Technique of robotic assisted minimally invasive esophagectomy (RAMIE)

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Abstract: Minimally invasive esophagectomy (MIE) has gained popularity over the last two decades as an oncologically sound alternative to open esophagectomy. Robotic assisted minimally invasive esophagectomy (RAMIE) has been developed at few highly-specialized centers, and overall experience with this technique remains limited. Herein, we describe our overall approach to this operation and specific technical issues.

Keywords: Esophagectomy; robotic; minimally invasive; esophageal cancer

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Introduction

Esophagectomy remains a central component in the therapy of esophageal cancer and the salvage therapy of choice in many benign esophageal pathologies. Despite having been described more than a hundred years ago, esophagectomy remains an operation with potential high morbidity and mortality outside of specialized centers (1-3). To maximize the benefit of the procedure while minimizing its risks, surgeons have sought to refine the procedure. Minimally invasive approaches to esophagectomy were first described in the 1990's, and recent works have demonstrated oncologic equivalence and safety in total laparoscopic/thoracoscopic trans-thoracic minimally invasive esophagectomy (MIE) compared to open operations (4,5).

The first reports of robotic assisted minimally invasive esophagectomy (RAMIE) were published in the early 2000's (6,7). Though overall utilization of robotics in esophagectomy is low, a relative boom in the increase of the use of RAMIE has been seen in recent years. Various specialized centers such as the University of Alabama, Memorial Sloan Kettering, and our own institution (University of Pittsburgh) have since described their individual initial experiences and approaches to total laparoscopic/thoracoscopic RAMIE, demonstrating the relative safety of the procedure (8-10). Some centers, including our own, have suggested the robotic platform offers several potential advantages that significantly facilitate and improve the primary surgeon's control over the conduct of the operation, related primarily to superior instrument dexterity, stable high definition and stereoscopic visual capabilities, and multi-arm platforms allowing surgeon self-assist. Herein, we describe our Ivor Lewis approach to RAMIE, which represents the majority of operations we perform for lower esophageal tumors. The current report describes our approach with the most current available robotic platform (DaVinci Xi, Intuitive Surgical Inc., USA).

Patient selection

Patients considered for esophagectomy are preoperatively evaluated for significant comorbidities, cardiopulmonary fitness, and functional status. All patients preoperatively obtain a formal pathologic diagnosis with esophagogastroduodenoscopy and biopsy, endoscopic ultrasound, fluorodeoxyglucose-18

Figure 1 This video demonstrates the key steps in performing a successful robotic assisted minimally invasive esophagectomy (11). Available online: http://www.asvide.com/articles/1677

positron emission tomography, and computed tomography of the chest abdomen and pelvis. Bronchoscopy is routinely performed for middle and upper esophageal tumors to assess airway involvement. Many patients undergo a laparoscopic staging procedure for evaluation of metastatic disease, surgical resectability, and placement of a chemotherapy infusion port when induction treatment is warranted. Patients with T3 disease or N1 disease are referred for neoadjuvant chemotherapy and/or radiation therapy. Patients considered suitable for an MIE approach are also considered appropriate for RAMIE.

Equipment preference card

- Robotic platform: DaVinci Xi Robotic Surgical System with 30-degree camera system and near infrared imaging (Firefly, Intuitive Surgical, USA).
- Robotic 8 mm instrumentation: fenestrated bipolar grasper, robotic ultrasonic shears, small grasping retractor, large needle driver, large suture cut needle driver, Cadiere forceps, Maryland bipolar forceps (as indicated), shears.
- The 28 mm extended/long EEA circular stapler (DST XL, Covidien, USA).
- Anastomotic purse string suture: 2-0 and 0 polypropylene on SH needle (Prolene, Ethicon, USA).
- Other suture: 2-0 on SH needle (Ethibond, Covidien, USA).
- Other: 5 mm suction/irrigator system, 5 mm 30-degree standard laparoscope, 12 French percutaneous jejunostomy and introducer, Endostitch device with 2-0 surgical suture (Covidien, USA), 10 mm medium/large clip applier (Covidien, USA).

