Robotic Transhiatal Esophagectomy

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Abstract

The first published report of robotic esophagectomy was in 2002, the transhiatal approach. Patients with severe dysplasia and early stage esophageal cancer, end-stage achalasia, severe refractory reflux disease, and other end-stage esophageal diseases that have resulted in a severely diseased nonfunctioning esophagus appear amenable to this approach. The anesthetic and surgical management are described along with the lessons learned from the surgical team. Each step of the procedure is illustrated and the outcomes of the procedure described. The outcomes from this procedure demonstrate an efficient technique that has great potential.

Keywords

Robot-assisted • Minimally invasive surgery • Esophagectomy • End stage achalasia • End stage gastroesophageal reflux disease • Computer-assisted surgery • Esophageal neoplasms • Thoracoscopy • Laparoscopy

11.1 Background and Specific Indications

Esophagectomy is among the most complex and traumatic operations in gastrointestinal surgery, and has been associated with major postoperative morbidity and mortality [1]. The indications for esophagectomy range from benign conditions, such as megaesophagus and severe strictures to premalignant and malignant lesions.

Currently, the major indication for this operation is carcinoma of the esophagus, with incidence of 5 per 100,000 people in the United States. In 2009, The National Cancer Institute estimated that yearly, 13,200 Americans would be diagnosed with esophageal cancer and 12,500 would die from it [2]. Adenocarcinoma accounts for about 50% of all new cases of esophageal cancer in the US [3, 4], it is usually located in the lower esophagus or at the gastroesophageal junction. The most important risk factor associated with this disease is gastroesophageal reflux disease (GERD). Approximately 15% of patients with GERD develop intestinal metaplasia and 1% of these develop esophageal cancer. Moreover, it has been shown that Barrett's with high-grade dysplasia (HGD) harbors unsuspected adenocarcinoma in 60% of the cases [5].

The first successful esophagectomy with gastric pull-up was performed through the left chest in 1933 [6]. Since then the technique evolved from open to laparoscopic to robotic procedures. Minimally invasive surgical techniques were introduced in an effort to lessen the invasiveness of the open approaches [7, 8]. In 1990s De Paula [9] and Swanstrom [10] reported the first trans-hiatal laparoscopic esophagectomy (THE), reporting excellent visualization up to the level of the inferior pulmonary vein, with minimal blood loss, shorter operative times and hospital stay [7]. However, the

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shortcoming of laparoscopy, such as lack of stereoscopic view, unstable camera platform, straight laparoscopic instruments with limited degrees of freedom, and poor ergonomics, made it difficult to perform an adequate middle and upper esophageal dissection and mediastinal nodal harvesting [11]. Some surgeons have adopted hybrid laparoscopic and thoracoscopic approaches in order to overcome the limitations of laparoscopy, and consequently purely laparoscopic esophagectomy has failed to become widely adopted as the treatment of choice for esophageal cancer. For those reasons many esophageal surgeons still debating over the most beneficial approach and no surgical technique has prevailed over the others [12].

In 2003, we described the very first robotic assisted transhiatal esophagectomy [13], followed by several reports that confirmed the feasibility and safety of the technique. The robotic system allows the surgeon to work in the narrow space of the mediastinum, overcoming spatial limitations experienced during standard laparoscopy. It offers stereoscopic view and utilizes instruments that are 7.5 cm longer than standard laparoscopic instruments; therefore, allowing more proximal mobilization, reaching sometimes beyond the level of the carina. Furthermore, the dissection in the vicinity of the pulmonary veins, aorta, parietal pleura and pericardium can be accomplished safely due to the articulated instruments tip, the three dimensional visualization and the magnification of the operative field. It has also been shown that this approach maintains the oncological principles without the need of concomitant thoracoscopy when compared with standard laparoscopic trans-hiatal esophagectomy (THE) [14–16].

11.2 Operative Set-Up

A dedicated large operating room for the robotic equipment is highly recommended, where enough room can be provided for the anesthesia equipment, the da Vinci robotic system, the standard laparoscopic towers and the endoscopic tower.

