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HOW I DO IT

# Hybrid Trans-thoracic Esophagectomy with Side-to-Side Stapled Intra-thoracic Esophagogastric Anastomosis for Esophageal Cancer

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**Abstract** Esophagectomy is the primary treatment modality for non-metastatic esophageal cancer. A trans-thoracic approach is used in most centers in the United States. Anastomotic complications, such as leakage and stricture, are associated with worse short-term and long-term outcomes. Recent data suggest that a side-to-side mechanical intra-thoracic esophagogastric anastomosis is associated with a reduced rate of anastomotic leaks and strictures. This article describes the technique of trans-thoracic hybrid esophagectomy with side-to-side intra-thoracic esophagogastric anastomosis for esophageal cancer.

**Keywords** Esophageal cancer · Laparoscopic esophagectomy · Thoracotomy · Esophagogastric anastomosis · Anastomotic leak

## Introduction

Adenocarcinoma of the esophagus, which occurs in most cases as a consequence of the progression of Barrett's esophagus, is currently the most prevalent histopathologic type of esophageal malignancy in the United States.[1]

Esophagectomy is considered the gold standard for the surgical treatment of non-metastatic esophageal cancer. However, controversies exist about the optimal surgical approach (transhiatal versus transthoracic, open versus minimally invasive) and the type of esophagogastric anastomosis (mechanical versus hand-sewn, end-to-side versus side-to-side).

A significantly higher incidence of recurrent laryngeal nerve injury and anastomotic complications are reported after transhiatal esophagectomy, while respiratory complications are more frequently observed after a transthoracic approach.[2,3]

During the last two decades, minimally invasive (laparoscopic, thoracoscopic, and hybrid) approaches to esophagectomy have been increasingly used, with reported lower overall morbidity rates and shorter length of hospital stay as compared with the open approach.[4,5] In addition, several types of esophagogastric anastomosis, including a semi-mechanical side-to-side esophagogastric anastomosis, have been described in an effort to reduce the risk of anastomotic stricture and leak.[6]

This manuscript describes a step-by-step approach of a trans-thoracic hybrid esophagectomy with side-to-side stapled intra-thoracic esophagogastric anastomosis for the treatment of esophageal cancer.

## Preoperative Work-Up

The preoperative work-up includes clinical evaluation, endoscopic ultrasound to assess the level of esophageal wall invasion and the presence of peri-esophageal lymph nodes, chest and abdominal computed tomography (CT) scan, and total body positron emission tomography to rule out distant metastases. When a locally advanced esophageal cancer (T3–T4 or N+) is diagnosed, the patient is referred for neoadjuvant chemoradiation therapy. In case of metastatic disease, palliative therapy includes endoscopic esophageal stenting and chemotherapy. In addition, a cardiac evaluation and pulmonary function tests are obtained.

## Anesthesiologic Setup

A thoracic epidural catheter is placed preoperatively for the management of postoperative pain, along with an arterial line

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for perioperative arterial blood gas analyses and continuous monitoring of arterial pressure. A venous central line is also placed when peripheral venous lines are not available.

## Positioning of the Patient on the Operating Table

The patient lies supine on the operating table over a bean bag that is inflated to prevent sliding during the operation when a steep reverse Trendelenburg position is used. After induction of general endotracheal anesthesia with a double lumen endotracheal tube, a nasogastric tube is inserted to keep the stomach decompressed. The legs are extended on stirrups, and the knees are flexed at a 20° to 30° angle. The surgeon performs most of the laparoscopic procedure standing between the patient's legs, with an assistant on the right side and another one on the left side of the operating table (Fig. 1).

## Step 1: Placement of Trocars

We initially inflate $CO_2$ into the abdominal cavity through a Veress needle that is placed 16 cm inferior to the xyphoid process to a pressure of 15 mmHg at a steady flow of 30 L/min. Alternatively, a Hasson cannula can be used. We recommend using an optical trocar with a 0-degree scope to obtain access.

