9.1 Video-assisted thoracoscopic surgical port sites. Reproduced with permission from the UPMC Heart, Lung and Esophageal Surgery Institute, University of Pittsburgh Medical Center, Pittsburgh, PA

the scapula tip; it is used to place instruments for retraction and counter-traction. In most patients a single retracting suture (0-Endostitch) is placed near the central tendon of the diaphragm and brought out through the inferior anterior chest wall through a 1-mm skin incision. Doing so provides downward traction on the diaphragm, allowing good exposure of the distal esophagus.

Next, the inferior pulmonary ligament is divided. The mediastinal pleura overlying the esophagus is divided up to the level of the azygos vein to expose the thoracic esophagus. An endoscopic stapler (Endo-GIA vascular load) is used to divide the azygos vein. Care is taken to preserve the mediastinal pleura above the azygos vein, leaving some degree of a mediastinal seal around the gastric tube near the thoracic inlet, thereby minimizing the downward extension of a cervical leak into the chest. Circumferential mobilization of the esophagus is performed up to the level of 1–2 cm above the carina, including all surrounding lymph nodes, periesophageal tissue and fat; the plane along the pericardium, aorta and contralateral mediastinal pleura up to but not including the thoracic duct and azygos vein laterally. Care is taken to clip any aortoesophageal vessels and to clip any lymphatic branches from the thoracic duct. A Penrose drain is placed around the esophagus to facilitate traction and exposure. The entire intrathoracic esophagus is mobilized from the thoracic inlet to the diaphragmatic reflection. As the dissection proceeds toward the thoracic inlet, care is taken to stay near the esophagus to avoid trauma to the posterior membranous trachea and the recurrent laryngeal nerves. Care is also taken to avoid extending the distal dissection too low into the peritoneal cavity to avoid difficulty in maintaining pneumoperitoneum during the abdominal dissection. Each intercostal space is injected with 1–2 mL of 0.5% bupivacaine with epinephrine. The lung is then inflated to search for any air leaks from the trachea, proximal bronchus, and re-expanded lung. We then, place a 28-F chest tube, close the thoracic ports, and turn the patient to the supine position.

9.8.2 Laparoscopic Steps

Prior to beginning the laparoscopic and neck phases of the McKeown approach, the double lumen tube must be switched to a single lumen tube to avoid excessive stiffness of the trachea during the neck dissection.

The surgeon remains on the patient's right; the patient is positioned in steep reverse Trendelenburg. The arms are on arm boards approximately 30° away from the midline. Five abdominal ports (four 5-mm and one 11-mm) are used (Fig. 9.2). The gastrohepatic ligament is divided; the right and left crura of the diaphragm are dissected. The stomach

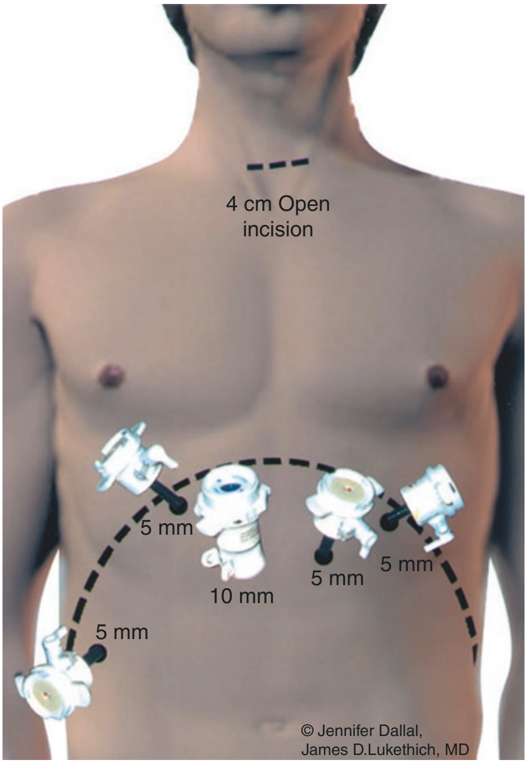

Fig. 9.2 Abdominal port sites for laparoscopy. Cervical incision. Reproduced with permission from the UPMC Heart, Lung and Esophageal Surgery Institute, University of Pittsburgh Medical Center, Pittsburgh, PA

