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Editorial

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Robotic trans-hiatal esophagectomy chapter

George Peek, Sharona B Ross

Digestive Health Institute, Tampa, FL 33613, USA.

Correspondence to: Dr. Sharona B Ross, MD, FACS, Digestive Health Institute, 3000 East Fletcher Avenue, Tampa, FL 33613, USA. E-mail: mysharonaross@gmail.com

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Esophageal cancer represents a formidable malignancy and stands as a significant contributor to cancer-associated mortality globally. Ranked as the eighth most prevalent cancer and the sixth leading cause of cancer-related deaths, its impact is underscored by two primary histological classifications: squamous cell carcinoma and adenocarcinoma. Particularly notable in the United States and numerous Western nations is the predominance of adenocarcinoma, a trend paralleled by an increased incidence of obesity, gastroesophageal reflux disease, and Barrett's esophagus[1]. For individuals diagnosed with advanced-stage carcinoma, the prevailing treatment modality involves a multimodal approach comprising chemotherapy and radiation, followed by surgical intervention, which remains the cornerstone of management for the majority of patients.

Early efforts to address esophageal disorders date back to the 17th century, characterized by rudimentary procedures such as using whale bones for dilation in patients with benign esophageal strictures[2]. Progressing to 1913, Franz Torek of New York achieved acclaim for performing the first successful open esophagectomy for intrathoracic esophageal cancer. Notably, Torek also introduced double-lumen intubation, a development credited with significantly reducing postoperative mortality rates[3]. Subsequently, in 1933, Grey Turner of the United Kingdom conducted the inaugural successful open Trans-hiatal esophagectomy (THE), initially overshadowed by the transthoracic approach due to the advent of general anesthesia[4]. However, in 1978, Dr. Orringer revitalized interest in the transhiatal method, aiming to mitigate pulmonary complications, a primary concern of the transthoracic approach, by advocating for a thoracic incision-free procedure, thus minimizing the risks of anastomotic leak[5]. The rising prevalence of adenocarcinoma in the Western world further propelled the adoption of the transhiatal approach. Nevertheless, traditional anastomosis posed challenges due to the delicate nature of deep viscera, highlighting the significance of mechanical staplers as a pivotal innovation in the surgical subspecialty, reducing both the incidence and severity of anastomotic fistulas[6]. The advent of laparoscopic techniques provided a less invasive alternative to traditional open approaches for esophageal carcinoma, offering advantages such as decreased postoperative pain and shorter hospital stays. Jim Leketich's development and widespread adoption of totally minimally invasive esophagectomy in 1993 marked a significant milestone in surgical treatment[7]. Following the approval of the Da Vinci robotic surgical system by the Food and Drug Administration (FDA) in 2000, Broussard *et al*. pioneered robotic esophagectomy in 2002[8]. Since then, robotic technology has gained traction in esophageal surgery, with steady increases in utilization and efficacy.

ESOPHAGECTOMY TODAY AND TOMORROW

The Da Vinci robotic platform, approved by the FDA and developed by Intuitive Inc.®, serves as a valuable tool in various abdominal procedures, particularly those involving intricate and confined anatomical regions. Core features of this system include three primary components: articulated arms with free mobility, advanced three-dimensional high-definition video imaging capabilities, and a human-computer interaction design integrated into the primary control console[9]. While introducing robotic assistance has not notably altered the indications for esophagectomy or the specific surgical methodologies employed, its integration enables surgeons to expand the pool of eligible patients for procedures. This technology provides superior visualization compared to two-dimensional laparoscopic approaches and effectively mitigates tremors, enhancing surgical precision. Other notable advantages include decreased blood loss, fewer incisions, and an expedited recovery period[10,11]. Furthermore, studies indicate that, compared to non-robotic approaches, robotic operations do not exhibit significant disparities in terms of charges, costs, or profitability. However, the primary obstacle to widespread adoption of robotic technology in surgery remains its high financial investment. Consequently, refining operative strategies and optimizing outcomes in esophageal resections becomes imperative for effectively mastering robotic esophagectomy[12]. In recent developments, our team has concluded training sessions for the Single Port Da Vinci Robot. As part of this progression, we are poised to initiate the inaugural surgeon-led investigation device exemption (IDE) pilot study for Single Port Da Vinci Foregut and hepatopancreaticobiliary (HPB) operations. This milestone marks a significant advancement for the robotic platform, highlighting the efficacy of this cutting-edge technology in enhancing patient outcomes.