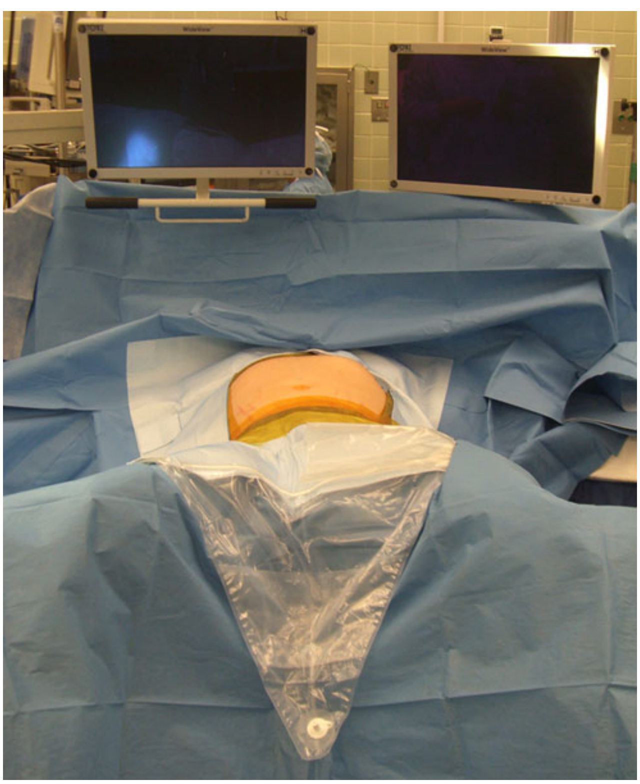


**Fig. 1** Patient's positioning

Four 11-mm trocars and one 12-mm trocar (for insertion of the mechanical stapling device) are used for the operation (Fig. 2). Trocar 1 is placed in the same location of the Veress needle, and it is used for a 30° camera. Trocar 2 is placed in the left mid-clavicular line at the same level with trocar 1, and it is used for insertion of a Babcock clamp; a grasper to hold the Penrose drain surrounding the esophagus; or for devices used to divide the short gastric vessels. Trocar 3 is placed in the right mid-clavicular line at the same level of the other two trocars, and it is used for the insertion of a retractor to lift the left lateral segment of the liver (a commercially available five-prong retractor is used) and then to place the camera during the performance of the pyloroplasty. Trocars 4 and 5 are placed under the right and left costal margins, so that their axes form an angle of about 120° with the camera. They are used for the dissecting and suturing instruments. An additional 5-mm trocar (5bis) can be placed in the right upper quadrant for the performance of the pyloroplasty.

Inspection of the abdominal cavity is initially done to rule out the presence of metastatic disease to the liver, peritoneal carcinomatosis, or ascitis.

## Step 2: Initial Abdominal and Lower Mediastinal Dissection

The gastrohepatic ligament is divided, beginning the dissection above the caudate lobe of the liver, where the ligament is thinner, and continuing toward the diaphragm until the right pillar of the crus is identified. The right pillar of the crus is then separated from the right side of the esophagus by blunt dissection.

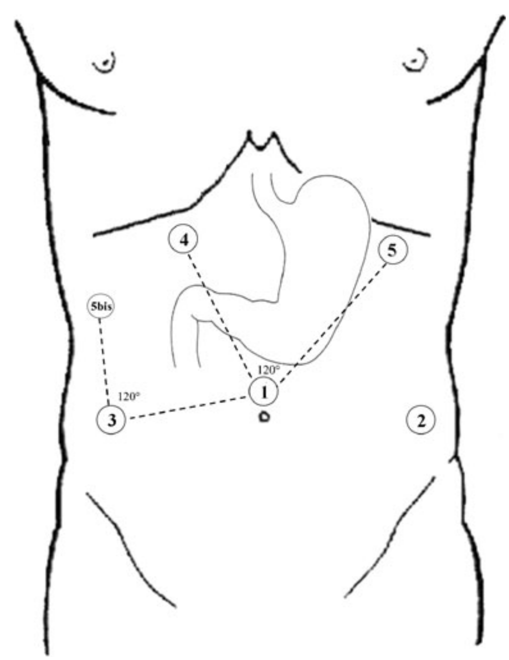



**Fig. 2** Placement of trocars

Subsequently, the peritoneum and phreno-esophageal membrane overlying the esophagus are divided. The left pillar of the crus is then separated bluntly from the esophagus toward the junction with the right crus.