is mobilized by dividing the short gastric vessels using the harmonic scalpel. The gastrocolic omentum is divided with care taken to preserve the right gastroepiploic arcade. The stomach is retracted superiorly, and the left gastric vessels are identified. The left gastric artery and vein can be divided from the retrogastric or lesser curve view, depending on the anatomy, using the Endo-GIA stapler (vascular load). We perform pyloroplasty in all cases. The harmonic scalpel is used to open the pylorus, and the Endo-stitch (2.0) is used to close the pylorus transversely. A gastric tube is then constructed by dividing the stomach starting at the lesser curve and preserving the right gastric vessels with the Endo-GI stapler. The initial staple load is fired approximately 5-6 cm superior to the pylorus, preserving the right gastric artery. There may be some variability in the construction of the gastric tube based on the characteristics of the tumor. It may be necessary to construct a slightly more narrow tube or to resect some of the proximal stomach in tumors with significant gastric extension. If gastric extension of the tumor is significant on pre-op EGD or Laparoscopic staging procedure, we generally prefer to resect more stomach and to make an intrathoracic anastomosis. For most patients in the 2003 report, there was minimal gastric involvement. If extensive gastric cardia extension is present, it may be necessary to perform a colon interposition. If so, we prefer to do this via open laparotomy.

Currently, we prefer a gastric tube of 3 cm in diameter (Fig. 9.3). Extreme caution must be used when manipulating the gastric tube during mobilization and stapling to avoid trauma. The most cephalad portion of the gastric tube is then attached to the esophageal and gastric specimen using two 2.0 Endo-sutures. An additional superficial stitch may be placed on the anterior proximal gastric tube to facilitate orientation and prevent twisting as the tube is brought up into the neck. We also place a marking stitch at the point where the diameter of the conduit enlarges somewhat near the lower antral reservoir. If performing an Ivor Lewis, when we retrieve the gastric conduit into the chest, we look for this transition stitch and try to maintain the antral reservoir completely within the abdomen. An omental flap is used only as part of the Ivor-Lewis approach.

A feeding jejunostomy tube is placed laparoscopically by first attaching a limb of proximal jejunum (35–40 cm distal to the ligament of Treitz) to the anterior abdominal wall in the left lateral mid-quadrant with the Endo-stitch (2.0). We add an additional 10-mm port in the right lower quadrant to facilitate suturing of the jejunum to the anterior abdominal wall. A laparoscopic j-tube kit is used (MIC jejunal feeding tube. HALYARD, Alpharetta, GA). Under direct laparoscopic vision, a large needle and the guide wire and catheter are directed into the loop of jejunum that has been tacked to the anterior abdominal wall. The entry site into the jejunum is carefully witzeled using 2-0 endo-stitches. The entry site of the needle catheter j-tube is tacked completely to the anterior abdominal wall for a distance of several centimeters to seal the area and to prevent torsion.

The last step in the abdominal operation is the dissection of the phrenoesophageal membrane.

