Robotic Assisted Minimally Invasive Esophagectomy

4

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Introduction

The esophagus is an organ that traverses three body cavities, hence the difficulty and possible morbidity associated with esophagectomy. Resecting the esophagus always requires accessing the peritoneal space, in addition to either a direct approach to the intrathoracic esophagus as in trans-thoracic esophagectomy (TTE) or an indirect dissection of this portion of the esophagus as in transhiatal esophagectomy (THE). Multiple approaches have arisen for this operation but no one technique has been universally accepted as the standard. In fact, with the advent of minimally invasive techniques in the latter part of the twentieth century, there have been even more techniques described for esophagectomy. The most-commonly performed procedures for esophagectomy include:

1. *Ivor Lewis TTE procedure*: which incorporates a laparotomy for gastric mobilization and tubularization followed by a right thoracotomy for completion of the esophageal resection and creation of an intrathoracic esophagogastric anastomosis.
2. *THE*: this also includes a laparotomy as described for TTE in addition to a cervicotomy. Mobilization of the intrathoracic esophagus is done through the hiatus and the neck, mostly in a blunt fashion. The anastomosis is made at the neck.
3. *McKeown esophagectomy (MKE)* or the "3-hole esophagectomy": attempts to provide a more radical approach to the procedure. A right thoracotomy is made for dissection of the entire thoracic esophagus and mediastinal lymph nodes. This is followed by a laparotomy as described above and a cervicotomy. The gastric conduit is delivered to the neck as in THE where a cervical esophagogastrostomy is performed. This approach allows the potential for a three-field lymphadenectomy of the entire lymph node basin of the esophagus, in the neck, thorax, and abdomen. It also allows removal of most of the esophagus, leaving only a short proximal segment to complete the anastomosis.
4. *Left thoracotomy or left thoracoabdominal approach*: this is less commonly used than the above-mentioned procedures. It allows resection of only the distal esophagus. The stomach is mobilized either through an incision in the left diaphragm or through an extension of the thoracotomy across the costal margin. After the specimen is resected, the esophagogastrostomy is performed in the left chest.

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Table 4.1 Published reports on robotic esophagectomy

Horgan et al. [1]	2003	1	Hybrid	RATS + laparoscopy	THE
Dapri et al. [2]	2006	2	Hybrid	RATS + Laparoscopy	MKE
Gutt et al. [3]	2006	1	Hybrid	Robotic laparoscopy	THE
Kernstine et al. [4]	2007	14	Mix of hybrid (6) and totally robotic (8)	RATS + laparotomy, laparoscopy, RALS	MKE
Kim et al. [5]	2010	21	Hybrid	RATS + Laparoscopy	MKE
Sutherland et al. [6]	2011	36	Hybrid	Robotic laparoscopy	THE
Puntambekar et al. [7]	2011	32	Hybrid	RATS + Laparoscopy	MKE
Weksler et al. [8]	2011	17	Hybrid	RATS + laparoscopy	ILE

RATS robotic assisted thoracoscopic surgery, *RALS* robotic assisted laparoscopic surgery, *THE* transhiatal esophagectomy, *MKE* McKeown esophagectomy, *ILE* Ivor Lewis esophagectomy

Each of the above procedures except perhaps for the left thoracotomy approach has been described in a "minimally invasive" fashion. Thoracoscopy and laparoscopy may replace thoracotomy and laparotomy, and in the hands of surgeons experienced in these techniques, may offer results that are equivalent to those achieved by their traditional open counterparts while still providing all the established benefits of minimally invasive surgery.

More recently, robotic technology has entered the arena of minimally invasive surgery. The benefits of dexterous dissection and manipulation in a confined space make it ideal for esophageal dissection in the mediastinum. In the abdomen, the ability of the surgeon to handle and manipulate the stomach with excellent visualization allows the safe creation of the conduit. Robotic surgery has allowed fine dissection of lymph nodes with better precision than traditional endoscopic techniques.