Dissection is then performed in the posterior mediastinum (laterally, anteriorly, and posteriorly) for about 5 cm above the diaphragm. Lower mediastinal lymph nodes are retrieved.

This step is extremely important as it allows the surgeon to rule out infiltration of the aorta by the tumor.

### Step 3: Division of the Short Gastric Vessels

A laparoscopic bipolar instrument is introduced through trocar 2. A grasper is introduced through trocar 5 and held by the surgeon, while an assistant applies traction on the greater curvature of the stomach through trocar 4. The dissection is started at the level of the middle portion of the gastric body and is continued upward until the most proximal short gastric vessel is divided.

### Step 4: Placement of Penrose Drain Around the Esophagus

A Babcock clamp is applied at the level of the esophagogastric junction to retract upward the esophagus. A window is opened by a blunt and sharp dissection under the esophagus, between the gastric fundus, the esophagus, and the left pillar of the crus. The window is then enlarged, and a Penrose drain is passed around the esophagus.

### Step 5: Gastric Mobilization

The mobilization of the stomach continues with the transection of the coronary vein and the left gastric artery using an Endo-GIA stapler with a 45 mm long vascular cartridge. This is done after dissecting both vessels all the way to their base in order to retrieve as many left gastric lymph nodes as possible. The gastro-colic ligament is then opened all the way to the pylorus, respecting the right gastroepiploic artery. The opening of the gastrohepatic ligament is then completed preserving the right gastric artery. At this point, the blood supply of the stomach is based on the right gastric artery and the right gastroepiploic artery.

### Step 6: Pyloroplasty

The pylorus is opened longitudinally and closed transversely using interrupted 2–0 silk sutures. For this step of the procedure, the camera is moved to trocar 3 so that the camera looks at the pylorus and trocars 1 and 4 are used for the suturing, with the surgeon standing on the right side of the patient. An additional trocar (trocar 5bis) can be placed in the right upper quadrant to facilitate the creation of a 120° angle for the suturing.

### Step 7: Feeding Jejunostomy

No special jejunostomy kits are used. Trocar 1 is used for the camera, and trocars 2 and 5 for the manipulation of the bowel and suturing. A 10 F feeding tube is inserted about 40 cm distal to the ligament of Treitz. A purse string of 3–0 silk is placed around the tube, and a 4-cm Witzel tunnel is then created with interrupted stitches of 3–0 silk. Finally, the jejunum is fixed to the left side of the abdominal wall with four stitches of 3–0 silk. One hundred cubic centimeters of saline are then injected to confirm the proper position and function of the tube.

### Step 8: Abdominal Closure

The trocars are removed under direct vision. After achieving hemostasis, the trocar sites are closed, local anesthesia is injected, and sterile dressings are applied.

### Step 9: Mobilization and Resection of the Esophagus

After completion of the abdominal portion of the operation, the patient is turned to the left lateral decubitus, and the chest is entered through a postero-lateral thoracotomy in the fifth intercostal space. A 1.5-cm-long segment of the posterior portion of the sixth rib is resected in order to allow better spreading of the ribs and achieve better exposure. Inspection of the pleural cavity aims to rule out the presence of metastatic disease. Inflammatory changes secondary to neoadjuvant chemoradiation are frequently present in the posterior mediastinum.

The inferior pulmonary ligament is divided; the pleura is opened above and below the azygous vein. The azygous vein is transected with an Endo-GIA stapler with a vascular cartridge. The esophagus is then dissected, starting from about 3 cm above the azygous vein all the way to the gastroesophageal junction, joining the dissection performed laparoscopically. A formal thoracic lymph node dissection is not performed, and an average of 20 lymph nodes is usually obtained. This is based on the belief that the lymphadenectomy has prognostic but not therapeutic value. The stomach is pulled up, and the upper portion of the stomach is transected with the Endo-GIA stapler with green cartridges through a window opened along the lesser curvature between the second and third branches of the left gastric artery,

