Technique of Minimally Invasive Ivor Lewis Esophagectomy

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Although a variety of surgical techniques exist for esophageal resections, the two most common approaches are the transhiatal esophagectomy and the Ivor Lewis esophagectomy. The choice of the most suitable operation takes into consideration several factors including the location of the tumor; the patient’s medical condition, body habitus, prior surgical history, and history of radiation therapy; the organ to be used as a replacement conduit; the limits of node dissection; and finally, the surgeon’s preference.

Despite evolving techniques and improvements in both the transhiatal and the Ivor Lewis surgical approaches, esophagectomies are complex operations that are associated with significant morbidity and mortality. Furthermore, surgical candidates are often elderly patients with coexisting medical comorbidities including respiratory and cardiovascular diseases. Nationwide, the mortality rates from esophagectomies range from 8% in high-volume centers to as high as 23% in low-volume centers.1 Therefore, to limit the physiologic stress and inflammatory responses associated with open esophagectomy, minimally invasive surgical approaches have been developed.2-5 This paradigm shift has been driven by the observation that minimally invasive surgery is associated with equal efficacy, less pain, and an earlier return to work as compared with open surgery. Minimally invasive esophagectomy can be performed via transhiatal, modified McKeown, and Ivor Lewis approaches.

In our initial experience, we utilized a three-field, laparoscopic-thoracoscopic approach. Our earlier publications with this technique demonstrated that minimally invasive esophagectomy could be performed safely with equivalent stage-specific survival compared with the larger open series in the existing literature.2 Although technically demanding and associated with a significant operator learning curve, data from our series revealed a decrease in operative blood loss, length of stay, pulmonary complications, and narcotic requirements. In both our own experience and publications elsewhere, concerns have arisen regarding an increased incidence of technical complications associated with cervical esophagogastric anastomoses including anastomotic leak, stricture, recurrent laryngeal nerve injury, and pharyngoesophageal swallowing dysfunction. In light of these concerns, we have evolved our technique to a completely laparoscopic-thoracoscopic (Ivor Lewis) esophagectomy with complete lymph node dissection for typical gastroesophageal junction tumors. Unless contraindicated by tumor location or previous thoracic surgery, we presently favor the totally minimally invasive Ivor Lewis approach.

