

Robotic Esophagectomy: Technical Aspects and Outcomes

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Abstract

The emergence of Minimally Invasive Esophagectomy (MIE) was associated with significant reduction of the rate of postoperative complications. Despite the promising results associated with MIE, the laparoscopic/thoracoscopic approach remains technically challenging and has failed to obtain diffuse acceptance in clinical practice. Robotic esophagectomy has been initially introduced to overcome the limitations of conventional Minimally Invasive Esophagectomy. The improved optical capabilities in combination with significantly improved dexterity of the instruments as well as the better ergonomics are only few of the numerous technical advantages that make this constantly evolving technology unique. Over the last decade, the increased robotic use and experience demonstrated that robotic esophagectomy is feasible, safe, and oncologically appropriate surgical treatment for esophageal cancer.

In this review, we provide general and technical updates on the current use of robotic esophagectomy and report on the wide range of outcomes following this novel minimally invasive approach.

Keywords: Esophagectomy; Esophageal cancer; Ivor Lewis; Robotic; Thoracic

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Robotic Nomenclature

In order to allow accurate communication among scientists and surgeons, but also to ensure proper outcome comparison, the American Association of Thoracic Surgeons Writing Committee proposed recently a definition and nomenclature for robotic thoracic surgery. According to the consensus statement, Robotic Portal (RP) operation is defined as an operation that use ports only and the port incision(s) is/are not generally enlarged at any time during the operation to be larger than the trocars in them except for the removal of a specimen. Robotic operations that include a utility incision are defined as Robotic-Assisted (RA) procedures. For more precise description of the various procedures the Committee described the following four step system:

- First Letter=R for robot
- Second Letter =P for portal or A for assist
- Third letter=type of procedure (for the purpose of this paper-E for esophagectomy)
- Fourth letter -the number of robotic arms used

A similar report is underway for MIE.

Preoperative Work up

We initiate the staging process with upper endoscopy and biopsies, followed by CT of the chest/abdomen/pelvis with oral and intravenous contrast. If no metastatic disease has been identified, we proceed with Positron Emission Tomography (PET) scan in order to detect potential lymphatic or distant metastatic disease. In addition, an Endoscopic Ultrasound (EUS) is also performed not only to determine the depth of the invasion and lymphatic involvement, but also by some, to place markers above and below the tumor to optimize planning for possible neoadjuvant radiation therapy as well as to determine lymph node status.

Introduction

Esophagectomy is a complex surgical procedure and continue to be one of the most morbid operations performed [1-4]. It is however the gold standard not only in providing optimal chance for cure in cancer patients but also it an option for palliation of severe dysphagia. The choice of technique depends on multiple factors and especially on the location of the tumor and the experience of the surgeon [5-7].

Three decades ago, surgeons across the globe started to have increasing interest in Minimally Invasive Esophagectomy (MIE) as a way to reduce the rate of complications [8,11-12]. Patients who underwent minimally invasively surgery were found to have better global quality of life, physical performance, fatigue and pain at 3 months after surgery [9-10].

Despite the promising results associated with MIE, the laparoscopic/thoracoscopic approach remains technically challenging and has failed to obtain diffuse acceptance in clinical practice. Robot assisted esophagectomy has been initially introduced to overcome the limitations of conventional MIE [9-12]. The magnified 3D vision, the significant maneuverability of the “endo wrist” instruments, the motion scaling and tremor filtration are only few of the multiple advantages offered by the current robotic systems.

The aim of this report is to provide general and technical update on the current use of robotic esophagectomy and report on the outcomes following this novel minimally invasive approach.

Neoadjuvant chemoradiotherapy is used for patients with T2 or greater or N1 or greater disease (exception being patients >75 years of age with T2 N0 M0 lesions). All patients who undergo neoadjuvant treatment are restaged after completing the therapy with PET-CT and EUS.

Perioperative Phase and Conduct of Operation

Equipment

To date Da Vinci system® (Sunnyvale, CA, USA) is the only FDA approved robotic system that is eligible to perform advanced thoracic surgical procedures. The robotic console has evolved over the years introducing four different generations (Standard, S, Si and Xi) with improvements of wide variety of technological features.