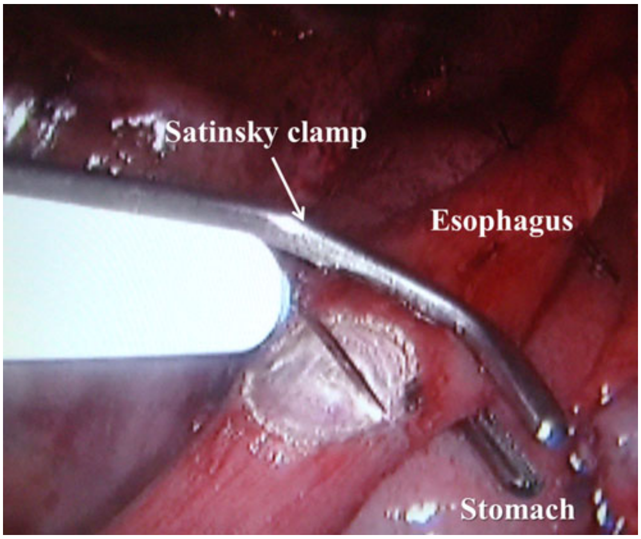



**Fig. 3** Transection of the esophagus

toward the angle of His. It is our preference to avoid tubularization of the stomach. The esophagus is then transected about 3 cm above the azygous vein. In order to avoid separation of them mucosa from the muscle layers, the esophagus is clamped with a Satinsky clamp before transection (Fig. 3).

### Step 10: Intra-thoracic Esophagogastric Anastomosis

The esophagus is placed over the anterior wall of the stomach and full-thickness stay sutures (3–0 silk) are placed to align the posterior wall of the esophagus and the anterior wall of the gastric fundus (Fig. 4). Stay sutures (3–0 silk) are also placed at the four corners of the esophageal opening to keep together the mucosa with the other layers of the esophageal wall, therefore avoiding sliding of the mucosa when the stapler is inserted. A gastrotomy is then made in the anterior wall of the stomach just distal to the esophageal transection line, and this opening is fixed to the posterior wall of the esophagus with interrupted 3–0 silk stitches (Fig. 5a, b). Then, a 45-mm Endo-GIA stapler with either a white or a blue cartridge (depending on the thickness of the esophagus and gastric wall) is inserted and advanced, the thinner branch into the stomach and the thicker portion into the esophagus (Fig. 6a). The stapler is fired, and a 4-cm-long anastomosis between the posterior wall of the esophagus and the anterior wall of the stomach is obtained. The staple line is then checked for bleeding (Fig. 6b). Endoscopic inspection of the anastomosis is not routinely performed. A nasogastric tube is passed under direct vision down the esophagus into the stomach so that the tip is above the diaphragm. The anterior aspect of the anastomosis is closed with an inner layer of running 3–0 absorbable braided suture (Fig. 7a), followed by an outer layer of interrupted 3–0 silk sutures (Fig. 7b). Nothing else is done to buttress the anastomosis.

The stomach is not fixed to the diaphragm. A final inspection is then performed. A tip for recognizing the proper position of the gastric conduit is that the lesser curvature has to be oriented toward the thoracotomy.