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176

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Operative Technique

Figure 1 The patient is initially positioned in the supine position, and a double lumen endotracheal tube is placed in preparation for the thoracoscopic mobilization of the esophagus. An esophagogastroscopy is performed to determine the precise location of the tumor and any extension proximally or distally, especially onto the cardia of the stomach. The stomach is also evaluated to determine its suitability as a gastric conduit. The surgeon operates from the right side of the table, while the assistant is positioned to the patient’s left side. Five abdominal ports are used for the gastric mobilization. A marking pen is used to trace the midline from the xiphoid to the umbilicus, and this line is further divided into thirds. To avoid potential injury to any abdominal viscera or organs, the initial port is placed via an open technique. The two midepigastric ports are placed on the lower third of the marked line to assist with gastric mobilization.
Figure 2  After an initial inspection of the peritoneal surfaces and the liver to rule out any metastatic disease, the gastrohepatic omentum is opened. The left gastric artery/vein pedicle is identified and, by tracing its course proximally, the celiac lymph nodes are then examined. A complete lymph node dissection is performed to include the celiac nodes, sweeping all nodal and fatty tissue with the specimen, the nodal dissection is continued along the splenic artery and the superior border of the pancreas. This plane continues cephalad toward the right and left crus, continuous with the preaortic dissection plane into the lower thoracic cavity. If any lymph nodes appear suspicious for metastatic involvement, they are dissected and sent for frozen-section analysis. If the nodes do not appear malignant or are pathologically free of cancer on analysis, dissection of the right crus is initiated to mobilize the lateral aspect of the esophagus. a. = artery.
The dissection is then carried anteriorly and superiorly over the esophagus to finally expose the anterior hiatus. As the dissection is continued toward the left crus, the fundus of the stomach begins to be mobilized. Complete dissection of the phrenoesophageal ligaments is usually left until the conclusion of the laparoscopic mobilization, as this allows for the maintenance of pneumoperitoneum. The medial border of the right crus is dissected inferiorly until the decussation of the right and left crural fibers, thereby exposing a retroesophageal window and completing the mobilization of the superior portion of the lesser curvature and gastroesophageal junction. Attention is then turned to the posterior mobilization of stomach. After identifying the gastrocolic omentum, the antrum of the stomach is retracted, and a window is created in the greater omentum, thus allowing access to the lesser sac. Dissection is carried along the greater curve of the stomach until the end of the gastroepiploic arcade is reached. During this mobilization, it is important to be constantly mindful of the location of right gastroepiploic vessel.
Figure 4 The short gastric vessels are divided and coagulated with the ultrasonic shears (Autosonix; Covidien, Mansfield, MA) or the LigaSure device (LigaSure; Valleylab, Boulder, CO). Occasionally, clips will be required during division of large-diameter, short gastric vessels. Once the greater curve of the stomach is mobilized, the fundus is rotated toward the patient’s right shoulder to expose its retroperitoneal attachments. These are dissected free toward the lesser curvature until the left gastric artery and vein are encountered. The retrogastric attachments are also divided superiorly toward the hiatus to complete the mobilization of the fundus and the distal esophagus. The mobilization of the stomach is then carried back toward the pyloro-antral region. The dissection here must be meticulous for any injury to the gastroepiploic arcade or the gastroduodenal artery may render the gastric conduit useless. There are often significant adhesions in the retro-antral and peri-duodenal regions that also need to be dissected to allow for adequate mobilization of the inferior portion of the stomach. The pylorus is considered adequately mobilized when it is able to reach the right crus under no tension. This may require a partial or complete Kocher maneuver. Particular attention to mobilization of the pyloro-antral area is needed in patients who have had prior cholecystectomy or biliary tract procedures. lig. = ligament.
Once the stomach and celiac lymph nodes are completely mobilized, the left gastric artery and vein are divided with a vascular load on the Endo GIA stapler. This is done by approaching the pedicle from the lesser curve. It is important that the pedicle be dissected completely clean with all celiac nodes swept up into the specimen. Once the pedicle is divided, the distal esophagus, gastric fundus, and antrum should be completely mobilized. The gastric tube is usually created before the completion of the pyloroplasty and placement of the feeding jejunostomy tube, as this provides time to assess the viability of the gastric tube as a conduit before bringing it into the chest. The first stapler used for creating the gastric conduit contains a vascular load to control bleeding from the adipose tissue and vessels along the lesser curve. The stapler is placed just up to, but not onto, the gastric antrum, which is usually thick and will require staples appropriate for thick tissue. The initial 5/12-mm right midclavicular port is changed to a 15-mm port to allow for the placement of a 4.8-mm Endo GIA stapler (Autosuture, Covidien). An additional 12-mm port is placed in the right lower quadrant to assist with the creation of the gastric tube. \( a. \) = artery.