The first published report of a robotic-assisted esophagectomy is that by Horgan et al. [1] who described a transhiatal approach. Table 4.1 summarizes several published reports for robotic esophagectomy. Most reported series have described hybrid techniques with robotic-assisted thoracoscopy in addition to laparotomy or laparoscopy [2, 4, 5]. Others have described a robotic-assisted THE with cervical esophago-gastrostomy [3, 6]. Few reports have described totally robotic laparoscopic and thoracoscopic approach [4].

Debating the merits of each approach is beyond the scope of this chapter, which focuses on the applicability of robotics to esophagectomy. The preferred approach by both authors is that of the totally endoscopic robotic-assisted three-field approach, or a robotic MKE procedure. The technique described is that employed in the vast majority of our patients with esophageal cancer or end-stage benign esophageal disease.

Technique

1. Anesthesia (Fig. 4.1):

All patients are done under general anesthesia with endotracheal intubation. A 8 mm single lumen endotracheal tube is utilized through which a right-sided bronchial blocker is placed. This blocker is used for the thoracic portion of the procedure, after which it is simply removed and the remainder of the case is done with double lung ventilation. Esophagogastroscopy is performed by the surgeon to confirm location of the tumor and clear the esophagus and stomach of any retained contents. It is important to avoid excessive insufflation of the stomach, which would hinder the abdominal exposure and may affect mucosal integrity. A nasogastric tube is then passed and connected to low intermittent wall suction to keep the stomach decompressed. There is no need for placement of an epidural catheter as most patients can be easily managed

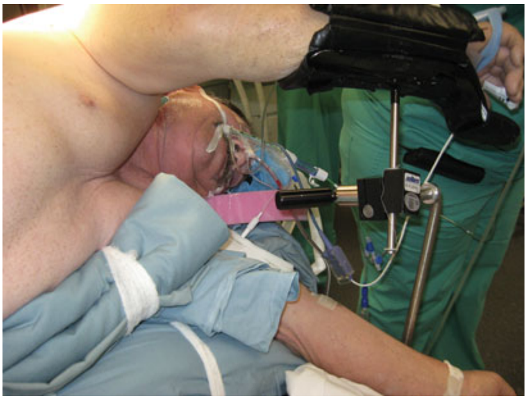

Fig. 4.1 Patient intubated with right bronchial blocker and nasogastric tube

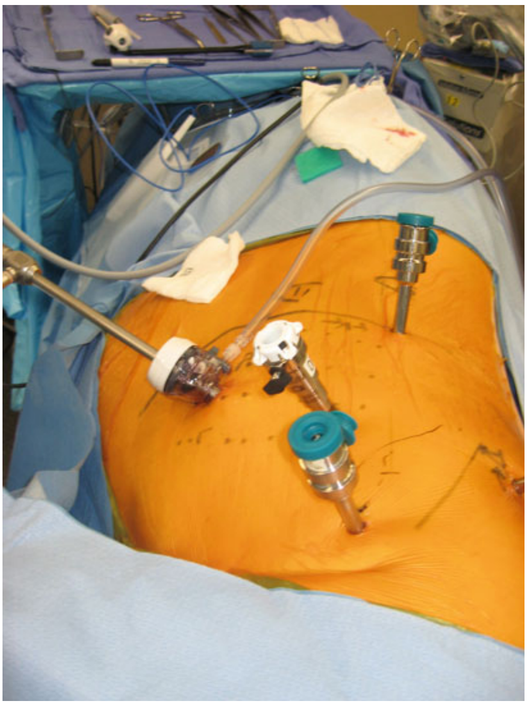

Fig. 4.2 Right thoacoscopic ports

with routine parenteral non-opioids. Early extubation is strongly recommended.

2. Right Robotic Assisted Thoracoscopic Surgery (RRATS):

The patient is then placed in the left lateral position with slight flexion and slight anterior tilting. A total of four ports are placed (Fig. 4.2).