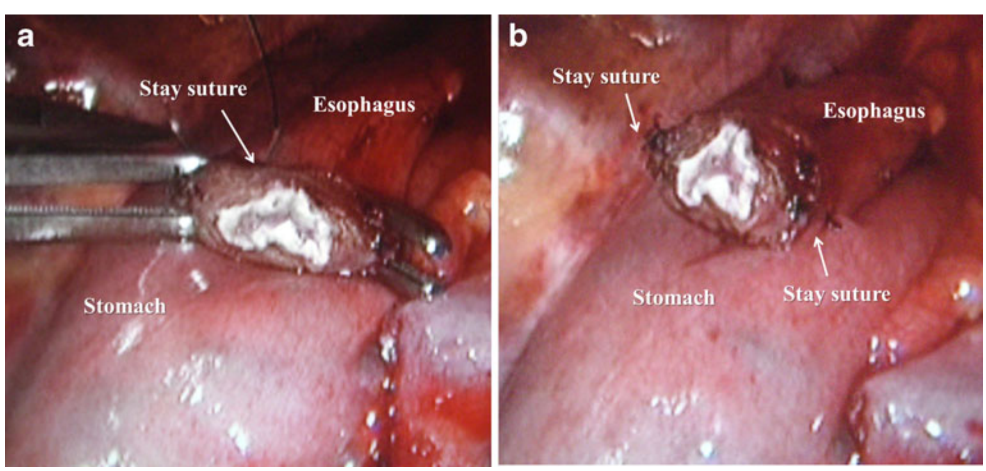
### Step 11: Drainage and Closure

Two chest tubes (one straight and one curve) are routinely placed for drainage, and the chest wall is closed in layers. After watching the lung expand under direct vision, we approximate the ribs with Maxon #1 interrupted stitches. We then approximate the muscle layer with 2–0 Dexon and the skin edges with staples.

### Postoperative Course

Patients are usually extubated in the operating room at the end of the esophagectomy. They spend the first night in the Intensive Care Unit for monitoring, and then they are

**Fig. 4** Stay sutures to align esophagus and stomach



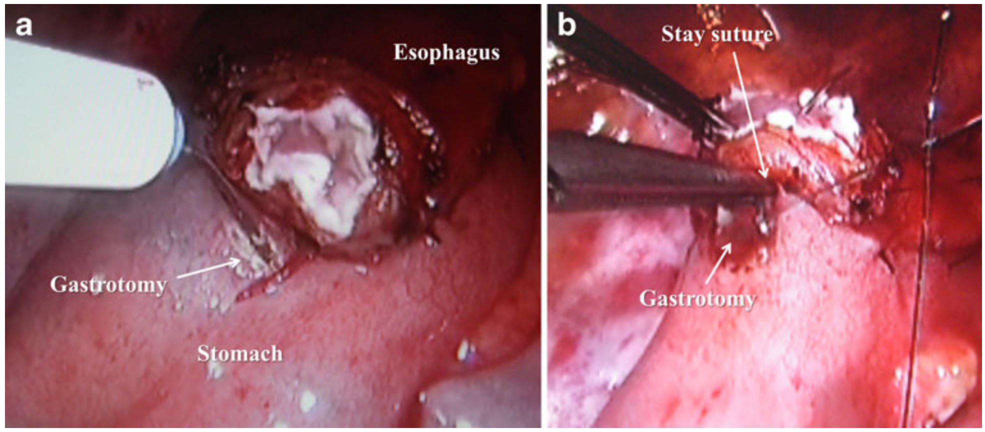



**Fig. 5** **a** Gastrotomy; **b** stay suture between gastrotomy and the esophagus

transferred to the floor the day after, if hemodynamically stable. The epidural catheter is kept in place until the fifth postoperative day in order to minimize postoperative pain and encourage patient's mobilization.

No routine barium swallow is obtained postoperatively. When an anastomotic leak is suspected, a contrast study and a CT scan are obtained. In the presence of a small and contained leak and in the absence of septic complications, the patient is kept fasting, antibiotic therapy is started, and enteral nutrition is given through the feeding jejunostomy. The contrast study is then repeated 7 days later or if new symptoms develop. In presence of septic complications, the patient is resuscitated, antibiotics are started, and then three different options are available according to the severity of the infection: (1) percutaneous drainage and nasogastric tube; (2) percutaneous drainage and esophageal endoscopic stenting; and 3) surgical re-exploration after performing an upper endoscopy that aims to evaluate the viability of the gastric conduit. When the anastomotic leak is uncontained, the patient is taken to the operating room where an upper endoscopy is performed. If the patient is stable and the gastric conduit is viable, the anastomosis is repaired with or without a muscle flap. If part of the stomach is not viable it is resected, the remaining stomach is brought back into the abdomen, and a cervical esophagostomy is performed.

Postoperative pain is managed initially by the epidural catheter and then by pain medications either taken by mouth or injected through the feeding jejunostomy.