The anesthesia machine and monitors must be positioned away from the patient due to the position of the da Vinci® surgical system over the patient's head.

11.3 Anesthetic Management

The anesthesiologist must understand the special implications on the management of patients undergoing robotically-assisted THE. Some important concern related to the procedure are the patient positioning, duration of the procedure, development of hypothermia, and the well-known hemodynamic and respiratory effects related to the pneumoperitoneum.

The induction of general anesthesia takes place with the patient in supine position, where a single-lumen endotracheal tube is utilized. The use of invasive hemodynamic monitoring, pneumatic compression stockings on both legs and preoperative antibiotics are recommended routinely. Due to the extreme positioning, the possibility of patients sliding off the operating room table increases, therefore restraints must be used. Also a foam egg crate mattress should be placed in between the patient pressure points and the operating room table to avoid tissue and nerve impingement. Finally, careful attention should also be given to the robotic arms location and motion to prevent them from contacting the patient and cause pressure or crush injuries.

Another important consideration is the access of the patient's airway by the anesthesiologist when the robot is docked. Due to the substantial size of the robot and it's cephalad position over the patient during the procedure, significant draping on both the robot and patient is required, additionally the patient's airway has to be located at an increased distance from the anesthesiologist and the anesthesia machine, therefore making access the patient head rather difficult.

11.4 Stepwise Conduct of the Operation

The aims of this operation are to resect the esophagus, perform lymphadenectomy when indicated, create a gastric conduit and perform a cervical anastomosis. The surgical steps are:

1. Perioperative EGD
2. Positioning
3. Port placements
4. Exposure of the Hiatus and mobilization of the Stomach
5. Ligation of the left gastric artery
6. Trans-mediastinal esophageal dissection
7. Open cervical dissection
8. Creation of the gastric tube and resection of the specimen
9. Cervical anastomosis

11.4.1 Upper Flexible Endoscopy

After endotracheal intubation, Esophagogastroduodenoscopy is performed to assess endoluminal anatomy and reconfirm the nature and location of the esophageal lesion.

11.4.2 Positioning

The patient is placed in low dorsal lithotomy position, and the abdomen, chest, and neck are prepared and draped in the usual sterile fashion. It is important to acknowledge that repositioning the patient on the operating room table after the robotic arms have been docked is extremely cumbersome, therefore the patient must be optimally positioned before the robotic portion of the operation begins. To allow proper placement of the robotic arms and optimal access to the upper abdomen and hiatus the patient should be positioned in steep reverse Trendelenburg, where the gravitational effect assists on the displacement of the small bowel and omentum from the surgical field (Fig. 11.1).

11.4.3 Port Placement

The peritoneal cavity access is obtained with the insertion of a 12-mm trocar under direct visualization, using an ENDOPATH Optiview® trocar (Ethicon Endosurgery, Cincinnati, OH) with a 0° laparoscope, in the left side of the