Operative technique (*Figure 1*)

Abdominal approach

The patient is placed in the supine position and shifted to the right side of the bed to facilitate use of the liver retractor (DiamondFlex, Snowden Pencer, USA) and stabilization system (MediFlex, USA). Esophagogastroscopy is performed in every case by the operating surgeons to assess suitability of the stomach for later gastric conduit creation. The left arm is tucked to the patient's side and the right arm left abducted. A footboard is placed for support during reverse Trendelenburg positioning.

Port placement

A midline robotic 8mm is placed using an open cut down technique at the level of the umbilicus. Standard CO_2 insufflation is utilized at a pressure of 15 mmHg. The 8 mm ports are then placed in mid right and left mid clavicular line and at the left costal margins. A standard 5 mm port is as posterior as possible at the right costal margin while avoiding the right colon and a liver retractor is placed through it. A robotic atraumatic grasper (small grasping retractor) is placed in the left most costal port, an ultrasonic shear in the left midclavicular port and a bipolar forcep in the right midclavicular port. A 12 mm robotic stapler port is placed in the right para umbilical position for use as a bedside assist and for later stapler use. Alternatively, if standard staplers are to be used, a routine 12 mm port may be placed. An additional 5 mm port is placed further lateral in the same para umbilical line for use by the assistant's left hand.

Hiatal dissection and retrogastric dissection

The dissection begins with the division of the lesser omentum and assessment of the resectability of the tumor including the celiac axis, crura, aorta, and pancreas. All lymphatic tissues from the proximal common hepatic, splenic, and left gastric arteries, as well as retrogastric basins are dissected and swept above the line of division of the left gastric artery for later *en bloc* removal with the surgical specimen. This dissection is facilitated by anterior retraction of the stomach with the left most small grasping retractor. A vascular stapler is used to divide the left gastric. In the event of a significant replaced left hepatic artery arising from the left gastric artery, the common origin and left gastric artery are carefully skeletonized of all lymph node bearing tissues and divided distal to the origin of the replaced hepatic artery, preserving the replaced hepatic artery in its entirety. Through this retrogastric exposure, significant retrogastric adhesiolysis and mobilization of the gastric fundus can be achieved from the pancreas to the left crus and along the spleen, including initial division of the short gastric arteries.

Gastric mobilization and conduit creation

Gentle medial and superior retraction of the stomach with the robotic retractor arm while using a "no touch technique" on the greater curve aids the division of the short gastric vessels from the mid body of the stomach to the left crus. The gastroepiploic arcade is fully preserved along the greater curvature. If available, near infrared imaging with indocyanine green (Firefly, Intuitive Surgical, USA) can be used to identify the entire course of gastroepiploic artery, which may be useful patients with significant intra-abdominal adiposity. In patients who have received induction chemoradiation therapy, a pedicled omental flap based off 2 omental perforating arteries is created as a buttress for later reinforcement of the intrathoracic anastomosis. Development of this flap is aided by medial retraction of the stomach and lateral retraction of the omentum. The stomach is fully mobilized from the crura to the pylorus, ensuring especially that all retrogastric and retropyloric adhesions are lysed. This maneuver is made easier by superior and medial retraction using the small grasping retractor from either under the stomach, or with gentle grasping of the stomach antrum below the intended point of conduit creation.

Pyloroplasty

The pylorus is retracted superiorly and leftwards for exposure with a gentle grasp on the distal gastric antrum by the small grasping retractor. Braided, non-absorbable hemostatic sutures are placed at the superior and inferior aspect of the pylorus and aid in retraction (2-0 Ethibond, Covidien, USA). The pyloroplasty is routinely performed in a Heinecke-Mikulicz fashion with the initial incision through the pylorus performed with the ultrasonic shears. The pyloroplasty is completed with approximately 5–6 robotically placed interrupted sutures.

Conduit formation

The robotic small grasping retractor retracts the fundic tip to the left upper quadrant against the diaphragm. Sequential applications of the straight 45mm robotic gastrointestinal stapler are used to create a straight, narrow gastric conduit approximately 4–5 cm in width. The gastric conduit is secured to specimen in proper orientation for later traverse into the chest and the omental flap is tacked to the tip of the gastric conduit to facilitate locating it and manipulating it during the thoracic portion of the operation. Lastly a marking stitch is placed at the transition of gastric conduit to antral reservoir. Feeding jejunostomy is performed using standard laparoscopic equipment and techniques to facilitate the surgeon's transition back to the bedside in preparation for lateral positioning. The abdomen is inspected for hemostasis and the abdominal portion of the operation is concluded.