In absence of anastomotic complications, patients start on clear liquids on postoperative day 4, after the nasogastric tube is removed. The diet is then advanced to soft food if no adverse events occur. The jejunal feeding tube is not used if no anastomotic leak is present and the patient can be fed. It is usually removed 4 weeks later during the first postoperative clinic visit.

The chest tubes are usually removed on postoperative day 7 and 8 if there is no evidence of anastomotic leak or chylothorax.

In the last 100 consecutive esophagectomies for distal esophageal adenocarcinoma, the morbidity rate was 30 %, including two anastomotic leaks. The leaks were successfully treated conservatively with a combination of a perianastomotic drain placed by interventional radiology and nasogastric tube drainage (Fig. 8). Four patients developed an anastomotic stricture: Three were treated by passage of an esophageal bougie (56 F), while

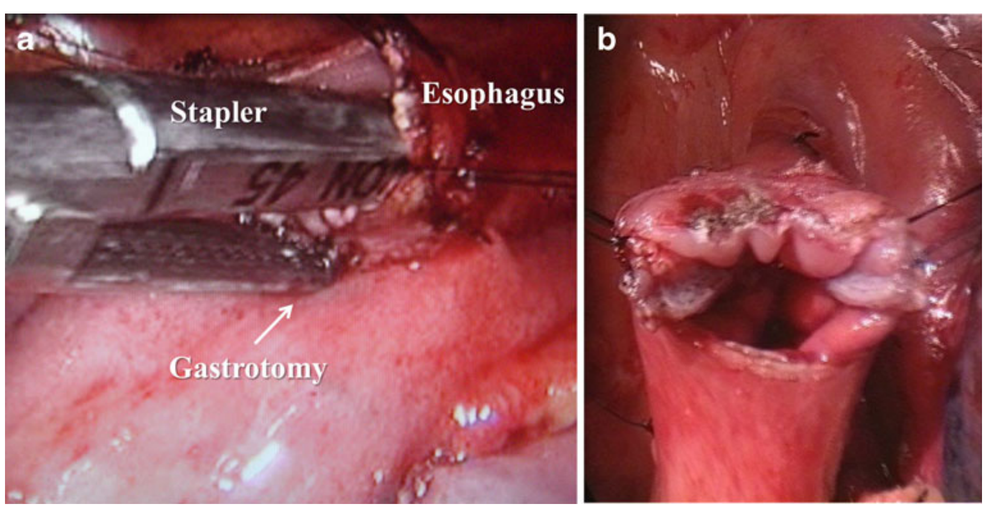



**Fig. 6** **a** Insertion of the stapler; **b** view of the anastomosis

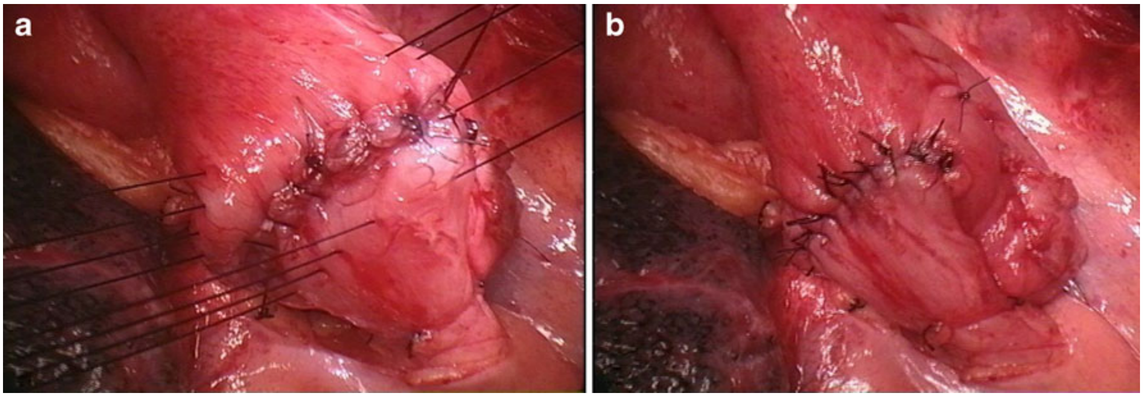



**Fig. 7** Suture of the anterior wall of the anastomosis. **a** Inner layer; **b** outer layer

one patient underwent a pneumatic dilation with a 20 mm balloon. Two patients died, one because of a myocardial infarction and one because of pneumonia, for an in-hospital mortality rate of 2 %.