The first is a 12 mm port at the seventh intercostal space (ICS), just anterior to the anterior axillary line. A 5 or 10 mm thoracoscope is placed and after ensuring intrathoracic placement of the port, carbon dioxide insufflation of the pleural space is administered to a maximum pressure of 10 mmHg. The standard thoracoscope is then utilized to assist in proper placement of the other three ports. A 8.5 mm port is placed for the robotic camera at the sixth ICS, mid-axillary line. It is important to avoid placing this port too far posteriorly. Ideally this port will be at the mid-point of the thoracic esophagus, about 2 in. below the azygous vein arch. Following this an 8 mm port is placed in the third ICS, mid-axillary line for the right arm and am 8 mm port is placed in the ninth intercostal space at the mid-axillary line also (this one can be slightly more posterior). Before placing the latter three ports, it is helpful to pass a needle percutaneously at the proposed sites and using the thoracoscope to confirm adequacy of location. The standard guideline of ensuring at least a hand's breadth between ports is important to avoid arm-collision.

For the thoracic dissection, the right arm (#1) will alternate using the robotic harmonic scalpel and the bipolar Maryland dissector while the left arm (#2) will use mainly the Caudier forceps for retraction. The assistant at the bedside will assist in providing suction and in passing the stapler. The lung is retracted anteriorly and the inferior pulmonary ligament is divided. The mediastinal pleura are then divided longitudinally both anterior and posterior to the esophagus up to the level of the azygous vein arch. The vein is then dissected free and divided using the endo-GIA stapler with a vascular load. Above the divided vein, it is important not to divide the pleura and to let it remain as a "tent" to overlie the eventual conduit. This may help wall off any cervical anastomotic leakage from the chest. The esophagus is then dissected circumferentially to include all the lymphatics and fatty tissue in-between the azygous vein, aorta and pericardium. The harmonic scalpel is helpful in dividing the aortic esophageal branches. This dissection must include a complete mediastinal nodal dissection.

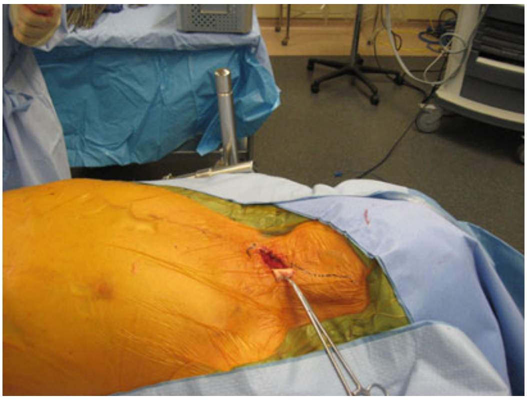

Fig. 4.3 Left cervicotomy and delivery of penrose drain

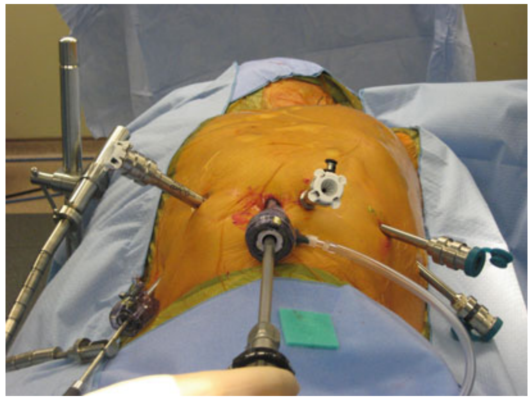

Fig. 4.4 Laparoscopic ports

Stations 7, 8 and 9 are left on the esophagus, while stations 2 and 4 are removed separately. After completing the dissection of the thoracic esophagus in its entirety, a penrose drain is placed to encircle it at both the thoracic inlet and outlet of the esophagus. These drains help in identifying the esophagus in the next stages of the operation. A flexible 19 F drain is then placed along the posterior esophageal gutter. This drain may be secured to the pleura with an absorbable suture to avoid its dislodgement with ventilation. The instruments are then removed and the robot is undocked.