All four generations share the same general concept: the operating surgeon is positioned at a console short distance from the patient, who is positioned on an operating table in close proximity to the robotic unit with its 4 “operating” arms. Fine proprietary end wrist instruments are attached to the arms allowing wide range of high-precision motions. Those motions are initiated and controlled by the surgeon’s hand movements, via “master” instruments located at the console. The master instruments sense the surgeon’s hand movements and translate them electronically into scaled-down micro movements to manipulate the small surgical instruments.

A 6-Hz motion filter removes any hand tremor. The operation is controlled via binocular screen located at the surgeon’s console. The image comes from a highly maneuverable high-definition digital camera (endoscope) attached to one of the robot arms. In addition, the console is provided with foot pedals that allow the surgeon to engage and disengage different instrument arms, reposition the console master controls without the instruments themselves moving, and activate the various instruments. A second optional console could be linked to the system in for tandem surgery and/or training.

Surgical Technique

One of the pioneers of MIA and robotic esophagectomy Dr. Luketich reported that he switched his initial technique of performing the anastomosis in the neck to a chest anastomosis (between the esophagus and the gastric conduit). In our institution we have always prefer the chest anastomosis as well, in particular because we believe that it provides lower rates of recurrent laryngeal nerve injury, lower leak rates and also fewer aspirations [13-16].

A. Patient and port position-Abdominal phase

We usually start with the abdominal portion of the procedure. The patient is placed in a supine position and 5mm or 8mm port is used in order to enter the abdominal cavity under direct scope guidance. We locate the camera port approximately 16-18cm inferior to the xiphoid process and 3cm to the left of the midline. A liver retractor is placed using right subcostal port using Mediflex (Islandia, NY) Positractor with a Lapro-Flex self-forming retractor or via subxiphoid port (Nathanson retractor). The further additional ports are placed laterally to the midline camera port, between 8cm away from one another as follows: two ports placed to the right and one left as previously described. We use the lowest most stapling port for the robotic stapling in creating the gastric conduit (as described further in the text). In such a way we provide the optimal angle for stapling the gastric conduit. The 5mm trocar to the left of the umbilicus could be later used for the feeding jejunostomy after completion of the gastric mobilization.

B. Conduct of operation-Abdominal phase

With the patient in the supine, reverse Trendelenburg position the abdominal cavity is explored. During the initial dissection we try to preserve a tongue of omentum in order to later cover the anastomosis and protect the carina from fistula formation or leak. While preserving the right gastroepiploic vessels as main blood supply to the conduit, we divide the short gastric arteries and continue the dissection of the esophagus at the hiatus and into the mediastinum. Next, attention is turned to the lesser curvature, the left gastric artery is identified, lymph node tissue pushed upward followed by transection of the artery and vein using a vascular staple load. We do not perform a Kocher maneuver routinely because it does not truly add length to the conduit. We confirm an adequate mobilization by the ability of the pylorus to reach the diaphragmatic hiatus. Botulinum toxin injection (100 Units diluted in 4cc of normal saline) is injected into the pylorus-a maneuver that serves as the pyloric drainage procedure. A 5cm wide plastic loop/penrose catheter is placed around the lowest part of the lesser curve and allows downward traction of the conduit (patients left hip). The bedside assistant will hold the loop as the conduit is being stapled. At the same time robotic arm number 4 holds the gastric fundus including the tip of the stomach towards the patient left shoulder (above the spleen) in order to fully stretch but also elongate the stomach. A 4-5cm wide conduit is prepared using multiple gastro-intestinal staple loads. It is our intention to maintain the conduit wider where the anastomosis is to be constructed. The newly constructed conduit is sutured to the future specimen and positioned into the mediastinum along with a penrose drain placed around the esophagus. We complete the abdominal portion of the operation by creating a 12Fr jejunostomy tube in modified Seldinger technique.