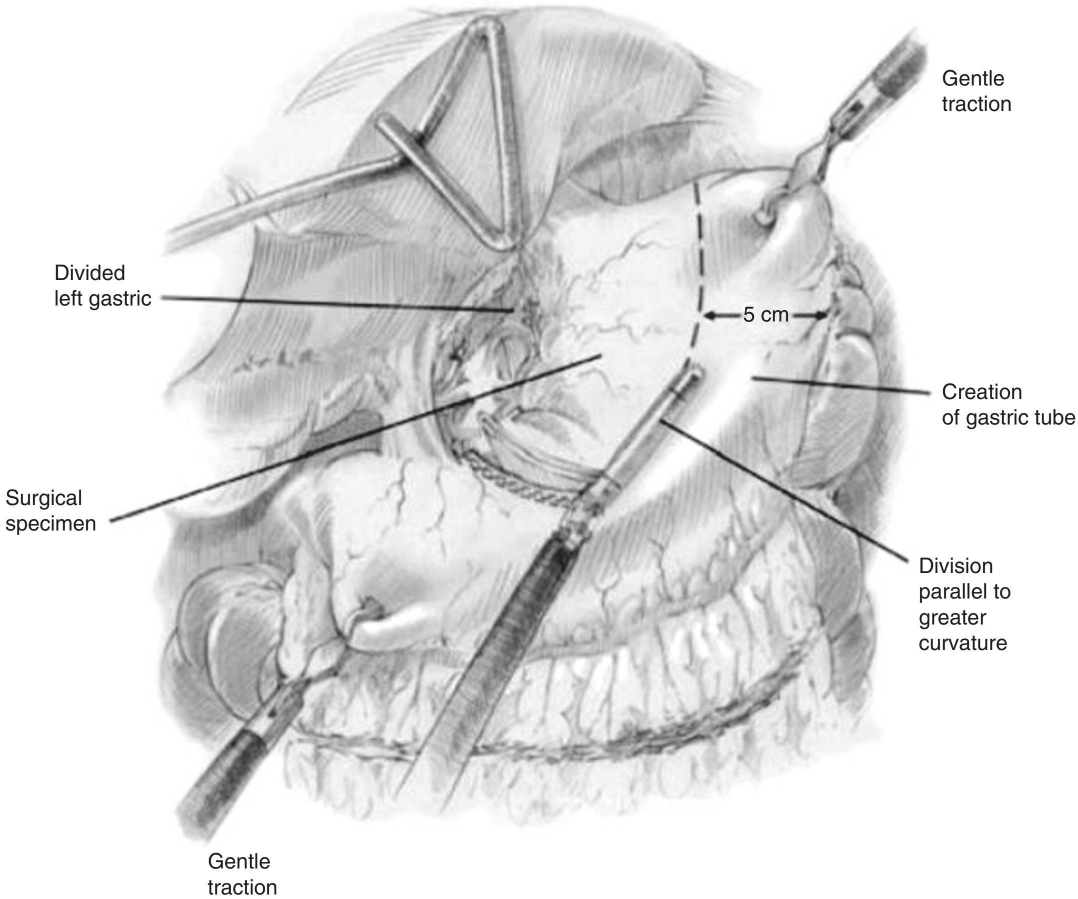

Fig. 9.3 Construction of gastric conduit. Reproduced with permission from the UPMC Heart, Lung and Esophageal Surgery Institute, University of Pittsburgh Medical Center, Pittsburgh, PA

Doing so at this stage helps to minimize the loss of pneumoperitoneum into the mediastinum during the earlier parts of the laparoscopic procedure. In some cases, it may be necessary to partially divide the right and left crura to allow easy passage of the gastric specimen and tube through the hiatus and to prevent later gastric outlet obstruction. However, in the current era, more frequently, we are dealing with a larger hiatal opening due to an associated hiatal hernia and it actually may be necessary to close this opening to some degree.

9.8.3 Neck Steps

Next, a 4- to 6-cm horizontal neck incision is made. The omohyoid muscle is visualized and divided. Deep to the omohyoid dissection we switch to bipolar electrocautery to minimize risk to the recurrent laryngeal nerve. The cervical esophagus is exposed. Careful dissection is performed down until the thoracic dissection plane is encountered, generally quite easily since the video-assisted thoracoscopic surgery (VATS) dissection is continued well into the thoracic inlet. In addition, we leave a penrose drain around the esophagus during the thoracic dissection and push the drain into the peri-esophageal plane at the thoracic inlet, so that it is easily visualized during the neck dissection and actually allows the surgeon to pull the penrose out through the neck to facilitate the neck dissection. The esophagogastric specimen is pulled out of the neck incision and the cervical esophagus divided high (2–3 cm below the cricopharyngeal muscle). The specimen is removed from the field. An anastomosis is performed between the cervical esophagus and gastric tube using standard techniques. In most patients, we prefer using a 25–28-mm EEA stapler. Alternatively, if length is somewhat of a concern, we perform a hand-sewn esophagogastric anastomosis, with a single layer of interrupted stitches of non-absorbable 3-0 Silk or PDS sutures.

Next, the surgeon returns to the laparoscopic view and gently pulls downward on the pyloroantral area to retrieve any excess gastric tube that may have been pulled up into the chest during the neck anastomosis and mobilization. The laparoscopic pull is performed gently, and only until the assistant at the neck observes the tube and the anastomosis beginning to be pulled down at the level of the anastomosis. We strive to achieve a very high anastomosis just below the level of the cricopharyngeus to ensure adequate removal of any islands of Barrett's and to ensure that any anastomotic leak, will be more likely to drain out via the neck.

The last step of the laparoscopic approach is to place tacking sutures between the gastric tube and the diaphragm to prevent hiatal herniation. Care must be taken during this step to maintain orientation of the greater curve vessels towards the left crus and to avoid compromise of these vessels during suturing. We usually place three tacking sutures; one between the left crus and stomach just anterior to the greater curve arcade; the second on the right side of the gastric tube just above the right gastric vessels to the right crus; the third suture is placed anteriorly between the stomach and the diaphragm [9].

9.9 Operative Technique for Ivor Lewis MIE

With any esophagectomy, we always start the case with an on-table endoscopy that allows for assessment of the proximal and distal extent of the tumor as well as to plan the surgical resection margins and also determine the optimal site of anastomosis. For example, a tumor with more gastric cardia extension may require a more extensive resection of stomach in the abdomen and will necessitate the anastomosis to be performed in the chest, rather than the neck. On the other hand, in a patient with a tumor extending proximally to the high thoracic esophagus, a more proximal resection margin and anastomosis in the neck may be required. It is key to limit insufflation with air while performing the EGD, as this may interfere with subsequent laparoscopic surgery. We always decompress the stomach before removal of the endoscope. Patients with a mid on upper esophageal tumor require a bronchoscopy to evaluate the airway and exclude its involvement. The endotracheal tube is then changed to a double-lumen endotracheal tube [11].