3. Left Cervicotomy:

The patient is then positioned supine and a foam roll is placed under the left shoulder as well as under the left flank. A 4 cm incision is made along the inferior anterior border of the left sternocleidomastoid muscle. A careful circumferential dissection of the cervical esophagus is then made with care to avoid injuring the left recurrent laryngeal nerve. This dissection is carried down to the level of the Penrose drain, which was previously placed at the thoracic inlet. This drain is then partially delivered through the wound (Fig. 4.3).

4. Robotic Assisted Laparoscopic Surgery (RALS):

Following this, standard laparoscopic technique is used to establish a pneumoperitoneum. The authors prefer a Verres needle through the umbilicus. We then proceed to place a 12 mm port just above the umbilicus and again use a laparoscope to aid in correct placement of the robotic ports using a percutaneous needle before committing to the location of the port. Four other ports are placed. An 8.5 mm port for the camera at the left paramedian line, about 1 in. above the level of the umbilicus and below the lowest point of the greater curve of the stomach. Two 8 mm ports are placed in the left flank (#3) and the left midclavicular line (#2), at about the same horizontal level. A 13 mm port (#1) is placed at the right midclavicular line, about 7 cm below the costal margin. The preferred approach for liver retraction is used. The author places a flexible retractor through a 5 mm port in the right flank, which is secured to the table with a self-retainer.

Figure 4.4 shows the location of the abdominal ports. Before docking the robot, the patient is placed in a reverse Trendelenburg position to help keep the omentum and bowel away from the operating field.

The #3 arm is used mainly for retraction using atraumatic double fenestrated robotic clamp. The #2 arm or right hand will alternate the Harmonic scalpel and any other instruments such as the Bipolar Maryland dissector or a needle holder as the need arises. The #1 arm will mainly use the Caudier forceps to assist in dissection. Dissection is begun by dividing the gastrohepatic ligament and the peritoneum along the edges of the diaphragmatic hiatus. It is helpful to delay complete division of the phrenoesophageal ligament until the end of the gastric mobilization to avoid loss of pneumoperitoneal pressure and also avoid creating a pneumothorax. The short gastric vessels are then divided using the Harmonic scalpel. After visualizing and confirming the location of the right gastroepiploic arcade, the greater omentum is divided just lateral to the right gastroepiploic vessels along the entire length of the arcade. This requires division of several omental branches and it is important to always confirm that the main vessels are not injured during this procedure especially in cases with excessive omental fat. The attachments of the hepatic flexure are divided to allow exposure of the duodenum. Gentle "kocherization" of the duodenum is then done. This promotes a tension-free gastric outlet. The pylorus at this stage is identified and can be approached according to the surgeon's preference regarding gastric drainage. These preferences range from no gastric drainage procedure to pyloroplasty and certainly all the techniques are possible at this time. One of the authors (MD) prefers to inject Botox while the other author (AEA) performs a pyloromyotomy using bipolar cautery. At this time, the stomach is retracted anteriorly to expose retro-gastric adhesions, which are divided until the left gastric pedicle is identified. A complete dissection is done of the lymphatic and nodal tissue down to the trifurcation of the celiac artery. The artery is divided using the stapler at its most proximal point. A separate dissection of nodal tissue around the celiac trunk and hepatic artery is then undertaken.

At this point the stomach has been completely mobilized and the phrenoesophageal ligament is divided to deliver the penrose drain into the abdomen. The stomach is then ready for tailoring of the conduit. It is important at this point to pull back the nasogastric tube until its tip is in the thoracic esophagus. The assistant using the endo-GIA stapler divides the stomach. The conduit is fashioned as a long 5 cm tube extending from the incisura to the fundus. It is important to avoid the common mistake of stapling too close to the esophagogastric junction (EGJ) as this precludes an adequate lateral margin at the EGJ and may predispose to local recurrence. The initial angle for division of the stomach may be easier from the right subcostal 13 mm port. After completing the conduit, the distal end of the specimen and the proximal end of the conduit are connected with a silk stitch.