Ongoing advancements in robotic technology, imagining modalities, and surgical techniques continue to refine the field of esophageal surgery, focusing on improving outcomes, reducing morbidity, and enhancing patient experience. The trajectory of robotic assisted minimally invasive esophagectomy (RAMIE) is intricately intertwined with advancements in robotic platforms. Anticipated in the coming years is the emergence of multiple novel hardware systems. Recent enhancements in robotic tri-stapling devices, energy dissection instruments, and Firefly integration have streamlined the procedure. The most significant strides in robotic surgery are expected to stem from software innovations. Incorporating artificial intelligence (AI), data integration, and image connectivity will not only enhance precision surgery but also facilitate extensive data collection and machine learning capabilities[13-16]. For a succinct overview, the integration of AI in surgery encompasses machine learning (ML) and deep learning (DL) methodologies designed to emulate the cognitive processes of the human brain, thereby enhancing comprehension of intricate scenarios and facilitating improved decision-making capabilities. These algorithms, ML and DL, are rapidly advancing the prospects of autonomous surgical interventions[17]. By applying AI in robotic surgery, surgeons can harness the potential of these emerging technologies to enhance various aspects of the surgical process, spanning preoperative, perioperative, and postoperative phases. This includes analyzing motion and timing for simulated training, establishing standardized grading systems, precisely placing surgical clips, interpreting and processing images, delineating anatomical structures, detecting surgical instruments, and, in due course, enabling surgical systems to adapt to dynamic conditions, mitigating physiological movements, and augmenting surgical precision[18]. Furthermore, personalized medicine and targeted therapies offer new avenues for optimizing treatment strategies and improving survival rates for esophageal cancer patients. As esophageal cancers undergo thorough genomic profiling, agents such as ramucirumab, trastuzumab, and pembrolizumab are already used for treating esophageal carcinomas, reflecting this shift towards tailored treatment approaches[19].

DISCUSSION AND METHODS

Our institution prefers the transhiatal approach, necessitating comprehensive knowledge of preoperative patient readiness, pertinent surgical anatomy, and perioperative alterations. This is also largely because we are located in the United States, where the histologic subtype adenocarcinoma is most prevalent. In 2012, our facility conducted its inaugural robotic transhiatal esophagectomy (THE). Subsequently, our facility transitioned the entire esophagectomy program from laparoscopic to RAMIE. This strategic shift aimed to expand the pool of candidates eligible for minimally invasive surgery, capitalizing on the advantages offered by the robotic platform. RAMIE has proven to be both safe and efficacious regarding oncological outcomes, although proficiency in this approach requires overcoming a learning curve inherent to any novel surgical technology. Mastery entails enhancements in operative time, blood loss, and lymph node retrieval[18]. Moreover, a recent comprehensive analysis conducted by our cohort using the National Surgical Quality Improvement Program (NSQIP) database has underscored the safety and efficacy of the robotic approach in THE. The findings reveal not only the safety of this approach but also its superiority in terms of oncologic outcomes, as evidenced by a median survival exceeding 95 months[20]. The following discussion will outline our preferred institution's approach to performing a robotic-assisted THE.

Robotic THE is undertaken using the following steps:

1. Patient preparation for THE
2. Operation set up and robotic instrumentation for THE
3. The THE operation set up
    (1) Resection
        1) Kocher maneuver
        2) Crural and gastric dissection
        3) Pyloromyotomy
        4) Division of the left gastric vessels and lymphadenectomy
        5) Mediastinal dissection and neck dissection
    (2) Reconstruction
        1) Creation of gastric conduit and gastric pull-up
        2) Neck anastomosis and closure
        3) Closure of esophageal hiatus
        4) Postoperative patient management

Patient preparation for THE

The optimal treatment for esophageal cancer depends on the stage of the disease and typically involves a combination of treatment modalities. All patients in our institution undergo staging with computed tomography (CT), magnetic resonance imaging (MRI), endoscopic ultrasound/fine needle aspiration (EUS/FNA), and positron emission tomography (PET)/CT. Neoadjuvant therapy has been shown to improve long-term survival by providing locoregional disease control and by reducing the risk of long-term recurrence[13]. At our practice, per National Comprehensive Cancer Network (NCCN) guidelines, patients with T1b and T2 < 2 cm disease undergo surgical resection. Those with T2 > 2 cm disease or more advanced stages receive neoadjuvant chemoradiation followed by an operation. Generally, all patients with N1 disease or greater, regardless of T staging, undergo neoadjuvant therapy.