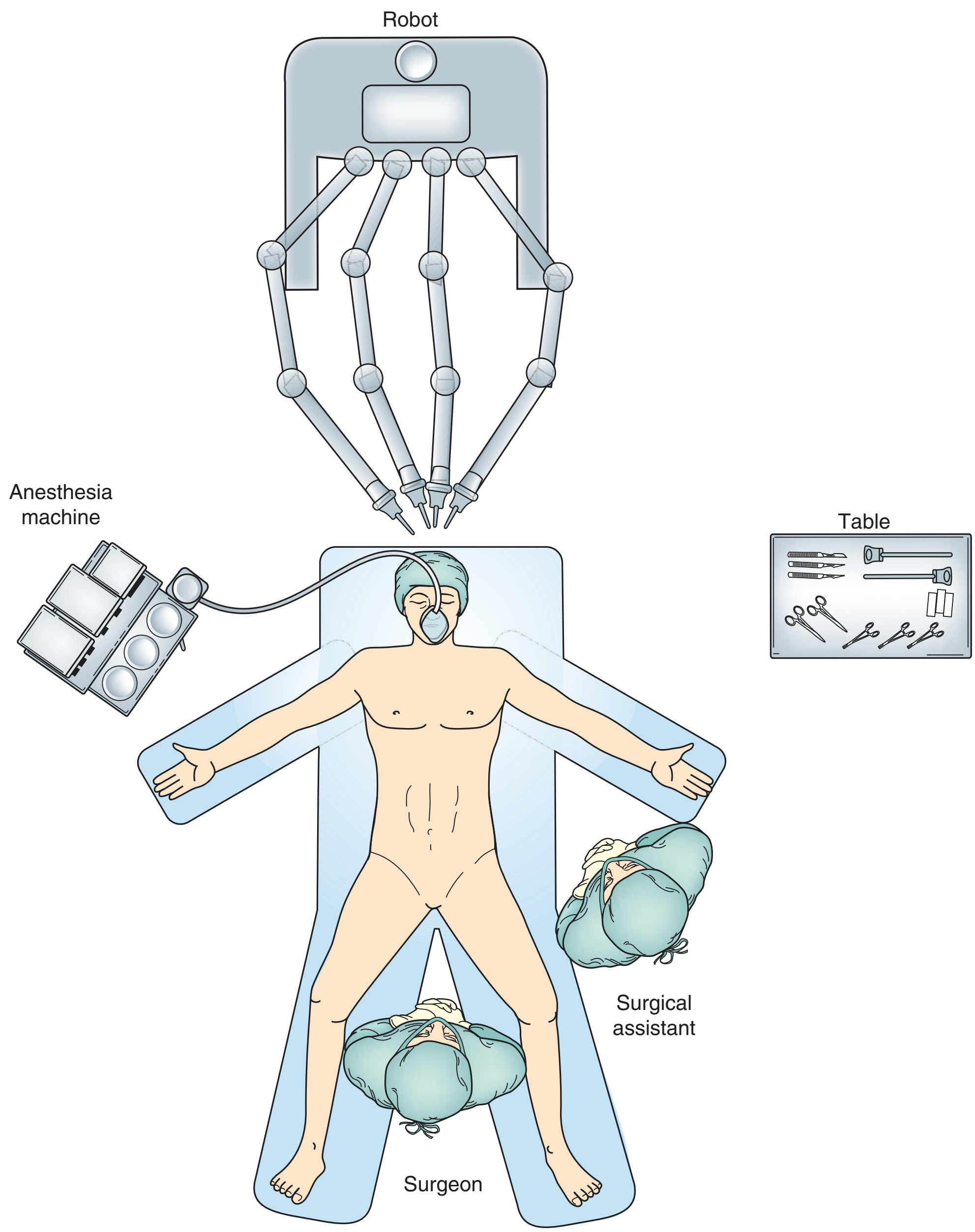

Fig. 11.1 Patient position for the robotic transhiatal esophagectomy. The patient is placed in low dorsal lithotomy position, and the abdomen, chest, and neck are prepared and draped in the usual sterile fashion. It is important to acknowledge that repositioning the patient on the operating room table after the robotic arms have been docked is extremely cumbersome; therefore, the patient must be optimally positioned before the robotic portion of the operation begins. The patient is then placed in steep reverse Trendelenburg position. The surgeon stands in between the patient's legs and the first assistant on the patient's left side

mid-abdomen, two fingerbreadths lateral to the umbilical scar and one palm width inferior to left subcostal margin, to allow optimal visualization of the gastroesophageal junction. This 12-mm trocar will be later utilized by the robotic system's camera. After successful access to the peritoneal cavity, pneumoperitoneum is accomplished at 15 mmHg using CO_2. The peritoneal cavity is then surveyed to rule out carcinomatosis. Under direct visualization two 8-mm ports are individually placed at the left and right mid-subcostal margin. Through a subxyphoid 5 mm incision, a Nathanson retractor is introduced to retract the left lobe of the liver anteriorly. Finally a 10-mm assistant port is placed at the patient's left midabdomen at the level of the anterior axillary line for the use of suction and passage of sutures during the operation. The patient is then placed in steep reverse Trendelenburg position. The surgeon stands in between the patient's legs and the first assistant on the patient's left side (Fig. 11.2).