9.10 Laparoscopic Phase

9.10.1 Port Placement and Exploration

Proper port placement is important to optimize exposure and the conduct of the operation (Fig. 9.2). Port placement can be modified to suit the body habitus of the patient or in patients with prior surgery. The patient is positioned in a steep reverse Trendelenburg position. A total of five abdominal ports (four 5-mm and one 10–12-mm) are used. The first port placed is a 10–12-mm port, which is placed with a cut down technique. Subsequent ports are placed under direct visualization of the laparoscope. A liver retractor is placed, and the left lobe of the liver is retracted. After placement of the ports, the first step is an exploration of the abdomen to rule out advanced disease before starting the gastric mobilization.

9.10.2 Gastric Mobilization

The mobilization of the stomach is started with the division of the gastrohepatic ligament. Subsequently, the right crus is visualized and dissected, followed by dissection of the left crura of the diaphragm. It is important to avoid dividing the phrenoesophageal membrane at this point, which may lead to loss of pneumoperitoneum. It is important to handle the stomach gently during the mobilization using a no-touch technique of our planned gastric conduit. The greater curvature of the stomach is mobilized by dividing the short gastric vessels using the ultrasonic coagulating shears. We leave 3–4 cm of fat margin with the arcade to help separate the conduit from its ultimate position near the posterior membranous airway. The gastrocolic omentum is then divided, with care taken to preserve the right gastroepiploic arcade. During this portion of the dissection, we selectively mobilize and preserve a well-vascularized omental flap which later would be used as a buttress after construction of the intrathoracic anastomosis. The omental flap is used only if chemo and radiation have been used preoperatively. The posterior attachments of the stomach are then divided after retraction of the stomach anteriorly. A complete celiac node dissection is performed before division of the left gastric vessels with a vascular stapler. On a rare occasion, during gastric mobilization, we may encounter a hepatic branch originating from the left gastric artery. If there is a concern that this branch is a significant major replaced left hepatic artery, we apply a removable clip and observe the left lobe of the liver. If there is concern about ischemia, we remove the clip and preserve this replaced left hepatic artery.

9.10.3 Pyloroplasty

The next step is the performance of the pyloroplasty. The pylorus is mobilized, and its mobility is verified by lifting the pylorus gently up to the caudate lobe of the liver without any tension. A Kocher maneuver is performed to achieve adequate mobilization. An additional 5/11 port is placed in the mid right lower quadrant of the abdomen to facilitate the construction of the pyloroplasty, construction of the gastric tube, and placement of the feeding jejunostomy tube. Then we place two traction sutures at the edges of the pylorus with the Endostitch (2.0). A Heineke-Mikulicz type pyloroplasty is then performed. The pylorus is incised longitudinally with the harmonic scalpel and then closed transversely with interrupted sutures using the Endostitch device. The pyloroplasty is buttressed with an omental patch.

9.10.4 Construction of the Gastric Tube

This is a critical component of the procedure. We create a gastric tube approximately 3 cm in diameter, starting at the lesser curve (Fig. 9.3). The right gastric vessels are preserved. We start with a stapling device (Endo-GIA) beginning in the lesser curve, about 5 cm proximal to the pylorus. It is important to avoid excessive manipulation and trauma to the gastric conduit during this step. To facilitate exposure and protect our planned conduit with a no-touch technique, we have one assistant gently retracting the fundic tip of the stomach (which will subsequently be resected) superiorly and another assistant simultaneously gently retracting the pyloroantral area inferiorly. This retraction facilitates proper alignment and the construction of a gastric tube with uniform diameter of 3 cm. In rare instances, if it is thought that the gastric margin may be a concern, the gastric staple line on the specimen side is sent for a frozen section before the thoracic portion of the operation.

We then routinely place a jejunostomy tube using Seldinger technique, at about 40 cm from the ligament of Treitz. The jejunum is secured to the anterior abdominal wall at the jejunostomy site after doing a Witzel tunnel, then we place an anti-torsion stitch about 3 cm distal to the jejunostomy tube site, using a 2-0 Endo-stitch. The final step is the division of the phrenoesophageal membrane. At this time a careful 360° dissection is performed and the gastric resected specimen is carefully pushed up into the hiatus to facilitate later VATS retrieval. The abdomen is inspected to make sure that hemostasis is adequate and the incisions are closed.