**Figure 5** Once the stomach and celiac lymph nodes are completely mobilized, the left gastric artery and vein are divided with a vascular load on the Endo GIA stapler. This is done by approaching the pedicle from the lesser curve. It is important that the pedicle be dissected completely clean with all celiac nodes swept up into the specimen. Once the pedicle is divided, the distal esophagus, gastric fundus, and antrum should be completely mobilized. The gastric tube is usually created before the completion of the pyloroplasty and placement of the feeding jejunostomy tube, as this provides time to assess the viability of the gastric tube as a conduit before bringing it into the chest. The first stapler used for creating the gastric conduit contains a vascular load to control bleeding from the adipose tissue and vessels along the lesser curve. The stapler is placed just up to, but not onto, the gastric antrum, which is usually thick and will require staples appropriate for thick tissue. The initial 5/12-mm right midclavicular port is changed to a 15-mm port to allow for the placement of a 4.8-mm Endo GIA stapler (Autosuture, Covidien). An additional 12-mm port is placed in the right lower quadrant to assist with the creation of the gastric tube. \( a. \) = artery.
When creating the gastric tube, it is important to stretch the stomach to create a straight conduit. The first assistant grasps the tip of the fundus along the greater curve and gently stretches it toward the spleen, while a second grasper is applied to the antral area with a slight downward retraction. The staple line should parallel the greater curvature of the stomach and the gastroepiploic vessels. The stomach is first divided across the antrum with 4.8-mm staple loads. Because this region is generally quite thick, larger staples are required to secure its closure. Early in our experience, we discovered that very narrow gastric conduits were associated with increased gastric tip necrosis and anastomotic leaks, and, therefore, we now construct wider conduits measuring about 4 to 5 cm in diameter. Once the thicker antrum has been divided, the operating port is changed back to an 11-mm port, and the fundus is divided using a 3.5-mm stapler. As the fundus is divided, the graspers are readjusted to keep the stomach constantly stretched. If there is any concern about extension of tumor onto the gastric cardia, a wider margin is left in this region. The staple line is usually not reinforced with extraneous sutures. If there is any concern about the adequacy of the stapled closure, additional reinforcing sutures can be placed. The right gastric vessels are preserved.
Figure 7 (A) After the mobilization and creation of the gastric conduit, a pyloroplasty is performed. Stay sutures are placed initially on the superior and inferior aspect of the pylorus to aid in retracting the pylorus utilizing 2.0 Surgidac suture (Covidien) and the Endostitch device (U.S. Surgical, Norwalk, CT). (B) Once the pylorus has been placed on stretch, the anterior wall is transected with ultrasonic shears. (C) The pyloroplasty is then closed transversely in a Heineke–Mikulicz fashion using 2.0 Surgidac interrupted sutures. This usually takes four to six sutures. At the conclusion of the abdominal portion of the operation, the omentum is mobilized up to the pyloroplasty and secured with a suture. In our experience, a laparoscopic pyloromyotomy is difficult to perform. More recently, we have included the addition of a 3-cm-wide, 8- to 10-cm-long omental pedicle, originating from the upper greater curver of the gastric conduit. This pedicle is brought up into the chest with the new conduit and, at the time of the anastomosis, the pedicle is subsequently wrapped around the anastomosis. This technical step was added to lower the intrathoracic leak rate to near zero after personal communication with Dr. Earl Wilkins, Professor Emeritus at the Massachusetts General Hospital.
Using a needle catheter kit, a feeding jejunostomy tube (5- or 7-French needle catheter; Compat Biosystems, Minneapolis, MN) is placed in the left lower quadrant. The omentum is retracted out of the pelvis to expose the underlying transverse colon. By rotating the transverse colon up toward the hiatus and following the mesocolon posteriorly, the ligament of Treitz is easily identified. After tracing the jejunum distally for 30 to 40 cm, a loop of small bowel is tacked to the anterior abdominal wall by using an endostitch device. The 12-mm trocar previously placed in the right lower quadrant is now utilized as the operating port, and the camera is switched to the 11-mm port in the right upper quadrant. The feeding tube is then passed into the jejunum using the Seldinger technique under direct laparoscopic vision. Proper placement of the catheter is confirmed by observing distension of the jejunum as air is insufflated into the needle catheter. To prevent leakage from the enterotomy site, the jejunum is then tacked to the abdominal wall using several additional endostitches in a purse-string fashion. About 4 cm distally, another segment of the jejunum is secured to the anterior abdominal wall to prevent torsion of the bowel.