Thoracic approach

Patient positioning and port placement

The patient is placed in standard left lateral decubitus position. A Veress needle is inserted just below the tip of the scapula to allow for CO_2 insufflation. The intrathoracic pressure is set to 8 mmHg. The robotic 8 mm ports are sequentially inserted at the eighth intercostal space at the posterior axillary line, the third intercostal space in the mid to posterior axillary line, fifth intercostal place into the mid axillary line, and at the ninth intercostal space approximately in line with the tip of the scapula under direct vision. A 12 mm robotic stapler/assistant port is placed just above the diaphragmatic reflection. The robotic cart is driven over the patient's right shoulder. The camera is placed into the eighth intercostal space port, a bipolar retractor in the ninth intercostal space port, a harmonic scalpel in the 5th intercostal space and small grasping retractor in the third intercostal space port.

Esophageal mobilization

The pleura over the esophagus anteriorly and posteriorly are opened using the ultrasonic shears. The esophagus is mobilized circumferentially from the hiatus to the level of the azygos vein, ensuring all node bearing tissues are harvested with the esophagus. When harvesting the subcarinal lymph nodes, energy must be meticulously and sparingly applied when working near the airway, in particular the posterior membranous structures of the trachea, mainstem bronchi, and bronchus intermedius. Clear visualization, meticulous use of energy, sharp dissection and blunt dissection are critical to thermal injuries which may significantly increase the risk of entero-bronchial fistulae. This caution cannot be overemphasized. While this can often be achieved with use of the ultrasonic shears, alternative use of the Maryland bipolar forceps may be advisable during this portion of the dissection if the ultrasonic shears cannot be utilized in a relatively parallel orientation the bronchus intermedius and right mainstem bronchus. Early identification of the trachea may facilitate early and clear identification of the left mainstem bronchus, which tends to be "deeper" and more obscured in the surgical field. Along the posterior pleura, clips are used liberally to ligate large lymphatic and arterial perforating vessels from the thoracic duct and aorta respectively. Hiatal dissection is completed and the surgical specimen and proximal conduit brought into the chest with careful attention to maintain proper orientation of the conduit. The proximal conduit is separated from the specimen, partly delivered into the chest, and temporarily sutured to the diaphragm. The "deep" medial dissection is completed along the contralateral pleura and greatly facilitated by lateral retraction of the specimen by the small grasping retractor. Care must be taken to avoid injury to the left mainstem during this dissection if not fully visualized at the time of the subcarinal dissection. The esophagus is mobilized towards the thoracic inlet with division of the vagus nerves at the level of the azygos vein to prevent traction injuries to the recurrent laryngeal nerve. The azygos vein is divided with the robotic vascular stapler. Firm retraction is utilized to maximize visualization. The esophagus is sharply divided approximately three centimeters above the azygos vein using the robotic shears. The surgical specimen is removed through the fifth intercostal surgical port, which is extended to a 4 cm mini access incision along with placement of a wound protector device. This incision will later serve as the entry point for the anastomotic stapler.

Esophagogastric anastomosis

A running "baseball" purse string suture is placed at the esophageal orifice with 0 polypropylene suture on an SH needle (Prolene, Ethicon, USA). The robotic graspers hold the orifice of the proximal esophagus. and the 28 mm anvil of the extra-long end-to-end anastomotic (EEA) stapler is inserted (DST XL, Covidien, USA). An additional purse string suture is placed to reinforce this staple purse string suture. The EEA stapler is introduced through the access incision and is placed through a gastrostomy in the proximal conduit. The stapler spike is advanced out through the lateral wall of the conduit just above the level of the vascular arcade insertion. The stapler and anvil are docked ensuring flush apposition of the tissues and appropriate orientation. The stapler is fired and the anastomosis completed. Redundant conduit is resected with the robotic gastrointestinal stapler. If an omental flap has been previously harvested, it is secured around the anastomosis. It is advisable to maintain a modest amount of fat along the lesser curve to provide tissue between the airway and gastric conduit and anastomosis. A nasogastric tube is placed and its position in the conduit confirmed under direct vision. A small drain is placed posterior to the anastomosis and a chest tube is left in the right pleural space.