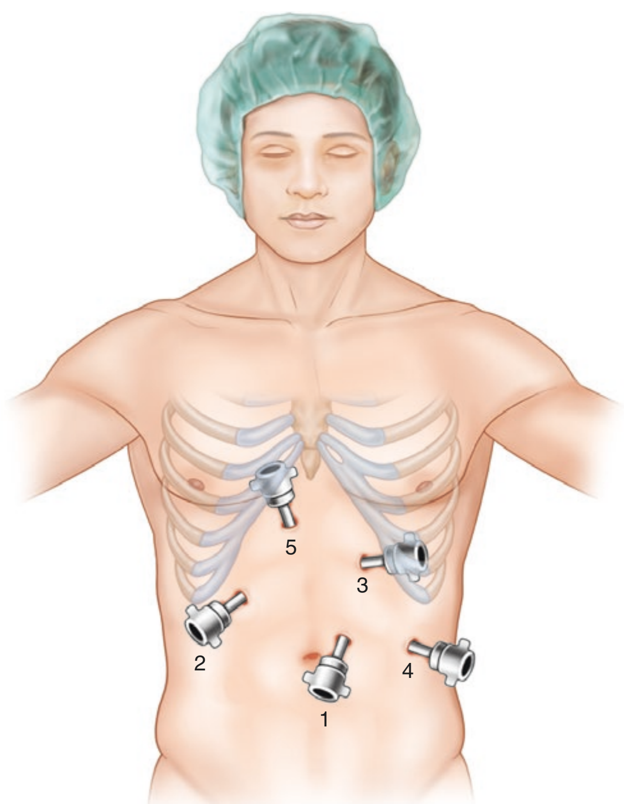

Fig. 11.2 Port placement for the robotic transhiatal esophagectomy. (1) 12-mm optical trocar, in the left side of the mid-abdomen, two fingerbreadths lateral to the umbilical scar and one palm width inferior to left subcostal margin. (2 and 3) 8-mm ports placed at the left and right mid-subcostal margin. (4) 10-mm assistant port placed at the patient's left midabdomen at the level of the anterior axillary line for the use of suction and passage of sutures. (5) 5 mm subxyphoid incision for placement of a Nathanson® retractor

11.4.4 Exposure of the Hiatus and Mobilization of the Stomach

The operation starts with standard laparoscopic instrumentation. The left crus is identified and freed from the phrenoesophageal membrane using ultrasonic shears, followed by blunt dissection to separate the former from the esophagus. The stomach's greater curvature is then mobilized by transecting the gastrocolic ligament and short gastric vessels, starting at the level of the distal gastric body and extending cephalad to the previously dissected left crus. The gastrohepatic ligament is then opened, and the hepatic branch of the Vagus nerve is divided, allowing identification of the right crus, which is freed from the phrenoesophageal attachments using electrocautery or ultrasonic shears. A retroesophageal window is created to permit passage of a Penrose drain, which is used to encircle the gastroesophageal junction and allow further manipulation of the esophagus during the remaining of the operation (Fig. 11.3).

11.4.5 Ligation of the Left Gastric Artery

Additional mobilization of the stomach is attained by transecting the left gastric artery and vein with linear EndoGIA stapler device (Endo-GIA Ethicon Endosurgery, Cincinnati, OH) using vascular load. The dissection of the gastrocolic ligament is extended along the greater curvature toward the antrum, where the pylorus is adequately dissected and the posterior gastric attachments within the lesser space are free. During this part of the operation, particular attention should be paid to avoid iatrogenic injuries to the right gastroepiploic artery, since it will be responsible for the vascular supply to the gastric tube. Kocher maneuver and pyloroplasty are not necessary in cases where adequate mobilization of the stomach is attained the Vagus nerves are preserved.