9.11 Thoracoscopic Phase

9.11.1 Thoracoscopic Port Placement

The patient is placed in a left lateral decubitus position. The position of the double-lumen tube is verified with flexible bronchoscopy, and single-lung ventilation is used. Typically, we use five thoracoscopic ports. The fifth, 5-mm port, placed anteriorly is used by the first assistant intermittently for suction. Similar to the ports in the abdomen, optimal port placement is important. A 10-mm port is placed at the seventh to eighth intercostal space, just anterior to the mid-axillary line, for the camera. Another 10-mm port is placed at the eighth or ninth intercostal space, posterior to the posterior axillary line, for the dissection instrument (ultrasonic coagulating shears). A 10-mm port is placed in the anterior axillary line, at the fourth intercostal space, and this is used to pass a fan-shaped retractor to retract the lung anteriorly and allow exposure of the esophagus. A 5-mm port is placed just posterior to the scapula tip, which is used to place instruments for retraction and counter traction. After thoracoscopic exploration, we place a retracting suture near the central tendon of the diaphragm (Endostitch 0), and this suture is brought out through the chest wall through a 1-mm skin incision several centimeters below the camera port. This allows us to provide downward traction on the diaphragm and aids with exposure of the distal esophagus. Later in the case, we make a 5 cm access incision to enable passage of the end-to-end stapler (EEA) and, for removal of the specimen.

9.11.2 Esophageal Mobilization and Lymph Node Dissection

We then proceed with the division of the inferior pulmonary ligament. The mediastinal pleura overlying the esophagus is divided and opened up to the level of the azygos vein to expose the thoracic esophagus. The azygos vein is then dissected and divided with an endoscopic vascular stapler. The esophagus, along with the periesophageal tissue and lymph nodes, is circumferentially mobilized from the diaphragm to the level about 2 cm above the carina. A Penrose drain is placed around the esophagus to facilitate traction and exposure**.** We use an ultrasonic coagulating instrument for the dissection, and endoscopic clips are applied generously for larger vessels and any lymphatics. Above the azygos vein, it is important to keep the plane of dissection directly on the esophagus to prevent injury to the airway and the recurrent laryngeal nerve. Mediastinal lymph node dissection, including a complete dissection of the subcarinal lymph nodes, is performed. With the most common location of tumors being distal esophageal or gastroesophageal junction tumors, we do not perform aggressive nodal dissection near the thoracic inlet to decrease the chance of recurrent laryngeal nerve injury. In addition, the vagi are divided at the level of the azygos vein to minimize traction injury to the recurrent laryngeal nerves. During the thoracoscopic mobilization of the esophagus, it is important to avoid thermal or ultrasonic injury to the airway and the pericardium. The distal esophagus and the gastric conduit are brought up in the chest. It is important to maintain the proper orientation of the gastric conduit, with care taken not to twist the conduit. We prefer a high intrathoracic anastomosis near the thoracic inlet; however, one should be cautious not to divide the esophagus too proximally because this makes construction of the intrathoracic anastomosis technically difficult. In some patients, when there is a concern about the proximal extent of the tumor, repeat endoscopy may be required at this point to determine the site of transection. A 5 cm access incision is made at approximately the 6th intercostal space, we then apply a wound protector; the specimen is removed through this access and sent for frozen-section analysis of margins.

9.11.3 Construction of Anastomosis

We then perform a stapled EEA intrathoracic anastomosis. The first step of the stapled anastomosis is the placement of a 28-mm EEA anvil in the proximal esophagus. The anvil is secured with a purse string suture (Endostitch 2-0). We have found that it is difficult to place this first suture perfectly, as the anvil tends to move and migrate out of the open esophagus. Therefore, we add a second purse string suture to secure the anvil. Because the fundus of the stomach is the most ischemic portion of the conduit, we plan the anastomosis so as to discard the fundic tip. The tip of the fundus is opened, the conduit is flushed with warm antibiotic saline to minimize soilage. Next, the EEA stapler is advanced into the gastrostomy just created in the tip of the fundus. A stapled anastomosis between the gastric conduit and the esophagus, high above the azygos vein, is then performed (Fig. 9.4). The redundant portion of the fundus is excised with a reticulating endo GIA staple, purple load (Fig. 9.5). A nasogastric tube is placed across the anastomosis, under direct visualization, and secured. The anastomosis is checked for any leaks. Avoiding use of the tip of the fundus helps minimize leaks. In some patients (those who have received pre op chemo-radiation), we buttress the anastomosis with an omental flap, which was earlier mobilized during the abdominal phase of the dissection. During the conclusion of the abdominal portion of the operation, the hiatus, if enlarged, is closed posteriorly, and typically one suture is required (Endostitch 0). This is decided based on the size of the hiatal opening, and tailored to avoid narrowing of the conduit and prevent herniation. In addition, at the conclusion of the chest portion of the operation, the conduit is