Informed consent is obtained. We implement a comprehensive enhanced recovery after surgery (ERAS) protocol to ensure thorough perioperative care. This protocol at our institution allows patients to take an active role in their healing process. ERAS patients typically leave the hospital sooner, recover quickly, and experience fewer side effects. The program consists of four steps: preparing the patient for an operation, managing patients' expectations on the day of their operation, educating them about recovery in the hospital, and recovery at home.

The surgeon discusses the operation's specifics with the patient and family. All possible complications, such as difficulties with swallowing, hoarseness, bleeding, infection, pneumonia, and inability to control the disease, are thoroughly explained and documented for the patients. All patients require cardiac and pulmonary clearances. If a patient smokes or drinks, She/He must stop four weeks before the operation. Incentive spirometers are provided to improve lung function, and ambulation with a physical therapist is encouraged. A diet and exercise plan is given to patients to best prepare them for the operation, which includes bowel preparation.

The bowel preparation regimen begins two days before the operation. Patients are asked to stop all aspirin or blood thinners seven days prior. Five days before the operation, patients begin taking immune-boosting protein shakes. Two days before the operation, patients start a liquid diet and take their first bottle of Citrate of Magnesia at 4:00 p.m. On the day before the operation, the patient follows a similar regimen and takes the second bottle of Citrate of Magnesia, ensuring that the two bottles were taken 24 h apart. The patient must refrain from eating or drinking anything after midnight.

On the day of the operation, the patient checks in two hours before the operation to undergo a surgical site infection (SSI) protocol. This protocol may include chlorhexidine body wipes, oral rinse, teeth brushing, and povidone intranasal swabs. SSIs related to robotic trocar incisions are generally minor and can be resolved with antibiotics, even if they occur after the patient is discharged from the hospital. The protocol also emphasizes pain management during the perioperative period, and our patients receive a preoperative epidural injection of Duramorph in the operating room, along with goal-directed fluid management.

Operation set up and robotic instrumentation for THE

Patients are positioned supine on the operating table with their arms extended. Once general anesthesia is administered, a nasogastric tube and a Foley catheter are inserted. The patient is then prepped from bedline to bedline. Typically, the procedure involves orienting the patient in a 15-20-degree reverse Trendelenburg position and a 5-degree rotation to the left. The operating room setup involves two teams, with two surgeons participating in the operation: one at the bedside and one at the robotic console. The bedside surgeon focuses on preparing the neck dissection, while the console surgeon handles both the peritoneal and mediastinal dissections.

The operation requires using four robotic trocars: three with eight-millimeter incisions and one with a 12-millimeter incision for the stapler device. Additionally, a single incision multi-trocar port is employed for laparoscopic instruments through a 2-3 cm incision, consisting of up to four different trocars. A laparoscopic suctioning device and an atraumatic bowel grasper are used through this port. Notably, this same port is used for specimen extraction. The robotic system is positioned just above the patient's right shoulder (see Figures 1 and 2).

The THE operation steps

Resection

Kocher maneuver

To initiate the surgical procedure, the Kocher maneuver is employed. It serves to mobilize the duodenum effectively and minimize any manipulation that could lead to injuries. Atraumatic bowel graspers, a fenestrated bipolar, and energized scissors are used to initiate and execute this maneuver. The maneuver begins by identifying the vena cava within the foramen of Winslow. The duodenum is then mobilized towards the left, allowing the pylorus to approach the hiatus. Particular attention is paid to avoiding any damage to the right gastric artery to ensure proper blood supply to and from the gastric conduit. There is no requirement to dismantle the Ligament of Treitz during this process.

Crural and gastric dissection

Next, the crural dissection and accompanying gastric mobilization commence. The gastro-hepatic ligament is opened in a stellate fashion, employing the same instruments of energized scissors, atraumatic bowel grasper and the fenestrated bipolar forceps. Afterward, the gastro-colonic omentum is carefully divided, being mindful not to injure the gastroepiploic vessels as the dissection proceeds toward the left crus. Subsequently, the short gastric vessels of the spleen are taken down. The dissection then progresses up and down the left crus, slightly extending into the mediastinum. This can be accomplished using just energized scissors and a fenestrated bipolar alone. Additionally, the dorsal attachments between the stomach and the ventral surface of the pancreas are taken down to allow free movement of the stomach towards the esophageal hiatus. Once this stage of the operation is completed, we proceed with pyloromyotomy.