Figure 9 The most superior portion of the gastric tube is stitched to the specimen. It is important to keep the stomach aligned correctly so that, during the mobilization of the conduit into the chest, it does not twist in the abdomen. We ensure this by suturing the greater curvature along the short gastric vessels to the staple line of the proximal gastric remnant.
Figure 10 The stitch connecting the gastric tube and the specimen maintains the correct orientation of the gastric conduit as it is delivered into the chest. The laparoscopic portion of the procedure is completed by dividing the phrenoesophageal membrane. If the hiatus appears wide, the crura are reapproximated with an endostich to avoid potential herniation of the conduit into the chest. As a final step, the pyloroplasty is covered with a patch of omentum and a final inspection for bleeding in the abdomen is made.
Figure 11  The patient is then turned to the left lateral decubitus position for the thoracoscopic mobilization of the esophagus and creation of the intrathoracic anastomosis. The operating surgeon stands on the right side of the table (facing the patient’s back) and the assistant stands on the left side of the table. Five thoracoscopic ports are used. A 10-mm camera port is placed in the seventh or eighth intercostal space, just anterior to the midaxillary line. The working port is a 10-mm port that is placed at the eighth or ninth intercostal space, posterior to the posterior axillary line. Another 10-mm port is placed in the anterior axillary line at the fourth intercostal space, through which a fan-shaped retractor aids in retracting the lung to expose the esophagus. A 5-mm port is placed just inferior to the tip of the scapula, and this is used by the surgeon’s left hand for countertraction. A final port is placed at the sixth rib, at the anterior axillary line for suction, and is important in the creation of the anastomosis.
The first step in the thoracoscopic portion of the procedure is the placement of a suture (0-Surgidac Endostitch device) through the central tendon of the diaphragm. The suture is brought out through the anterior chest wall at the level of the insertion of the diaphragm through a 1-mm incision. This retracts the diaphragm inferiorly, thus allowing visualization of the distal esophagus. Mobilization of the thoracic esophagus begins by dividing the inferior pulmonary ligament to the level of the inferior pulmonary vein. In taking down the inferior pulmonary ligament, it is important to dissect onto the pericardium as it is the medial aspect of the dissection. The inferior pulmonary vein is retracted anteriorly and the dissection is carried superiorly along the pericardium to the level of the subcarinal lymph nodes. Level 7 lymph nodes are completely dissected en bloc with the esophagus to the bifurcation of the right and left mainstem bronchi. The posterior, membranous wall of the right mainstem bronchus is at risk during this mobilization and should be clearly identified. With the lung retracted anteriorly, the pleura lying anterior to the esophagus is then incised to the level of the azygos vein. After the azygos vein is isolated and freed from the mediastinal pleura, it is divided with a vascular load of the Endo GIA stapler. The vagus nerve is transected at this point to prevent any traction injuries to the recurrent nerve during the mobilization of the esophagus. Attention is then turned to mobilizing the esophagus laterally. The pleura are divided superficially along the posterior groove to the esophagus to avoid injury to the thoracic duct and the underlying aorta. The thoracic duct is not routinely resected with the specimen and any tissue that appears suspicious for branches of the thoracic duct or aortoesophageal vessels is controlled with endoclips before dividing with the ultrasonic shears. A careful ligation should be considered if there are any concerns over trauma to the thoracic duct. The lateral dissection is carried from the azygos vein to the gastroesophageal junction and the deep margin of the dissection is the contralateral pleura, which is occasionally entered to remove a bulky tumor. With the esophagus mobilized medially and laterally, the specimen is pulled into the chest with the attached gastric conduit. It is also extremely important that the gastric tube remains properly oriented with the staple line facing the lateral chest wall. This alignment is mandatory to avoid spiraling or twisting of the conduit. The stitch is cut between the specimen and the conduit and the specimen is retracted anteriorly and superiorly. The dissection is continued medially to mobilize the rest of the esophagus completely from the contralateral pleura. Once the dissection is completed to the level of the azygos vein, the dissection plane moves onto the wall of the esophagus to avoid injury to the recurrent laryngeal nerve. We do not routinely harvest lymph nodes above the azygos vein. With the esophagus completely mobilized, the inferior, lateral port is enlarged to 4 to 5 cm and a wound protector (Applied Medical, Rancho Santa Margarita, CA) is placed to protect the skin and chest wall from trocar implants. The esophagus is transected using Endo Shears at a level appropriate for the tumor. The specimen is removed through the wound protector and sent for pathologic analysis of the margins. v. = vein.