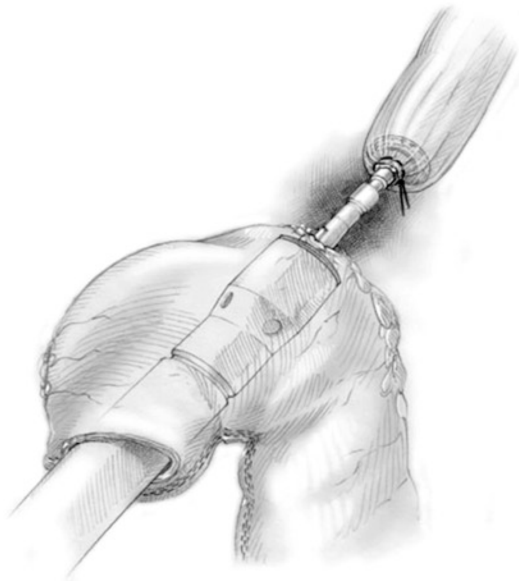

Fig. 9.4 Construction of minimally invasive Ivor Lewis anastomosis. Reproduced with permission from the UPMC Heart, Lung and Esophageal Surgery Institute, University of Pittsburgh Medical Center, Pittsburgh, PA

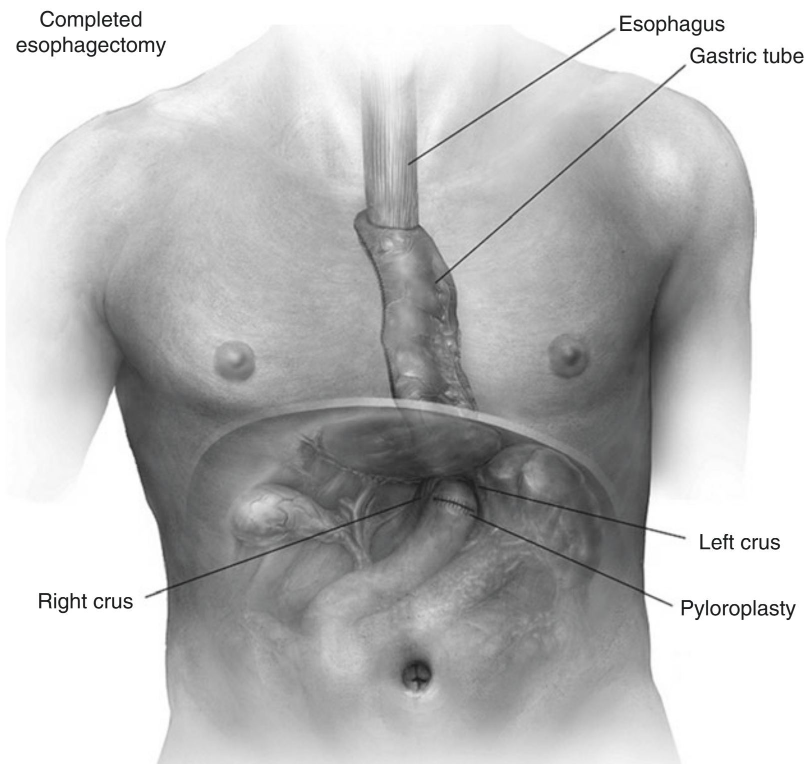

Fig. 9.5 Final aspect of the gastric conduit and anastomosis. Reproduced with permission from the UPMC Heart, Lung and Esophageal Surgery Institute, University of Pittsburgh Medical Center, Pittsburgh, PA

anchored to the right crus with an endostitch. This approach is used to minimize herniation of abdominal organs into the chest.

The chest is inspected closely, and hemostasis is verified. The conduit should be straight and free of redundancy. It is important to drain the chest well and place drains strategically in the chest. This is critical because a well-drained small leak, should it occur, is easy to manage. We place a 28F chest tube posteriorly in the pleural space, and a second No. 10 Jackson-Pratt drain posterior to the anastomosis, tracking behind the gastric conduit to the diaphragm, exiting at the costophrenic angle. It is also important to secure these drains well. We also perform a multilevel intercostal block at the conclusion of the procedure, and close all thoracic incisions in usual fashion. The chest tube is placed on suction, and the patient is turned to a supine position. The double-lumen endotracheal tube is then changed to a single-lumen endotracheal tube. A flexible bronchoscopy is performed, and any secretions in the bronchial tree are aspirated. We also perform an exhaustive aspiration of all oropharyngeal secretions at the end of the case, prior to exchange of the double lumen tube to avoid aspiration of oropharyngeal and/or esophageal debris and secretions.