C. Patient and port position-Thoracic phase

After placing the patient in left-sided (15 to 20°) semiprone position, 8 mm trocar (for robotic arm 1) is positioned below the axilla in the triangle between the latissimus dorsi and pectoralis muscles. We perform a paravertebral block under direct thoracoscopic vision on a regular basis. 8mm trocar for robotic arm 3 is inserted next as posteriorly and inferiorly in the chest as anatomically possible. After repositioning the camera through the posterior port, all other ports are placed under direct vision as follows: 12mm plastic port for the robotic camera is placed third approximately 8-9cm away from robotic arm 1 in a line towards the right patients hip. The fourth 8mm trocar (robotic arm 2) is placed 8-9cm away from the camera port. The port placement is concluded by introducing 12-15mm bedside assistant port, which is triangulated behind the camera port and the port intended for robotic arm 2. The assistant port is placed as low as possible in order to optimize the working space for the bedside assistant.

D. Conduct of operation-Thoracic phase

We insufflate the chest with low pressure CO₂ (~8mmHg) at the beginning of the procedure. A Cadiere grasper is used for robotic arm 2. A bipolar thoracic dissector (also known as a long curved tipped dissector) is placed in robotic arm 1. The 5mm thoracic grasper is used for robotic arm 3 and serves mainly as a retractor.

The thoracic portion of the procedure starts with mobilization of the intrathoracic esophagus from thoracic inlet to diaphragmatic hiatus. All tissue from the pericardium to the left pleural surface is removed. During the dissection, both the right and left inferior pulmonary veins will be visualized. The lymph nodes are carefully removed with the help of the bipolar instrument. A formal lymphadenectomy

including stations 1-4, 7-9, and 11 with or without station 12 is routinely performed. During this step of the operation, one should avoid any thermal injury to the airway. It is our preference to identify the right main stem bronchus first followed by the trachea and then the left main stem bronchus before the removal of the entire subcarinal lymph node basin. Next, the azygos vein is identified and transected with the help of a vascular stapler. In our technique we do not ligate the thoracic duct routinely. The esophagus including the vagus nerves are divided at the level of the previously transected azygos vein for distal tumors. For mid-esophageal tumors we divide the esophagus higher in order to assure appropriate negative margin. If esophageal dissection will be performed above the azygos vein, we use the bipolar cautery and stay in close proximity to the esophagus in order to avoid a potential recurrent laryngeal nerve injury. The right paratracheal lymph nodes are not routinely removed unless a mid or mid-low squamous cell cancer is the primary lesion.

E. Robotic Chest Anastomosis

After the proximal esophagus has been transected, the specimen is removed from the body. At this point the conduit is brought into the chest and prepared for the anastomosis. We tack the upper portion of the conduit to the posterior pleura, cranial to the azygos vein and anterior to the divided right vagus nerve-a maneuver that helps to line up the anastomosis. Next, longitudinal gastrotomy with a length of 4cm is performed on the posterior wall of the stomach starting at the tip of the conduit. Using a 30mm gastrointestinal load, we staple the posterior portion of the anastomosis (side to side) and close the anterior part with continuous 3-0 vicryl sutures on the inner layer and 3.0 interrupted silk sutures as the outer row.

Occasionally, if the stapling of the posterior stomach does create significant amount of tension, the entire anastomosis could be completely hand-sewn. At this point, the perfusion of both gastric conduit and esophagus is further assessed by the use of near-infrared fluorescence with indocyanine green.

After the anastomosis has been completed, we use the previously harvested omentum to buttress the anterior portion. The conduit is then secured to the diaphragmatic hiatus with interrupted silk sutures in order to prevent potential herniation of the intra-abdominal contents. A single 20Fr chest tube is placed in proximity of the anastomosis at the completion of the operation.

F. Postoperative Management

Enteral Nutrition: If a feeding tube has been placed, we start trophic tube feeds at a rate of 10cc/hr via the jejunostomy tube on postoperative day 1. The tube feed rates is carefully advanced to goal within the next 24-72 hours depending on the clinical condition of the patient, presence of distention and/or ileus and return of bowel function.

Oral intake: formal clinical speech evaluation is performed on postoperative day 3, 4 or 5. Once the swallowing capacity of the patient has been confirmed by a bedside Fiberoptic Endoscopic Evaluation of Swallowing (FEES), a barium swallow is performed to assess gastric emptying. Patients are discharged home on sips of clear liquids or even soft diet supplemented by the tube feeds.