## Discussion

Esophageal resection is the primary treatment modality for patients with resectable esophageal cancer. It was suggested that trans-hiatal esophagectomy could reduce the surgical trauma by avoiding the chest incision and that it was associated with decreased respiratory impairment and reduced postoperative discomfort. In addition, significantly lower leak-associated mortality rates were reported after a trans-hiatal esophagectomy as compared with the trans-thoracic approach.[7–9] However, recent studies have reported similar leak associated mortality rates between cervical and intra-thoracic anastomosis in high-volume centers.[10]

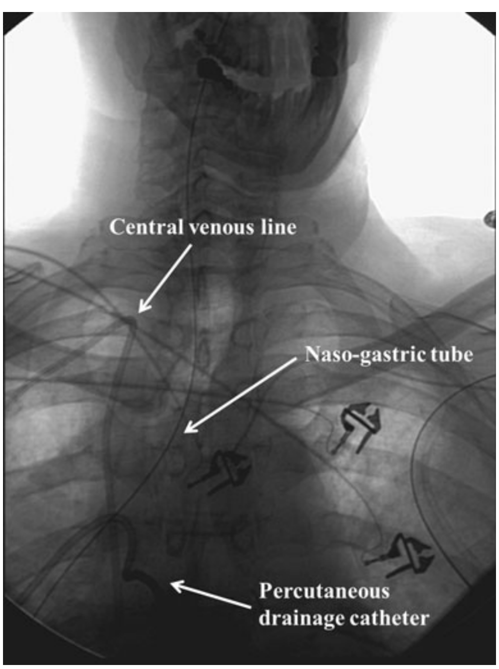



**Fig. 8** Anastomotic leak treated by percutaneous drainage and naso-gastric tube suction

The morbidity rate after an esophagectomy is around 30 %, and it is mostly due to cardiac (arrhythmias), respiratory (atelectasis, pleural effusion), and septic complications (anastomotic leak, pneumonia). Respiratory complication rates are higher after a transthoracic resection,[2] even though the routine use of thoracic epidural anesthesia has significantly decreased this problem.[11] In our experience, the non-tubularized stomach (with pyloroplasty) was not associated to gastric stasis. The overall mortality rate after esophagectomy for cancer is around 10 %,[2] but in specialized and "high volume" centers it is less than 5 %. These results are due to the presence of an experienced team composed of surgeons, anesthesiologists, intensivists, cardiologists, radiologists, and nurses.[12]

During the last two decades, minimally invasive approaches have been developed in the attempt to reduce postoperative morbidity, in particular, cardiopulmonary complications. Hybrid trans-thoracic esophagectomy, combining a laparoscopic approach and a right thoracotomy, has been proposed. For instance, Briez et al. looked at the outcome in 140 patients undergoing hybrid trans-thoracic esophagectomy compared with 140 patients undergoing an open Ivor Lewis esophagectomy in a case-matched study.[13] They found significantly lower rates of overall morbidity (35.7 % versus 59.3 %, $p<0.001$), particularly pulmonary complications (15.7 % versus 42.9 %, $p<0.001$), and in-hospital mortality (1.4 % versus 7.1 %, $p=0.018$) among the patients undergoing hybrid esophagectomy as compared with the patients treated with an open esophagectomy. By multivariate analysis, the hybrid approach and epidural analgesia were independent protective factors against pulmonary complications.

Our preferred approach to esophagectomy is hybrid and combines laparoscopy followed by a right thoracotomy. The laparoscopic approach follows the same principles of the open approach but with a significantly reduced surgical trauma and no risk of developing a postoperative incisional hernia. The potential advantages of the open approach to the chest include a wide exposure, reduced risk of laryngeal nerve injuries, and an easier performance of the esophagogastric anastomosis. We do not perform a formal mediastinal lymph node dissection, based on the belief that this has more a prognostic than therapeutic value. Overall, however, the average number of retrieved lymph nodes is about 20.