11.4.6 Trans-Mediastinal Esophageal Dissection

After the hiatus has been exposed and the stomach mobilized laparoscopic, the da Vinci Surgical System is then positioned cephalad to the patient and docked to the optic and to working trocars. A Cadiere® forceps (Intuitive Surgical, Inc. Sunnyvale, California) is placed at the surgeon's left hand, and an articulated hook cautery at the surgeon's right hand. During the robotic portion of this procedure, the assistant surgeon remains at the patients' left side. Trans-hiatal dissection of the esophagus is carried cephalad through the

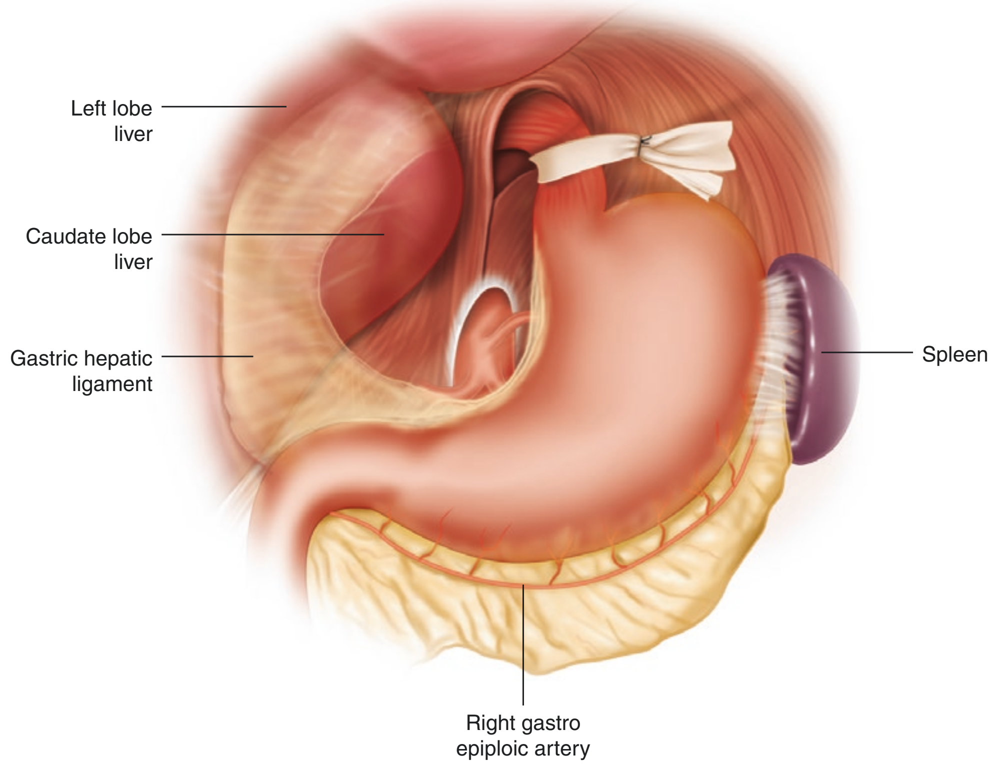

Fig. 11.3 Exposed esophageal hiatus. A Penrose drain is placed around the distal esophagus and used for retraction of the stomach by the assistant or bedside surgeon. The left gastric artery is dissected with the adjacent lymph nodes and divided with a vascular stapler

mediastinum along the circumferential borders of the esophagus. During this step the precise moments of the robotic instruments are fundamental to accomplish accurate circumferential dissection of the esophagus and proper lymph node harvesting, and at the same time to avoid injuries to the pleura and the pericardium and reach the thoracic inlet. Once the upper mediastinum is reached the robotic dissection is finalized, and the da Vinci Surgical System is undocked (Figs. 11.4 and 11.5).

