Assessment of the educational approaches for robotic minimally invasive esophagectomy

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Abstract: Esophagectomy is a key element in the trimodal therapy for esophageal cancer. The advancement in minimally invasive and robotic technique have reduced the morbidity and mortality associated with open esophagectomy while improving the postoperative quality of life without affecting the oncological outcomes. This has reduced operative length of stay and increased the chance of patient receiving adjuvant systemic therapy. Recently, the number of esophagectomies performed minimally invasively have surpassed open esophagectomy. However, implementation of innovative surgical techniques always faces a learning curve that delays its adaptation. Anastomotic leaks can increase during the learning curve for both conventional minimally invasive and robotic assisted minimally invasive esophagectomy. Multiple authors have documented the number of esophagectomies needed to achieve proficiency or overcome the learning curve morbidity. This review focus on complete video assisted approaches (laparoscopic, thoracoscopic and robotic approaches). Utilizing a trans-hiatal or a hybrid approach can be considered minimally invasive by some but it's outside the scope of this review. Determining the ideal educational program is challenging due to the complexity and variety of required skills in both the abdomen and chest. The absence of a standardized and validated robotic esophagectomy curriculum demonstrates the need for a thoughtful approach to prepare trainee and surgeons to adapt these approaches. Establishing dedicated training centers supervised by surgical and academic societies may help surgeons from lower volume centers adapt these techniques.

Keywords: Minimally invasive esophagectomy (MIE); esophageal cancer; robotics; education; robotic-assisted minimally invasive esophagectomy (RAMIE)

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Introduction

Since the first large series on minimally invasive esophagectomy (MIE) by Luketich *et al.* in 2003 (1), multiple techniques utilizing the minimally invasive or hybrid approach have been introduced. The improved morbidity, mortality and short hospital stay (2) with equivalent oncological outcomes (3,4), has led to the wide adaption of these techniques. Currently the number of MIE and robotic-assisted minimally invasive esophagectomy (RAMIE) have surpassed the number of open esophagectomy (OE) performed in the United States (2).

RAMIE offers a proficient approach for esophageal, lymph node and hiatal dissection, fluorescence technology to ascertain conduit perfusion and less challenging techniques for the intrathoracic anastomosis. In 2016 we reported our early experience with the Robotic intrathoracic anastomosis using Circular End-to-End stapler with 0% leak rate and no conversion to open procedures (5). Similar experience

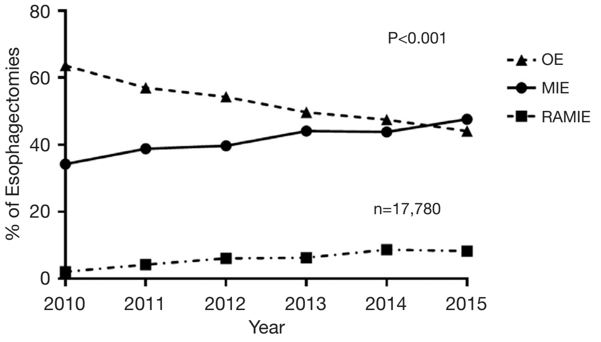

Figure 1 Trends of Esophagectomy for resectable middle and lower third esophageal cancer. National Cancer Database 2010 to 2015 (2). OE, open esophagectomy; MIE, minimally invasive esophagectomy; RAMIE, robotic assisted minimally invasive esophagectomy.

was reported by Okusanya in 23 cases performed by a single surgeon using a similar technique with 1 leak in a series of 23 cases (6). Other surgeons and institutions had reported the safety and feasibility of Robotic esophagectomy.

The first prospective trial comparing robotic-assisted minimally invasive thoraco-laparoscopic esophagectomy versus open transthoracic esophagectomy for resectable esophageal cancer (The ROBOT trial) comparing RAMIE (n=54) and OE (n=55) via a modified McKeown approach (7) with a 26% relative reduction risk in the RAMIE group in overall postoperative complications and similar oncological outcomes. Interestingly both arms utilized a cervical anastomosis and had a leak rate of 20%.