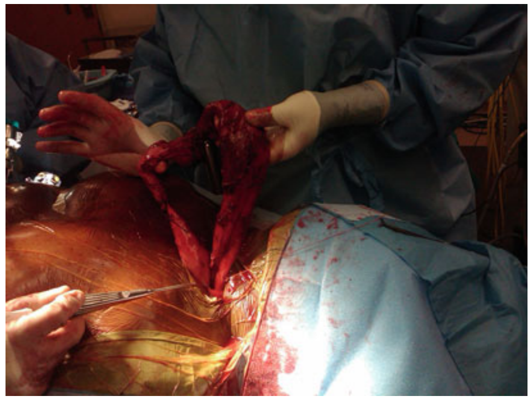

Fig. 4.5 Delivery of the specimen from the neck

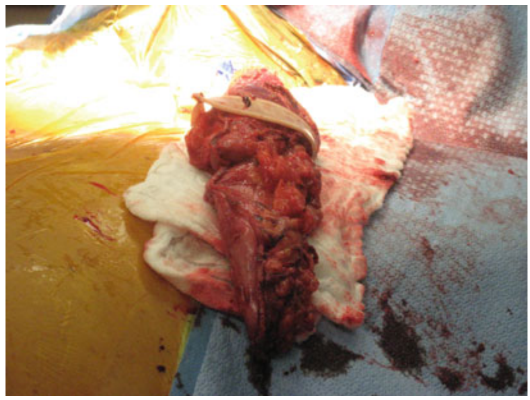

Fig. 4.6 Resected specimen

The assistant is then asked to deliver the esophagogastric specimen from the neck along with the attached conduit (Figs. 4.5 and 4.6).

During this procedure the surgeon remains at the console to ensure that the conduit does not twist and is free of tension. It is also important to close the diaphragmatic hiatus posterior to the conduit to avoid visceral herniation. This is done with interrupted silk sutures. The robot is then undocked and the surgeon returns to the table to

Fig. 4.7 Incisions upon completion

divide the proximal esophagus and complete the cervical anastomosis and perform a laparoscopic feeding jejunostomy. Figure 4.7 shows the abdominal incisions after closure.

Postoperative Management

Patients typically remain in the hospital until their thoracic and nasogastric drains are removed. This is usually achieved by postoperative day 4. They are discharged on jejunal tube feedings. A gastrografin swallow study is done as an outpatient procedure at postoperative day 10–14. When leakage is ruled out, the patient is allowed small amounts of food and drink. These rations are progressively increased over a period of 2 months while simultaneously decreasing the tube feeding.

Complications

The most common postoperative complications are the same as those encountered after open esophagectomy. They may be classified according to onset into early and late complications.

Early Complications

Anastomotic Leaks

These usually present after the fifth postoperative day. They range from mild to severe. Once identified, endoscopy is performed to evaluate the extent of the dehiscence and rule out gastric tip necrosis. The leak is treated according to the extent of the anastomotic dehiscence. In cases of disruption less than 50 % of the circumference of the anastomosis, conservative management with simple drainage, stent placement or passage of a percutaneous sump catheter through the defect into the gastric conduit. The cervical skin incision is always opened to allow drainage of any infection. Cases with complete disruption of the anastomosis are treated the same as those with gastric necrosis.

Gastric Tip Necrosis

This is a rare but lethal complication related to ischemia of the gastric conduit. This usually requires taking down of the anastomosis, resecting the ischemic portion and diversion of the esophagus with a cervical esophagostomy. The remaining healthy portion of the stomach is returned to the abdomen. The patient usually also requires decortications. It is necessary to identify these cases early to avoid the onset of sepsis.

Chylothorax

When identified, this complication should be treated surgically. After esophagecotmy it is almost always caused by complete division of the main thoracic duct and can seldom be treated conservatively with fasting and TPN. Delayed repair may predispose to malnutrition, infection and dehydration. Ligation of the thoracic duct can usually be performed by means of a reoperative right robotic-assisted approach. Injecting 100 cm^3 of cream or olive oil in the jejunostomy tube helps in identifying the source of chyle leak.