11.4.7 Cervical Dissection

After the trans-hiatal dissection has been successfully completed up to the level of the upper mediastinum, a cervical incision along the anterior border of the left sternocleidomastoid muscle is performed, and cervical esophageal dissection is undertaken to free the proximal esophagus. During this step, esophageal intubation with an NG tube or flexible gastroscope greatly facilitates the circumferential mobilization of the esophagus. A Penrose drain is then passed around the cervical esophagus, and finger dissection is taken down to the superior or mid mediastinum to connect the cervical and transhiatal dissection. It is important to mention that care must be taken to preserve and avoid injuries the recurrent laryngeal nerves.

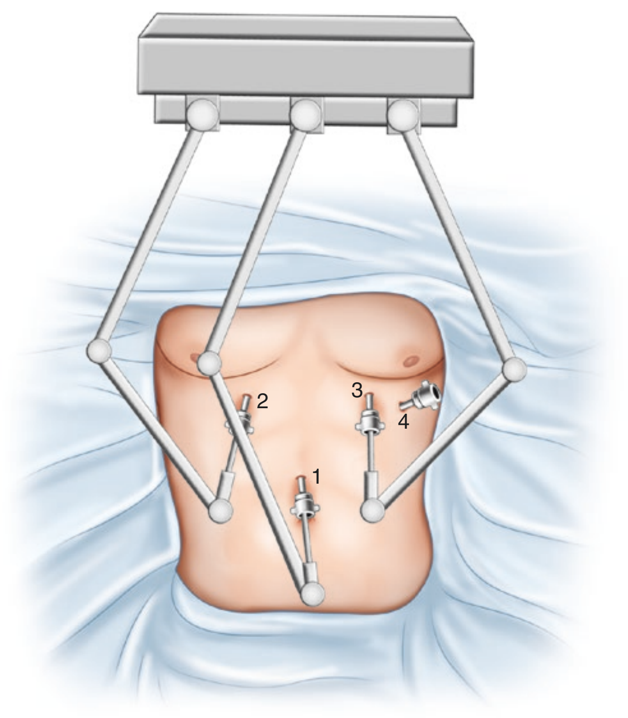

Fig. 11.4 Transhiatal dissection of the thoracic esophagus. After the hiatus has been exposed and the stomach mobilized laparoscopically, the da Vinci Surgical System is then positioned cephalad to the patient and docked to the optic and to the working trocars. (1) Robotic optical trocar; (2) Articulated Hook Cautery; (3) Cadiere® forceps; (4) Assistant's surgeon port

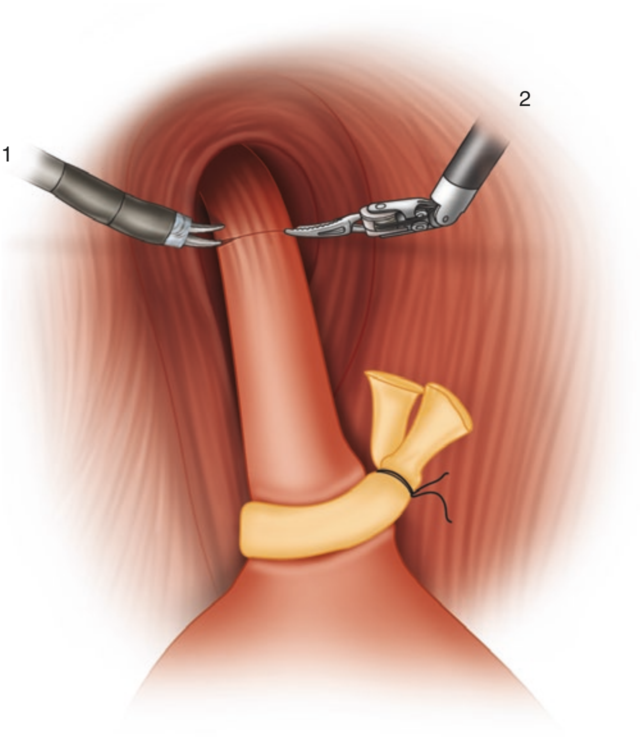

Fig. 11.5 Deep transhiatal dissection. The Assistant is retracting the stomach and esophagus using the Penrose drain. (1) Cadiere® forceps; (2) Articulating hook cautery or other energy device of choice