Figure 12  The first step in the thoracoscopic portion of the procedure is the placement of a suture (0-Surgidac Endostitch device) through the central tendon of the diaphragm. The suture is brought out through the anterior chest wall at the level of the insertion of the diaphragm through a 1-mm incision. This retracts the diaphragm inferiorly, thus allowing visualization of the distal esophagus. Mobilization of the thoracic esophagus begins by dividing the inferior pulmonary ligament to the level of the inferior pulmonary vein. In taking down the inferior pulmonary ligament, it is important to dissect onto the pericardium as it is the medial aspect of the dissection. The inferior pulmonary vein is retracted anteriorly and the dissection is carried superiorly along the pericardium to the level of the subcarinal lymph nodes. Level 7 lymph nodes are completely dissected en bloc with the esophagus to the bifurcation of the right and left mainstem bronchi. The posterior, membranous wall of the right mainstem bronchus is at risk during this mobilization and should be clearly identified. With the lung retracted anteriorly, the pleura lying anterior to the esophagus is then incised to the level of the azygos vein. After the azygos vein is isolated and freed from the mediastinal pleura, it is divided with a vascular load of the Endo GIA stapler. The vagus nerve is transected at this point to prevent any traction injuries to the recurrent nerve during the mobilization of the esophagus. Attention is then turned to mobilizing the esophagus laterally. The pleura are divided superficially along the posterior groove to the esophagus to avoid injury to the thoracic duct and the underlying aorta. The thoracic duct is not routinely resected with the specimen and any tissue that appears suspicious for branches of the thoracic duct or aortoesophageal vessels is controlled with endoclips before dividing with the ultrasonic shears. A careful ligation should be considered if there are any concerns over trauma to the thoracic duct. The lateral dissection is carried from the azygos vein to the gastroesophageal junction and the deep margin of the dissection is the contralateral pleura, which is occasionally entered to remove a bulky tumor. With the esophagus mobilized medially and laterally, the specimen is pulled into the chest with the attached gastric conduit. It is also extremely important that the gastric tube remains properly oriented with the staple line facing the lateral chest wall. This alignment is mandatory to avoid spiraling or twisting of the conduit. The stitch is cut between the specimen and the conduit and the specimen is retracted anteriorly and superiorly. The dissection is continued medially to mobilize the rest of the esophagus completely from the contralateral pleura. Once the dissection is completed to the level of the azygos vein, the dissection plane moves onto the wall of the esophagus to avoid injury to the recurrent laryngeal nerve. We do not routinely harvest lymph nodes above the azygos vein. With the esophagus completely mobilized, the inferior, lateral port is enlarged to 4 to 5 cm and a wound protector (Applied Medical, Rancho Santa Margarita, CA) is placed to protect the skin and chest wall from trocar implants. The esophagus is transected using Endo Shears at a level appropriate for the tumor. The specimen is removed through the wound protector and sent for pathologic analysis of the margins. v. = vein.
The anvil of a 28-mm EEA stapler is placed in the proximal esophagus and a 2.0 Endostitch purse-string suture is placed and tied (intracorporeal technique) to secure the anvil in position. It is technically challenging to make this first stitch perfect, as the anvil has a tendency to migrate out of the open end of the proximal esophagus. For this reason, a second purse-string suture is placed to further secure the anvil and pull in any mucosal defects, thereby ensuring complete rings following EEA firing. Ordinarily, we utilize a 28-mm EEA stapler in an attempt to minimize the risk of stricture and decrease need for postoperative dilations. In the majority of cases, we are able to secure the 28-mm anvil without difficulty. On rare occasion, we have had to use a Foley balloon catheter to dilate the proximal esophagus. Should the Foley balloon catheter fail, we would then utilize a 25-mm stapler. The gastric conduit is then pulled to the apex of the chest and the ultrasonic shears are used to open up the tip of the gastric conduit along the staple line. The EEA stapler is placed through the posterior, inferior port, which had been enlarged, and positioned in the conduit. The stapler tip is brought out along the greater curve of the gastric conduit to join the anvil. Before creating the anastomosis, we carefully estimate the amount of conduit that will lie in the chest. It is a common mistake to bring an excess amount of stomach into the chest in an effort to minimize tension on the anastomosis. This excess conduit will often assume a sigmoid conformation above the diaphragm and may lead to significant problems with gastric emptying. In addition, ensuring proper orientation of the stomach is critical to prevent twisting. EEA = end-to-end anastomosis.
Figure 14  The tip of the stapler and the anvil are docked and the stapler is fired, creating a circular esophagogastric anastomosis, joining the side of the gastric conduit to the end of esophagus, at approximately the level of the azygos vein. The excess gastric tip (the gastrostomy through which the stapler was placed) is trimmed using several loads of an articulating linear stapler, taking care not to injure the omental pedical wrap that was mobilized along the greater curvature. We do not routinely perform endoscopy to evaluate the anastomosis.
Surgical Outcomes