Vocal Cord Paralysis

Although this complication is usually temporary and secondary to retraction, it may impact on the patient's ability to clear pulmonary secretions. If necessary patients are referred for medialization of the cords.

Delayed Gastric Emptying

Precautions to avoid this devastating complication include performing a gastric drainage procedure such as pyloroplasty or pyloromyotomy, creating a narrow straight conduit to avoid pooling of contents, and avoiding a twist or kink of the conduit at the time of pulling up of the conduit through the hiatus. Medical management includes prokinetic agents such as metoclopramide or erythromycin. If the condition does not improve, endoscopic pyloric balloon dilation or pyloric Botox injection can be attempted.

Late Complications

Anastomotic Stricture

Typically patients present with late onset dysphagia. This may occur up to a year after surgery. Usually this can be managed endoscopically by endoscopic dilation. Refractory strictures may be amelriorated with temporary self-expanding covered stents, placed for 4–6 weeks. In severe cases, surgical strictureplasty is performed.

Hiatal Hernia

When the hiatus is not closed at the time of surgery, there is a risk of visceral herniation. Surgical repair may be approached by means of a thoracotomy on the side of the herniation or laparotomy. Minimally invasive repair is usually not possible.

Outcomes After Ramie

Totally robotic esophagectomy has not been reported frequently. Kernstine et al. [4] reported on 14 patients with a median age of 64 years who underwent robotic esophagectomy, 8 of who were completely robotic MKE while 6 were hybrid procedures. Total operating room time was 11.1 ± 0.8 h (range, 11.3–13.2 h). Complications included death ($n=1$), thoracic duct leak ($n=1$), severe pneumonia ($n=1$), anastomotic leak ($n=2$) and bilateral vocal cord paresis ($n=1$). Mean total operating time was 11.1 h.

Kim et al. reported on 21 patients who underwent hybrid RATS/laparoscopic MKE in the prone position [5]. One patient had a positive margin; major complications included anastomotic leakage ($n=4$), vocal cord palsy ($n=6$), and intra-abdominal bleeding ($n=1$).

Weksler et al. reported on 11 cases of robot assisted Ivor Lewis procedures [8]. In comparison with their series of traditional MIE, robotic thoracoscopic MIE did not offer clear advantages.

Dunn et al. reported on 40 patients underwent transhiatal RE [9]. Five patients were converted from robotic to open. Complications included anastomotic stricture ($n=27$), recurrent laryngeal nerve paresis ($n=14$), anastomotic leak ($n=10$), pneumonia ($n=8$), pleural effusion ($n=18$) and death ($n=1$).

The authors present their own series of totally endoscopic robotic McKeown procedures.

Author AEA's series includes 33 patients (3 females, 10 %) with median age of 62 who underwent totally endoscopic robotic assisted McKeown esophagogastrectomy in an 18 month period from January 2011 to July 2012. Indication for surgery was esophageal adenocarcinoma ($n=26$, 79 %), squamous cell carcinoma ($n=3$, 9 %), end-stage achalasia ($n=2$, 6 %), giant esophageal diverticulum ($n=1$, 3 %), and complicated eosinophilic esophagitis ($n=1$, 3 %).

For the 29 cases of esophageal cancer, neoadjuvant or definitive chemoradiation was administered in 15 cases ($n=51.7$ %) and pathologic stage was Stage 0 ($n=3$, 10.3 %), IA ($n=8$, 27.6 %), IB ($n=3$, 10.3 %), IIB ($n=4$, 13.8 %), IIIA ($n=9$, 31 %), IIIB ($n=2$, 6.9 %). Stage 0 related to complete pathologic response after neoadjuvant therapy, which occurred in 3 of 15 patients (20 %).

Mean duration of surgery was 310 min (range, 270–340 min) with no cases of conversion to open procedure. The mean number of lymph nodes with the specimen in all cases was 16 (7–44). The median length of hospital stay was 7 days (range, 4–31 days).