The esophagogastric anastomosis is associated with high morbidity rates. Potential causes for anastomotic leaks are tenuous blood supply and tension on the anastomosis. Leak rates vary. Reports from high-volume centers with the intra-thoracic anastomosis demonstrate a leak range of 5 % to 10 %, with others showing that it can be as high as 26 %, with a risk as high as 50 % to develop anastomotic stricture.[14,15] Even though the acute clinical sequelae of a cervical leak are lower than those associated with an intra-thoracic anastomosis, the incidence of a stricture is higher.[16] Several randomized clinical trials did not find differences between hand-sewn and stapled anastomosis in terms of both leak and stricture rates.[17]

In 1998, Collard et al. described a novel side-to-side technique for cervical esophagogastrostomy in an attempt to reduce these anastomotic complications.[6] They used a linear stapler to create a functional end-to-end anastomosis with a larger diameter than the classic end-to-side esophagogastric anastomosis. This anastomosis was performed at the tip of the mobilized stomach rather than on the anterior gastric wall. In 2000, Orringer et al. compared 114 consecutive patients undergoing trans-hiatal esophagectomy with a mechanical side-to-side cervical esophagogastric anastomosis to 114 patients with a hand-sewn anastomosis.[18] They found a 2.7 % rate of clinically significant anastomotic leaks with the mechanical anastomosis as compared with the hand-sewn anastomosis (14 %, $p$=0.0019). During follow-up, 35 % of patients with a stapled anastomosis required one or more anastomotic dilatations within 3 months after the esophagectomy compared with 48 % of patients who had a hand-sewn anastomosis. This finding was confirmed in subsequent studies.[19,20] Similar results were obtained by others.[21]

However, even though the anastomotic leak rate was reduced, it was still high, and the percentage of stricture did not change significantly. These findings suggested that poor blood supply of the proximal stomach and tension of the anastomosis in the neck played a role in the occurrence of these complications.

Based on the fact that today most esophageal cancers are located in the distal esophagus, a trans-thoracic esophagectomy with a side-to-side stapled anastomosis has been increasingly used, with a significant decrease in the anastomotic complications. For instance, in 2007, Blackmon et al. retrospectively reviewed the outcome of 214 patients undergoing trans-thoracic esophagectomy: A stapled side-to-side anastomosis was performed in 44 patients, while a circular stapled anastomosis or a hand-sewn anastomosis was performed in 147 and 23 patients, respectively.[22] They found comparable anastomotic leak rates between hand-sewn, circular stapled, and side-to-side anastomosis (4.3 % versus 4.3 % versus 8.7 %, respectively; $p$=0.78), while a stricture was more frequently observed after a hand-sewn anastomosis (34.8 % versus 8.7 % versus 8.7 %, respectively; $p$=0.04). In a landmark paper, Luketich and colleagues described the outcome of more than 1,000 minimally invasive esophagectomies.[3] Among the 530 patients who underwent a minimally invasive Ivor-Lewis esophagectomy, a median number of 23.5 lymph nodes were retrieved. The authors reported a rate of anastomotic leak requiring surgery of 4 %, gastric tube necrosis of 2 %, and a 30-day mortality rate of 0.9 %. Our results compare favorably to those of this study.

In 2008, Raz et al. analyzed 33 consecutive patients with distal esophageal cancer or high-grade dysplasia treated with a trans-thoracic esophagectomy and a side-to-side stapled intra-thoracic anastomosis.[23] Overall morbidity rate was 27 %, with no anastomotic leaks or strictures. These findings are probably the result of a better blood supply and decreased tension due to the intra-thoracic rather than cervical anastomosis. Some authors have achieved similar results performing this anastomosis thoracoscopically.[24–26] However, there are no definitive data comparing the results of this anastomosis performed thoracoscopically or through a thoracotomy.

In conclusion, we feel that a hybrid approach with a side-to-side stapled anastomosis is associated with low pulmonary and anastomotic complications. Further studies are needed to evaluate the role of the thoracoscopic approach to the esophagectomy.

**Conflict of Interest** The authors have no conflicts of interest to declare.

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