The TIME (8), MIRO (9) and the ROBOT (7) trials have shown that esophagectomy done Thoracoscopically, Laparoscopically or Robotically have the advantage in quality of life (QOL) questionnaires, facilitating the return to normal life and increasing the probability to complete systemic adjuvant therapy. The discussion of the best approach for esophageal cancer resection is ongoing and beyond the scope of this article. We think that the best approach is the approach that is feasible and safe for depending on the surgeon's experience and the patient characteristics.

The wide adaptation of MIE and RAMIE (*Figure 1*) (2,10) necessitate the need for a thoughtful educational approach to prepare the next generation of surgeons to master the complexities of esophagectomy. This review will consider the factors that may help trainees and surgeons achieve proficiency and navigate their learning curve for RAMIE.

Understanding the learning curve

The Learning curve is defined as the number of operations that must be performed by a surgeon to achieve a steady level of performance (11). Implementation of robotic surgery in various surgical fields have encountered a learning curve including colectomy (12), gastrectomy (13) and hepatectomy (14). This has been documented even in experienced hands for MIE (15). In a series of 170 MIE, White *et al.* described an accumulative learning curve for one surgeon over 7 years. In the study period, the length of stay and 90 days readmission decreased by the end of the study. No leak and one conversion to OE were reported in the fourth quartile, reflecting the ability of surgeon to affect outcomes from the experiences they gain during the learning curve (15).

The learning curve for MIE and RAMIE has been described by intraoperative blood loss, number of harvested lymph nodes, operative time and learning associated morbidity (15-19). Most of the studies analyzing the learning curve reported single surgeon and institutional experience with significant heterogeneity in methodology, how groups were assigned, surgical approach and surgeons experience. There is no universal admissible number of cases to overcome the learning curve as surgeons differ in their training and abilities but it is inevitable that surgeons will encounter a learning curve morbidity while implementing new technology. We aim to review the available literature that may help surgeons and trainee flatten their steep curve.

It is important to note that the learning curve for RAMIE is multiphasic. Van der Sluis has reported this finding for a proctor and a newly introduced surgeon in 312 RAMIE using the cumulative sum (CUSUM) analysis (17). Three phases of learning curve were described for both surgeons. Phase 1 describe the cases the surgeon needs to reach a relative plateau of proficiency. Phase 2 represent increasing competency and phase 3 represent the surgeons approaching more difficult cases including more proximal tumors or advanced staging (cT4b). This has been also described by Kim *et al.* in a multicenter prospective trial for robotic gastrectomy (13).

Attaining proficiency

Attaining proficiency level for trainees or new robotic surgeons require few key elements. This includes patient selection and preparation for robotic surgery, trocar placement, robot docking, trouble shooting, operating

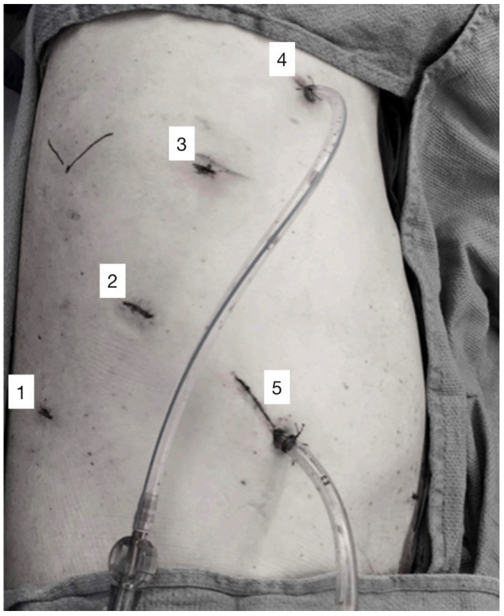

Figure 2 Robotic left lateral decubitus thoracic port placement. 1: tip-up forceps 8 mm port; 2: cadiere forceps 12 mm port; 3: zero-degree camera 8 mm port; 4: fenestrated bipolar 8 mm port; 5: assistant/end to end anastomosis stapler port. Source: Reference (21).