Postoperative care

Postoperatively, routine patients are admitted to the ICU and discharged the next day to the step-down ward. Enteral nutrition is initiated via jejunostomy tube on postoperative day 2. A barium swallow is performed after removal of the nasogastric tube on postoperative day 4–5 and a liquid diet initiated. All patients are discharged with their peri-anastomotic drain, which is removed at the first outpatient clinic follow up visit.

Tips, tricks and pitfalls

- If possible, a dedicated robotic team should perform these cases. The majority of delays, technical glitches and errors are avoidable and are easily dealt with by an experienced team.
- Small capillary networks that support the area of the conduit used for the anastomosis can easily be damaged by the robotic graspers. To avoid any compromise of the conduit microvasculature, a "no-touch" technique must be adhered to at all times when mobilizing the greater curve of the stomach. Direct grasping and instrumentation of the greater curve of the stomach must be avoided at all times. Virtually all exposures can be readily achieved with standardized robotic retraction techniques.
- Maintain orientation of the conduit when attaching it to the specimen during the abdominal phase. Rotation of the conduit, or uncertainty regarding its orientation, may necessitate re-exploration in the abdomen, and is easily avoidable. This can be prevented by attaching the conduit using either two separate stitches or a wide horizontal mattress suture to prevent twisting or spiraling of the conduit
- Thermal injury to the posterior airway during the mediastinal dissection must be avoided. Operative assistants can provide additional exposure and aggressive suction as needed to maintain optimal visualization, and ultrasonic shears can be exchanged for lower-energy Maryland bipolar forceps to reduce the amount of radially-displaced energy.

Discussion

Our approach to Ivor Lewis RAMIE is described in detail. Due limited utilization currently, extensive data on the advantages of RAMIE as compared to MIE or traditional open esophagectomy is limited. Our initial experience with RAMIE at the University of Pittsburgh has been reported with favorable outcomes, with no 30- or 90-day mortality (8). Perioperative outcomes, including blood loss, anastomotic leak rates, and morbidity are similar to reported MIE outcomes at UPMC. The quality of the initial institutional experience has been greatly aided by the extensive previous experience and expertise of the two senior authors of this publication (IS Sarkaria and JD Luketich). The previously published experience by one of the senior authors (IS Sarkaria) at Memorial Sloan Kettering Cancer Center reported excellent outcomes in 100 patients undergoing RAMIE with an anastomotic leak rate of 6%, 0% 30-day mortality, and a 90-day mortality rate of 1% (12).

The robotic platform offers many potential advantages to this specific operation. Dissection of the hiatus and mediastinum can be very challenging with traditional laparoscopic and thoracoscopic instruments, especially in obese patients and those with robust responses to induction radiation therapy. Superior visualization and optics, as well as the extra degrees of freedom provided by the robotic instrumentation, may facilitate ease and conduct of dissection. With the conduct of the operation predominantly under the operating surgeon's control, the surgeon is less reliant on the input and coordination of operative assistants, which can help streamline the overall conduct of the operation. Specific portion of the MIE, such as pyloroplasty and anvil placement during creation of the anastomosis, is greatly aided by robotic suturing, which often provides improved precision and visualization. Although these potential benefits are compelling to surgeons using these platforms, measurable clinical benefit to the patient over standard MIE may or may not be demonstrable, for example, within the auspices of a clinical trial. Also, the financial implications associated with RAMIE are yet unknown and warrant further study.

It is of utmost importance to maintain a strong focus on patient safety and outcomes when developing a RAMIE program. Preparation with simulation, team building, observation of cases, cadaveric laboratory time, and appropriate expert mentorship and proctoring may be greatly beneficial in avoiding the known pitfalls and morbidity of these operations. With appropriate preparation and graded accumulation of experience, recapitulation of mortal technical complications, such as airway fistulae, should be near-completely avoidable in these complex operations. Within the scope of these cautions, the potential technical advantages of RAMIE may certainly be realized by surgeons wanting to adopt this technique.

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None.

Footnote

Conflicts of Interest: IS Sarkaria is a Speaker for Intuitive Surgical.

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