Pyloromyotomy

This task is achieved using a hook cautery, fenestrated bipolar forceps, and a Maryland dissector. Starting from the distal stomach over the pylorus, a shallow incision is made using a hook cautery. The pylorus muscles are then divided while avoiding an injury to the submucosa. In the event of an inadvertent opening of the duodenal or gastric mucosa, a pyloroplasty is undertaken. However, such instances are rare as pyloromyotomy proves to be a highly efficient and expeditious procedure.

Division of the left gastric vessels and lymphadenectomy

Following the pyloromyotomy, the left gastric vessels are stapled and a thorough lymphadenectomy is undertaken. The stomach is elevated anteriorly to expose the left gastric artery and vein. By employing a hook cautery, the trifurcation of the celiac axis is dissected adequately to locate the left gastric artery at its origin. All lymph nodes surrounding the celiac trunk are meticulously removed, encompassing nodes along the common hepatic artery, the splenic artery, the left gastric vessels, peripancreatic lymph nodes, peri-distal esophageal lymph nodes, and lymph nodes near the proximal stomach. Utilizing a vascular stapler, the left gastric vessels are then divided at the trifurcation point.

Mediastinal dissection and neck dissection

The dissection is then carried into the mediastinum. The mediastinal dissection coincides with the circumferential dissection of the esophagus at the neck by the bedside surgeon. The esophagus is divided with an Endo GIA™ stapler at the neck while the surgeon at the console carries on the mediastinal dissection. At this stage, we transition to a vessel sealer in the mediastinum, although in certain cases, a

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Figure 1. Patient preparation: pictured is the patient and Dr. Sharona B. Ross after the patient was prepped from bedline to bedline. Typically, the procedure involves orienting the patient in a 15-20-degree reverse Trendelenburg position and a 5-degree rotation to the left.

hook cautery or energized scissors are chosen. Of note, radiation can lead to increased scarring in the esophagus and mediastinum. Nonetheless, effective dissection and lymphadenectomy of the esophagus can still be achieved, even without a large paraesophageal hernia that would provide more dissection space in the mediastinum. The dissection is carried up to the pulmonary veins. At times, it is necessary to enter into the pleura for a favorable oncologic resection. If such a situation arises, a small Cook catheter is inserted on the side of the capnothorax.

Reconstruction

Creation of gastric conduit and gastric pull-up

After the mediastinal dissection, the gastric conduit is constructed in the peritoneal cavity. As previously mentioned, the neck dissection can commence with the mediastinal dissection or may coincide with the construction of the gastric conduit. The console surgeon sections the stomach using a robotic green load stapler while preserving the gastric fundus. Once the conduit is constructed, a gastrotomy along the proximal stomach staple line is made, just distal to the esophagus. A nasogastric tube is inserted and carefully advanced through the posterior mediastinum into the neck which houses the proximal stapled esophagus. Upon reaching the neck, the nasogastric tube is sutured to the stapled esophagus and another nasogastric tube. Subsequently, the nasogastric tube is carefully pulled through the abdomen, facilitating the removal of the specimen. Once the specimen is extracted, the conduit is guided upward through the posterior mediastinum to the neck by pulling on the nasogastric tube at the neck.

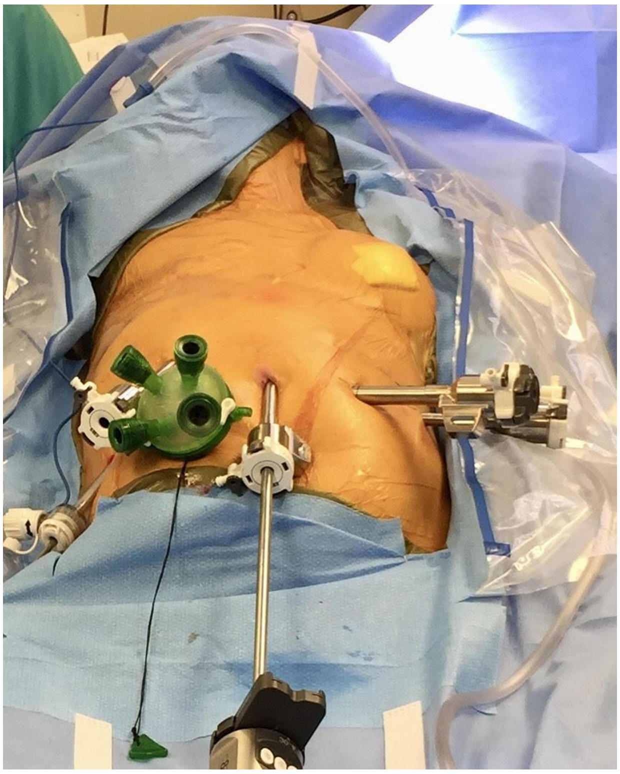

Figure 2. Port placement set-up: Dr. Sharona B. Ross and the patient are pictured with the surgical set-up of four robotic trocars: three with eight-millimeter incisions and one with a 12-millimeter incision for the stapler device. Additionally, a single incision multi-trocar port is used for laparoscopic instruments, involving a 2-3 cm incision and up to four different trocars.