room (OR) team efficiency, and emergency undocking scenarios (20). Error in docking, trocars positions and robotic positions can make RAMIE more challenging and can lead the surgeon to convert to an open or hybrid approach. Attending bedside robotic training can help avoid these pitfalls. Port placement for RAMIE has been described in multiple reports (21,22). Choice of port placement in the abdomen will facilitate good visualization of the conduit and the ability to perform a Kocher maneuver without the need to redock. In the chest, it is important to plan port placement to allow esophagus dissection, lymph node dissection as well allowing for an intrathoracic anastomosis while avoiding arm collision. *Figure 2* shows our preferred thoracic port placement. This can be applicable to all robotic cases but it's of great importance in RAMIE, as dissection and exposure can become challenging with improper docking or port placement. This is more relevant to RAMIE as inefficient port placement and docking can increase the operative time in an already complex and lengthy procedure. Port placement can be particularly challenging in patients who underwent previous jejunostomy placement due to the adhesions and poorly planned jejunostomy. We recommend planning to place all ports more cephalad to the jejunostomy if possible or redo the jejunostomy to improve exposure, hiatal dissection, and conduit creation.

Sarkaria *et al.* described the elemental keys to achieve proficiency in their first 100 RAMIE case (23). These elements include pre-program cadaveric study, alternating bedside, and console roles between 2 surgeons after first 50 cases, senior expertise, and graded teaching of the procedure for their residents and fellows. We believe that graded teaching helps trainees achieve proficiency at a single task before moving on to a more complex and challenging part of the operation.

A pathway to competency in robotic thoracic surgery was suggested by Cerfolio (24). This approach allows for skills progression while maintaining the team confidence and avoiding lengthy operation that hurt a surgeon's reputation, utilizing a gradual pathway to progress toward more complex procedures, for example, in completing an esophagectomy in the chest without anastomosis before performing a complete RAMIE. Learning robotic procedures may be better achieved in a cumulative approach. This cumulative nature is an important part of our educational approach in robotics for our trainee. Robotic surgery is an important part of General Surgery training and some trainees are more versed with the principles of robotics than others. It is important to understand your trainee's robotic experience. These discussions and feedback have better results and retention when done in advance or after the case.

The value of simulation

The competency training and simulator plays a critical role in learning robotics. It allows surgeons to master basic robotic skills that are applied in different portions of a RAMIE. The da Vinci Skills Simulator (Intuitive Surgical, Sinnyvale, CA, USA) using a da Vinci Console and MIMIC simulation technology offer some basic robotic skills simulation that have been validated and has the potential to increase psychomotor skills and platform familiarity (25,26). It is recommended to complete 19 of 30 simulation exercise with a score of higher than 80% for novice users (27). This training is often a part of a general surgery residency and sometimes even during a surgical rotation for medical students. With the scarcity and unavailability of robotic time, simulation can help trainees build muscle memory for suturing, tying and enforcing safe robotic principles. Transforming these skills into a complex procedure like RAMIE can be challenging, starting with novice steps (dividing gastrocolic omentum, hiatal dissection

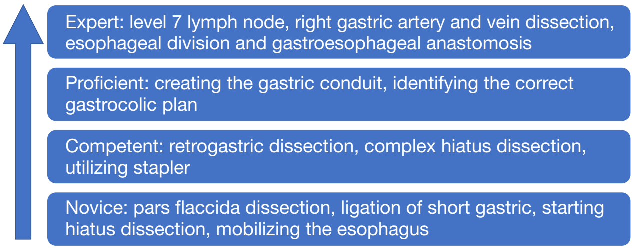

Figure 3 Flowchart of experience level and associated steps for RAMIE. Attending can help in exposure initially before progressing to "Expert" level. RAMIE, robotic assisted minimally invasive esophagectomy.

in the abdomen and opening the posterior pleura and dividing the azygous in the chest) can teach trainees visual feedback and tissue handling before progressing to more challenging parts.