9.12 Discussion of Thoracic Anastomotic Techniques

Campos et al. published in 2010 their preliminary results on 37 patients of a standardized 25 mm/4.8 mm circular-stapled anastomosis using a trans-orally placed anvil. The esophagogastric anastomosis was created using a 25-mm anvil passed trans-orally, in a tilted position, and connected to a 90-cm long polyvinyl chloride delivery tube through an opening in the esophageal stump. The anastomosis was completed by joining the anvil to a circular stapler (end-to-end anastomosis stapler (EEA XL) 25 mm with 4.8-mm staples) inserted into the gastric conduit. There were no intra-operative technical failures of the anastomosis or deaths. Five patients had strictures (13.5%) and all were successfully treated with endoscopic dilations. One patient had an anastomotic leak (2.7%) that was successfully treated by re-operation and endoscopic stenting of the anastomosis. They concluded that the circular-stapled anastomosis with the transoral anvil allowed for an efficient, safe and reproducible anastomosis [12].

A literature search on the current techniques and approaches for intrathoracic anastomosis was published in 2012 by Maas et al. Twelve studies were evaluated on leakage and stenosis rate of the anastomosis. The most frequent applied technique was the stapled anastomosis. Stapled EEA anastomoses can be divided into a transthoracic or a transoral introduction. This stapled approach can be performed with a circular or linear stapler. The reported anastomotic leakage rate ranges from 0 to 10%. The reported anastomotic stenosis rate ranges from 0 to 27.5%. The review found no important differences between the two most frequently used stapled anastomoses: the transoral introduction of the anvil and the transthoracic [13].

A large meta-analysis published in 2015 comprising 15 studies, total of 3.203 patients, compared the main clinical outcomes following linear stapler (LS) and hand-sewn (HS) esophagogastric anastomosis, including the rates of anastomotic leakage and stricture. Compared with HS, LS esophagogastric anastomosis has a lower rate of anastomosis leakage for several possible reasons: (1) the stapled anastomoses are considered to be more expedient and less traumatic to tissues; (2) the lateral stay sutures allow for reduced tension on the anastomosis without compromising gastric conduit microcirculation; and (3) LS provides triple-layered staple construction that is less traumatic and more watertight than HS.

A significantly reduced rate of anastomotic stricture associated with LS was also found. Performing a subgroup analysis, although there was no significant difference in the decrease in thoracic anastomotic leakage, there was a significant decrease in cervical anastomotic leakage associated with LS. The meta-analysis concluded that the LS technique contributes to a reduced rate of leakage and stricture compared with the HS method [14].

On the other hand, a meta-analysis published in 2013 showed no significant difference in the incidence of esophageal anastomotic leak (EAL) for the following technical factors: hand-sewn versus stapled esophagogastric anastomosis (EGA), minimally invasive versus open esophagectomy, anterior versus posterior route of reconstruction, and ischemic conditioning of the gastric conduit. However, the only technical factor associated with an increased incidence of EAL was a cervical location of the anastomosis, most likely due to a greater stretch placed upon the gastric conduit and impaired conduit microcirculation, as demonstrated on four randomized, controlled trials comprising 298 patients, included in the report, that compared cervical and thoracic EGA. Anastomotic leak was seen more commonly in the cervical group (13.64%) than in the thoracic group (2.96%) [15].

Despite this, some highly experienced surgeons have demonstrated a very low rate of anastomotic leak while performing cervical esophagogastric anastomosis [10].

In a recently published French large multicenter database study, the incidence of severe esophageal anastomotic leak (SEAL) after esophagectomy for esophageal cancer, in their large study population (2439 patients), was 8.5%. The results of the study suggest that SEAL was significantly associated with an adverse impact upon overall and disease-free survivals, and it was also associated with an increase in the incidence of overall, loco-regional, and mixed cancer recurrences. Clinically significant differences in survival were seen in all stages, but statistically significant only for stage 0 and stage III. The incidence of SEAL was independently associated with low hospital procedural volume, cervical anastomosis, upper third tumor location, and ASA score III/IV in multivariable analysis. The findings of this study call attention to the long-term consequences of failure during the anastomotic formation in esophagectomy, and further advise about short- and long-term benefits to the centralization of esophagectomy to high-volume centers [16].

In our experience, we have performed all types of intrathoracic anastomosis including hand sewn, EEA and linear stapled. We currently prefer the EEA technique, when possible with a 28-mm stapler.