Neck anastomosis and closure

Upon reaching the neck, a stapled esophagogastrostomy anastomosis is undertaken with an Endo GIA™ stapler, followed by closure of the common enterotomy using interrupted silk sutures. In the peritoneal cavity, we meticulously close the esophageal hiatus by employing V-Loc™ sutures in a running fashion, starting from the left crus and distal stomach all the way around to the right crus. This serves a dual purpose: firstly, to prevent internal herniation into the mediastinum, and secondly, to reduce tension on the anastomosis at the neck. We also make sure the pyloromyotomy is situated in the abdomen rather than the chest. An omental flap is created to provide coverage for the myotomized segment, minimizing the risk of any potential leaks. Once the omental flap is securely sutured, the surgical site is irrigated with Clorpactin® irrigation solution. Finally, we irrigate the diaphragm with bupivacaine solution and close all incisions both at the neck and peritoneal cavity along anatomic layers with absorbable sutures and steri-strips.

Postoperative patient management

After the operation, patients are encouraged to follow speech pathologist swallowing exercises daily. On postoperative day 3, they undergo a barium esophagogastrography to verify the prompt emptying of the gastric conduit and identify potential leaks at the esophagogastrostomy. To mitigate any complications, we encourage our patients to ambulate immediately following the operation, with the goal of walking for 20 min 4-5 times a day.

Additionally, swallowing difficulties and aspiration pose challenges to many patients, leading to progressive hoarseness over the initial 4-6 weeks. Soft foods, such as scrambled eggs and mashed potatoes, are better tolerated than liquids, particularly hot or cold liquids. Thickening fluids (i.e., nectarized) may be necessary for improved tolerance. Patients can expect discharge on the 4th or 5th day and should be closely monitored with an early return to the clinic. It is important to inquire about their eating, drinking, and bowel function, evaluate patients, and discuss with their families regarding general signs of failure to thrive.

CONCLUSION

The rise of adenocarcinoma as the dominant esophageal cancer subtype in the United States and Western nations necessitates continuously reevaluating treatment guidelines and techniques to optimize patient outcomes. While the current standard for advanced-stage disease incorporates a multimodal approach integrating chemotherapy, radiation, and surgery, the field of esophageal oncology has witnessed a remarkable evolution, transitioning from rudimentary procedures to contemporary minimally invasive techniques exemplified by robotic esophagectomy. This technological advancement signifies a pivotal milestone in surgical innovation, demonstrably paving the way for less invasive approaches with the potential for reduced postoperative complications and shorter hospital stays.

The Da Vinci robotic surgical platform represents a noteworthy contribution to abdominal surgery, offering enhanced precision, improved visualization, and potentially expedited patient recovery. While initial cost considerations may pose a challenge, the integration of robotic technology has the potential to broaden the eligibility criteria for procedures such as esophagectomy. Continued advancements in both hardware and software are anticipated to further refine robotic surgery, ultimately improving patient outcomes. Furthermore, the burgeoning field of AI and personalized medicine holds promise for developing optimized treatment strategies, potentially improving survival rates for patients afflicted with esophageal carcinoma.

As the field of Surgery continues to evolve, the paramount objective remains to maximize patient outcomes through the continuous refinement of surgical techniques, ensuring the sustained success of robotic-assisted procedures in this patient population.

DECLARATIONS

Authors' contributions

Data collection, drafting the article: Peek G

Conceptualization and design of the study, data analysis and interpretation, critical revision of the article, final approval of the version to be published: Peek G, Ross SB

Availability of data and materials

Not applicable.

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Conflicts of interest

Ross SB is a consultant for Medtronic, Johnson & Johnson, Qventus, Caresyntax, Boston Scientific, and serves as a consultant, proctor, and advisory board member for Intuitive Surgical. Other authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Consent to participate was obtained from all patients in this study prior to their procedures.

Consent for publication
Consent for publication was obtained from all patients in this study prior to their procedures.

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