Drains: the intraoperatively placed chest tube is removed once output is less <400cc/hr with no signs of chylothorax (drain amylase less than 200IU/L on postoperative day 3). We do not perform barium

studies to assess for leak, our leak test is in the form of drain amylase measurement.

Perioperative and Postoperative Outcomes

Sarkaria et al. reported in 2013 the results of prospective single cohort observational study including 21 patients who underwent robotic esophagectomy [17]. The authors performed an end-to-end anastomosis reinforced with a baseball suture and added pyloroplasty to the procedure. For a median operative time of 556 minutes (range, 395-807 min) the reported Estimated Blood Loss (EBL) was 307cc (range, 200-500cc). The median number of lymph nodes resected during this approach was 20 (range, 10-49). In this early study, 24% of the patients required conversion to open procedure and also 24% had major complications. As many as 14% had clinically significant anastomotic leaks. The patients remained in the hospital for median of 10days (range, 7-70 days) and one patient (5%) died on postoperative day 70 (see table 1).

De la Fuente et al., published in 2013 their initial experience of 50 patients undergoing robotic-assisted Ivor Lewis esophagogastrectomy for predominantly Adenocarcinoma (92%) [20]. The surgery was performed within 445+/- 85 min with mean estimated blood loss of 146+/-15ml. The authors reported that as the experience of the surgeon was growing the operative time was decreasing (479+/-93min-first half of the patients vs. 410+/-60min-the second half of the patients). Total of 28% of the patients had complications: pneumonia 10%, anastomotic leak 2%, conduit staple line leak and chyle leak 2.4%. The patients remained in the hospital for median 9 days (range, 6-35 days). The authors did report a trend for lower complications after case 29-however no statistical significance was reached in their analysis. With this novel approach the authors retrieved median of 18.5 (range 8-63) lymph nodes.

Within the following years robotic esophagectomy gained popularity and acceptance among surgeons. Hodari et al. reported their experience with 54 patients who underwent robotic-assisted Ivor Lewis esophagectomy [19]. In their study the majority of the patients were male (81%) and 70% of them underwent neoadjuvant therapy. Histologic diagnosis was adenocarcinoma in 85.2% and squamous cell carcinoma in 5.6%. The median operative time was 362 minutes (range 260-480 minutes) with an average blood loss of 74.4ml. Anastomotic leak was reported in 3 patients (6.8%) with and one patient had a leak originating from the gastric staple line. Three patients were managed with covered esophageal stent, whereas one of the anastomotic leak patients required primary reinforced repair with serratus muscle buttress. The mean length of stay was 12.9 days (range, 7-37 days) In this case series one mortality was reported secondary to pulmonary complications and respiratory failure. The average number of lymph nodes harvested was 16.2 (range, 3-35).

One of the largest reported series on robotic esophagectomy was published by us, Cerfolio et al., from the University of Alabama [18]. Eighty-five consecutive patients, predominantly male (87%) underwent robotic esophagectomy. The reported mean operative time was 360 minutes (range, 283-489 minutes). With a median blood loss of 35ml, none of the patients required a blood transfusion during the operation. The median number of harvested lymph nodes was 22. The patients were discharged after median stay of 8 days (range, 5-46 days). The overall reported morbidity was 36.4%. Anastomotic leak occurred in four patients (4.3%) and three of those were treated with the placement of a covered esophageal stent. In total, the authors re-

ported 7.1% confirmed anastomotic to conduit complications. The 30-day perioperative mortality was 3.5% and the overall 90-day mortality rate was 10.6%.

Conclusion

Esophagectomy is a technically demanding procedure with considerable peri-and postoperative morbidity and mortality. In spite of the various challenges reported in multiple studies, we believe that minimally invasive esophagectomy using a robotic platform offers multiple advantages including decreased postoperative pain, reduced ICU and hospital stay and faster recovery. The augmented dexterity, the advanced visualization and magnification of the robotic platform in combination with ability to intraoperatively assess blood supply to the anastomosis and conduit are only few of the multiple advantages that make robotic esophagectomy an attractive operation. Our paper describes the technical details and reports on key intra-and postoperative outcomes that demonstrate robotic esophagectomy as procedure of great safety and efficacy.

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