Complications are summarized in Table 4.2. Short-term complications after surgery occurred in 13 patients (39 %). Complications included mild anastomotic leak ($n=2$, 6 %), vocal cord paresis ($n=2$, 6 %) and chylothorax requiring reoperation ($n=2$, 6 %). One patient died of mesenteric ischemia on day 12 after surgery. Patients in the series were followed for a mean of 160.7 days (range, 12–492 days). Two patients have

Table 4.2 Complications after RAMIE. Author AEA series of 33 MKE procedures

Short-term	
Atrial arrhythmia	15 %
UTI	9 %
Pneumonia	9 %
Wound infection	6 %
Anastomotic leak	6 %
Vocal cord paresis	6 %
Delerium tremens	6 %
Chylothorax	6 %
ARDS	3 %
Pulm embolism	3 %
Renal failure	3 %
Mesenteric ischemia	3 %
Death	3 %
Long-term	
Anastomotic stricture	15 %
Delayed gastric emptying	3 %

developed metastatic disease (lung, peritoneum), five developed anastomotic stricture (15 %) and one patient (3 %) developed delayed gastric emptying (DGE). Strictures and DGE were managed successfully by endoscopic balloon dilation. All patients on follow-up are tolerating oral diet.

Author MD performed the procedure on 20 patients with mean age of 63 years, 17 males. Fourteen patients had Stage IIIA disease. Mean operative time was 303 min and conversion to open surgery was necessary in one patient due to adhesions. Average hospital stay was 9 days. Ninety-day mortality was 10 %. Leak rate was 15 % and vocal cord paresis was 5 %.

Summary

As we have seen with most other traditional operations, esophagectomy has also been shown to be feasible in a minimally invasive fashion. Robotic assistance offers the same benefits normally expected when applied in other procedures. In the case of esophagectomy, these benefits may be magnified in terms of minimizing the usual severe insult to the patient from an operation that invades three body cavities. It is also advantageous due to the ability to perform a superior oncologic procedure in terms of meticulous mediastinal and periceliac nodal dissection; areas that are not easily exposed by traditional endoscopic or even open surgery.

However, it is not the goal of the authors to convey that a robotic esophagectomy is a minor procedure. It requires advanced skills, usually greater than those needed for other thoracic operations. It remains a major operation with a mortality rate of up to 10 %, in addition to the risk for all complications that are seen with esophagectomy by other means. It will be important to provide long-term follow-up for this procedure in order to truly assess its value in managing esophageal cancer.

References

1. Horgan S, et al. Robotic-assisted minimally invasive transhiatal esophagectomy. Am Surg. 2003;69(7):624–6.
2. Dapri G, Himpens J, Cadiere GB. Robot-assisted thoracoscopic esophagectomy with the patient in the prone position. J Laparoendosc Adv Surg Tech A. 2006;16(3):278–85.
3. Gutt CN, et al. Robotic-assisted transhiatal esophagectomy. Langenbecks Arch Surg. 2006;391(4):428–34.
4. Kernstine KH, et al. The first series of completely robotic esophagectomies with three-field lymphadenectomy: initial experience. Surg Endosc. 2007;21(12):2285–92.
5. Kim DJ, et al. Thoracoscopic esophagectomy for esophageal cancer: feasibility and safety of robotic assistance in the prone position. J Thorac Cardiovasc Surg. 2010;139(1):53–9.e1.
6. Sutherland J, et al. Postoperative incidence of incarcerated hiatal hernia and its prevention after robotic transhiatal esophagectomy. Surg Endosc. 2011;25(5):1526–30.
7. Puntambekar SP, et al. Robotic transthoracic esophagectomy in the prone position: experience with 32 patients with esophageal cancer. J Thorac Cardiovasc Surg. 2011;142(5):1283–4.
8. Weksler B, et al. Robot-assisted minimally invasive esophagectomy is equivalent to thoracoscopic minimally invasive esophagectomy. Dis Esophagus. 2012;25(5):403–9.
9. Dunn DH, et al. Robot-assisted transhiatal esophagectomy: a 3-year single-center experience. Dis Esophagus. 2013;26(2):159–66.