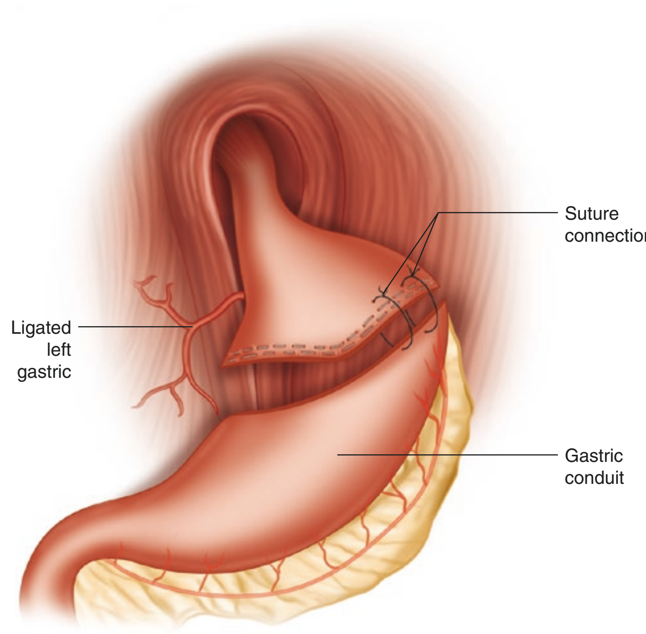

Fig. 11.6 Gastric tube sutured to the specimen. After the trans-hiatal dissection has been successfully completed up to the level of the upper mediastinum, the cervical esophageal dissection is undertaken to free the proximal esophagus through a left neck incision. The robot is undocked and laparoscopy is resumed, and the gastric conduit is created along the greater curvature of the stomach with several sequential staple loads. From the cervical incision, the specimen is removed and the gastric tube is pulled into the mediastinum to perform the anastomosis

11.4.8 Gastric Tube Formation and Resection of the Specimen

After the cervical mobilization of the esophagus is completed, the laparoscopy is resumed and the gastric conduit is created along the greater curvature of the stomach with several sequential staple loads, using a 3.5 mm EndoGIA stapler device (Endo-GIA Ethicon Endosurgery, Cincinnati, OH). From the cervical incision, the specimen is removed and the gastric tube is pulled through the mediastinum to perform the anastomosis (Fig. 11.6).

11.4.9 Cervical Anastomosis

Two different techniques can be used to complete the esophagogastric anastomosis. The classic two-layer hand-sewn anastomosis or the stapled technique, where a 3.5-mm GIA stapler device is used for the posterior wall, and a TA 55 stapler device is used for closure of the anterior wall. Finally a single 7-mm drain is placed at the mediastinal dissection bed lateral and posterior to the anastomosis and laparoscopic feeding jejunostomy are routinely performed.

11.5 Tips and Pitfalls

11.5.1 Tips

- Patients with BMI greater than 30 m^2/kg should be placed on liquid diet for 2 weeks before surgery to reduce the size of the liver and improve working space.
- The bedside cart should be positioned over the head of the patient, and the anesthesiologist with the anesthesia equipment positioned on the right side of the patient.
- The assistant should remain standing at the patients left side during the entire operation
- Steep reverse Trendelenburg position for surgery is preferred to optimize visualization of the hiatus and mediastinum.
- A specialized energy dissecting device, such as the harmonic scalpel or EndoWrist® One Vessel Sealer are essential to minimize blood loss and expedite the operation, especially during the gastric mobilization
- Left gastric artery should be ligated, as proximal as possible to its take off from the aorta to ensure optimal lymphadenectomy.