Transitioning from simulation to handling real tissue can be more challenging in robotics. In an open esophagectomy, the attending surgeon can easily redirect and provide exposure to the trainee. In robotics, the surgeon sitting on the console has full control, and it will be hard to overcome any mistakes once they are made. One way to overcome this is the attending maintaining control of the third robotic arm to improve retraction and optimize exposure while the trainee improve their skills using instruments like the bipolar or stapling.

This transition is granular and can be guided by meeting certain milestones while progressing from novice steps to more technically demanding. It's important for the mentor to provide transparent and constructive feedback in a non-stress environment after the operation. Our stepwise approach is listed in *Figure 3*. Once the trainee masters a task they move to the next level. Progression in these tasks is from low to high risk and with ascending technical difficulty not in the sequential order of the operation. The attending surgeon can optimize the exposure during the task or let the trainee obtain their exposure or work in less ideal situation to challenge their skills (28). The time given to complete each task depends on the complexity of the task and the progression made by the trainee.

Mitzman *et al.* has described their formal curriculum for robotic thoracic surgery (28). In their review they reported their approach to teaching trainee robotic lung resection utilizing simulation, a progressive approach for intra-op task and video-based review and coaching. In their review, the trainee masters novice steps like inferior pulmonary ligament take-down before eventually progressing to expert level task like fissure dissection.

No expert robotic courses or simulation module for RAMIE exist, but a model for robotic pulmonary resection exist and have been validated in 30 participants including novice users, intermediate level surgeons with experience in VATS lobectomy, as well as experts who have performed Robotic lobectomy (29). To our knowledge, no similar module is available for esophagectomy, and arranging a wet lab training for esophagectomy might be a solution for this inadequacy.

In our institution, we arrange an annual Robotic week to prepare the incoming new trainees on the basic robotic skills, emergency undocking scenarios, and an animal module for lung and esophagus surgery. This approach helps trainees familiarize themselves with these procedure in a low stress environment and also gives our faculty a chance to understand the trainee level of skills and advise them how to move forward.

The intrathoracic anastomosis remains the Achilles tendon of RAMIE, leading to the learning curve morbidity (16) which can be avoided in some scenarios. Fabian has described a simulation of Thoracoscopic Intrathoracic Anastomosis for MIE that can be replicated in similar fashion for RAMIE. Their model was validated in five trainees (30). A cervical esophagogastric anastomosis simulator was designed by Orringer *et al.* using a portable and low-cost training box (31) that can be valuable to teach this approach to trainee.

The problem and the solution, structured robotic training

In voluntary survey completed by recent graduates of thoracic surgery training, 61.5% reported discomfort with robotic esophageal operation (32). This demonstrates the need for a thoughtful approach to improve the current robotic training. This includes creating a validated systemic RAMIE curriculum to train the next generation of robotic esophageal surgeons.

Raad *et al.* have proposed a structured curriculum divided into two stages: pre-clinical (PGY 2 and 3) and clinical (PGY 4–6) (33). In the pre-clinical years, residents complete online modules via the Fundamentals of Robotic Surgery or Intuitive Surgical Inc. da Vinci Surgery Online Community (Sunnyvale, CA, USA) and complete simulation modules achieving >85% score. The clinical years residents serve as the beside assistants and console surgeons in a graduated