There are currently two case series (15 and 50 patients, respectively) and several case reports describing laparoscopic and thoracoscopic Ivor Lewis esophagectomies. In the largest series to date, our group reported a median intensive care unit stay of 1 day and a median hospital stay of 7 days. The mortality rate was 6% and the anastomotic leak rate was 6%. The initial outcomes regarding surgical margins and lymph node clearance were comparable to those of open approaches; however, the long-term oncologic advantages remain unclear. To date, we have performed over 500 minimally invasive Ivor Lewis operations and will report this data soon.

In several reported series of laparoscopic transhiatal esophagectomies, the mean operative time ranged from 160 to 390 minutes. The mean blood loss was 220 to 400 mL and the conversion rate was 0%-16.6%. The rate of anastomotic leaks ranged from 0% to 8.3% and the mean hospital stay was between 6.4 and 12.1 days. Mortality ranged from

Figure 15 A Jackson–Pratt drain is placed along the esophageal bed, longitudinally beside the new gastric conduit, and a 28-French chest tube is placed along the posterior recess of the chest cavity. The potential space between the conduit and the right crus of the diaphragm then is closed with a single interrupted stitch to prevent delayed herniation. As a final step, the omental pedicle flap from the greater curve is wrapped around the anastomosis.
0% to 13.6%. Long-term oncologic outcomes are not reported. For laparoscopic and thoracoscopic esophagectomies with cervical anastomoses, mean operative times ranged from 265 to 350 minutes and mean blood loss ranged from 200 to 300 mL.\textsuperscript{2,3,10} The conversion rates were reported as 2.2%-14.3%, and anastomotic leaks occurred in 8%-28% of patients. The median hospital stay was between 7 and 12 days. Mortality ranged from 0% to 4.3%. Our group reported the largest series of laparoscopic and thoracoscopic esophagectomies with cervical anastomoses (n = 222 cases).\textsuperscript{2} The median length of stay in the intensive care unit was 1 day and the median length of stay in the hospital was 7 days. The 30-day operative mortality rate was 1.4%. Major complications occurred in 32% of the patients and minor complications occurred in 24%. The most prevalent complications were atrial fibrillation and pleural effusions. Overall, the anastomotic leak rate was 11.7%; however, this rate dropped to 6% in the latter half of their series, suggesting a learning curve for the complicated techniques. At a median follow-up of 24 months, stage-specific survival was comparable to previously published open series.

**Conclusions**

The decision of which minimally invasive approach to use is based on the location and extension of the tumor and the experience of the surgeon with a particular technique. The superior results of the minimally invasive Ivor Lewis approach are attributed to the following: (1) the avoidance of a neck dissection, thereby lowering the potential for recurrent laryngeal nerve injury and microaspiration; (2) the ability to extend the resection onto the stomach and gastric cardia to obtain negative margins for tumors in the gastroesophageal junction; (3) adequate length of the tubularized gastric conduit, thereby decreasing tension on the anastomosis; (4) the ability to amputate the most proximal tip of the newly constructed gastric conduit, which is the most susceptible to ischemia and potential leak; and (5) the ability to perform the anastomosis with a wide view within the chest cavity.

As with all esophageal procedures, the surgeon must be experienced in several surgical options as a variety factors (tumor extension, body habitus, and prior surgery) often dictate the surgical approach. It clearly has been demonstrated that minimally invasive esophageal resections are technically feasible and can be performed as safely as conventional esophagectomies. However, we believe that minimally invasive esophageal surgery should be performed in high-volume centers with significant experience in both open and minimally invasive approaches to optimize patient safety and outcome.

**References**