- During the mediastinal dissection, the robotic zero degree laparoscope is preferred
- The gastric tube should not be wider the normal esophageal caliber
- Pyloroplasty is not recommended on a routine basis
- The placement of feeding jejunostomy should be based on individual institution's protocol. This step is not considered mandatory for us.

11.5.2 Pitfalls

- Avoid dissecting to close to stomach to minimize injury to the gastroepiploic arteries and veins and therefore devitalize the gastric tube.
- Use stapler loads with greater heights in the distal stomach, such as green load (4.1 mm) or gold load (3.8 mm), and moderate height, blue load (3.5 mm), in the proximal stomach to avoid leaks.
- Avoid dissection in close proximity to the aorta in the mediastinum to avoid vascular iatrogenic injuries.
- The pleura openings should always be closed, to avoid residual pneumothoraxes.
- Thoracoscopy may be indicated during robotic THE when dealing with tumors located in mid esophagus.

11.6 Outcomes

Esophagectomy is one of the most complex operations of the gastrointestinal tract and it is associated with considerable postoperative morbidity and mortality. The unique characteristics of the da Vinci surgical system, including the longer and articulated instruments with 7 degrees of freedom, 3 dimensional visualization, stable camera platform, and improved ergonomics, provide fine and accurate movements in the narrow and confined mediastinum space, overcoming spatial and visual limitations experienced during standard thoracoscopic or laparoscopic techniques.

The robotic platform distinct features allows us to perform precise dissection during critical portions of the esophageal mobilization, especially near to the pulmonary veins, aorta, parietal pleura and pericardium, resulting in minimal cardiac and pulmonary complications, and significant decrease in blood loss when compared with laparoscopic THE [17]. Furthermore, the longer instruments on this stable platform make possible proximal esophageal mobilization beyond the level of the carina and adequate dissection of the mid and upper thoracic esophagus with enhanced lymph node harvesting accuracy. Hence, the da Vinci robotic system is capable to enhance dexterity by nearly 50% when compared with standard laparoscopy [18].

Additionally, the transhiatal route overcomes some of the disadvantages observed during thoracoscopic esophagectomy, such as the need of repositioning of the patient after the gastric mobilization, and the morbidities associated with prolonged one-lung ventilation [19]. Those advantages translated in zero 30-day mortality in one of our published series, which in our opinion was due to lessen cardiopulmonary complications and reduction of the perioperative stress.

Our experience also demonstrated that the operative time improves with the OR robotic team familiarity with the equipments and steps of the operation. In a series of cases performed in our institution, the initial mean operative time including the robotic setup time was 267 min, which decreased to a mean of 210 min in the last five cases [17].

In conclusion, robotically assisted Trans-Hiatal Esophagectomy is a safe and elegant operation with minimal blood loss, minimal respiratory complications, and minimal hospital mortality. The current robotic surgical system capabilities, particularly the three-dimensional visualization with magnification of the operative field and the articulated wristed instruments enhance the surgeon's ability to perform minimally invasive Trans-Hiatal Esophagectomy with fine and precise dissection in the very narrow mediastinum surgical field. Those enhancements is dexterity permit accurate esophageal dissection with optimal proximal and distal resection margins and a mean number of harvested lymph nodes comparable to thoracoscopic esophageal mobilizations, hence preserving the oncological surgical principles [20–22].

Finally, as an increasing number of surgical robotic systems populate the markets and more adequately trained esophageal surgeons become available, this type of operation will potentially supplant laparoscopic/thoracoscopic esophagectomy as the preferred surgical technique for the treatment of esophageal cancer. Certainly multi-institutional trials with long-term survival and oncological outcomes are necessary to add statistical power and validate those initial observations, and ultimately determine if robotic Trans-Hiatal Esophagectomy has better or at least comparable oncological outcomes to the historical results of open transhiatal or transthoracic techniques.

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