9.13 MIE at Other Centers in the United States

We conducted a multi-center, phase II, prospective cooperative group study (coordinated by ECOG) to assess the feasibility of MIE in a multi-institutional setting. Patients with biopsy-proven high-grade-dysplasia or esophageal cancer were enrolled at 17 credentialed sites. Protocol surgery consisted of either 3-stage MIE or Ivor Lewis MIE. MIE was completed in 95 of the 104 patients eligible for the primary analysis (91.3%). The 30-day mortality in eligible patients who underwent MIE was 2.1%; perioperative mortality in all registered patients eligible for primary analysis was 2.9%. Median intensive care unit and hospital stay were 2 and 9 days, respectively. Grade 3 or higher adverse events included anastomotic leak (8.6%), acute respiratory distress syndrome (5.7%), pneumonitis (3.8%), and atrial fibrillation (2.9%). At a median follow-up of 35.8 months, the estimated 3-year overall survival was 58.4% (95% confidence interval: 47.7%–67.6%). Locoregional recurrence occurred in only seven patients (6.7%). We demonstrated that MIE is feasible and safe with low peri-operative morbidity and mortality and good oncological results in centers with significant open and minimally invasive esophageal surgical experience. The MIE approach can be adopted by other centers with appropriate expertise in open esophagectomy and minimally invasive procedures involving the foregut [17].

Conclusion

Surgical resection is a primary curative modality in patients with resectable esophageal cancer. One of the main concerns for recommendation of esophagectomy is the associated risks of surgery. In an effort to decrease the morbidity of esophagectomy, we have adopted a minimally invasive strategy. We have described our current technique of minimally invasive Ivor Lewis esophagectomy, as well as the minimally invasive McKeown esophagectomy technique in detail. Esophageal surgeons should decide on every individual case about the need for a cervical versus an intrathoracic anastomosis, based mainly on the location and extension of the tumor, but also on the surgical expertise required to perform every single step of a minimally invasive esophagectomy.

References

1. Di Pardo BJ, et al. The global burden of esophageal cancer: a disability-adjusted life-year approach. World J Surg. 2016;40(2):395–401.
2. Pennathur A, Gibson MK, Jobe BA, et al. Oesophageal carcinoma. Lancet. 2013;381:400–12.
3. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2016. CA Cancer J Clin. 2016;66(1):7–30.
4. Verhage RJ, Hazebroek EJ, Boone J, et al. Minimally invasive surgery compared to open procedures in esophagectomy for cancer: a systematic review of the literature. Minerva Chir. 2009;64:135–46.
5. Pennathur A, Zhang J, Chen H, et al. The "best operation" for esophageal cancer? Ann Thorac Surg. 2010;89:S2163–7.
6. Zhang J, et al. Refinement of minimally invasive esophagectomy techniques after 15 years of experience. J Gastrointest Surg. 2012;16:1768–74.
7. Luketich JD, Pennathur A, Awais O, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg. 2012;256:95–103.
8. Rindani R, Martin CJ, Cox MR. Transhiatal versus Ivor-Lewis oesophagectomy: is there a difference? Aust N Z J Surg. 1999;69:187–94.
9. Luketich JD, Alvelo-Rivera M, Buenaventura PO, et al. Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surg. 2003;238:486–94; discussion 494–5.
10. Orringer MB, Marshall B, Chang AC, et al. Two thousand transhiatal esophagectomies: changing trends, lessons learned. Ann Surg. 2007;246:363–72; discussion 372–4.
11. Pennathur A, Awais O, Luketich JD. Technique of minimally invasive Ivor Lewis esophagectomy. Ann Thorac Surg. 2010;89:S2159–62.
12. Campos GM, et al. A safe and reproducible anastomotic technique for minimally invasive Ivor Lewis esophagectomy: the circular stapled anastomosis with the transoral anvil. Eur J Cardiothorac Surg. 2010;37:1421–6.
13. Maas KW, et al. Minimally invasive intrathoracic anastomosis after Ivor Lewis esophagectomy for cancer: a review of transoral or transthoracic use of staplers. Surg Endosc. 2012;26:1795–802.
14. Deng X-F, et al. Hand-sewn vs linearly stapled esophagogastric anastomosis for esophageal cancer: a meta-analysis. World J Gastroenterol. 2015;21(15):4757–64.
15. Markar S, et al. Technical factors that affect anastomotic integrity following esophagectomy: systematic review and meta-analysis. Ann Surg Oncol. 2013;20:4271–81.
16. Markar S, et al. The impact of severe anastomotic leak on long-term survival and cancer recurrence after surgical resection for esophageal malignancy. Ann Surg. 2015;262:972–80.
17. Luketich JD, Pennathur A, et al. Minimally invasive esophagectomy: results of a prospective phase II multicenter trial-the Eastern Cooperative Oncology Group (E2202) Study. Ann Surg. 2015;261:702–7.