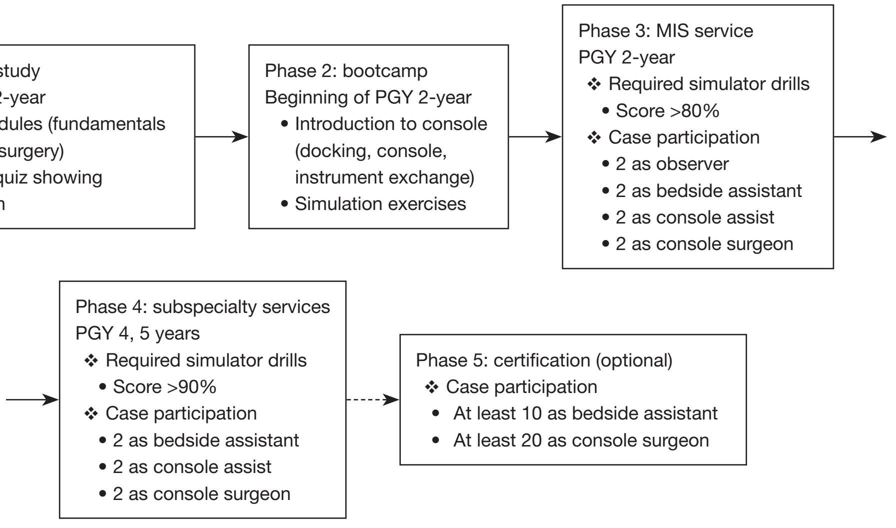

Figure 4 Proposed curriculum by Alicuben *et al*. (36) for general surgery trainee, each phase is completed by graduated responsibilities. PGY, post graduate year; MIS, minimally invasive surgery.

fashion. Once the residents show proficiency completing a task, they can progress to more complex components. This approach allows for training to occur during an extended period of time which decreases fatigue and enhances skill retention (34,35). Similar curriculum was suggested by Alicuben *et al.* for general surgery trainee (36) and is shown in *Figure 4*.

In Van Der Sluis *et al*. review of the learning curve in 312 RAMIE (17), they described the learning curve for two surgeons, a Proctor and Surgeon 2. Surgeon 2 was introduced to RAMIE after 20 procedures as bedside assistant and 5 observational cases. Fifteen RAMIE were performed under direct supervision by the proctor, who had performed 150 RAMIE at that time and achieved a steady performance. With this approach, surgeon 2 reached a steady performance within 13 months and after 24 cases which was a reduction of 66% in the number of cases and 76% in time compared to proctor learning curve. This highlights the importance of a structured and graduated curriculum to flatten the learning curve for RAMIE.

Recently, fourteen worldwide RAMIE experts were enrolled in a Delphi consensus project for elements of RAMIE training. This included 49 item questionnaire. Forty items reached consensus (20). All experts agreed to a standardized robotic curriculum that is divided into stages and includes baseline evaluation for assessment of training needs and bench marking to assess progress. Almost 93% agreed on the need for completion of e-learning and baseline evaluation before attending a robotic training course. 66% felt that the trainee's ability to practice independently depends on achieving benchmarks and not a minimum number of cases. The authors also proposed the idea of RAMIE training centers that can be accredited via recognized education entity. This might be an important tool to help surgeons from lower caseload centers to adapt RAMIE, as the current curriculum are industry-based and not regulated by a scientific society. Although the proposed curriculums have not been validated, they offer the foundation for a dire need in a program that will facilitate the growth and adaption of RAMIE.

Conclusions

Robotic esophageal surgery continues to advance and gain more acceptance. This creates a need for a structured educational approach that helps trainee and future adaptors navigate the learning curve of these procedures. Establishing a RAMIE curriculum that includes a staged training in basics of robotics, bedside assistant and proctored cases will help surgeons attain proficiency and reduce the learning curve.

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Footnote

Conflicts of Interest: Both authors have completed the

ICMJE uniform disclosure form (available at https://vats.amegroups.org/article/view/10.21037/vats-22-46/coif). JOW serves as an unpaid editorial board member of *Video-Assisted Thoracic Surgery* from June 2022 to May 2024. JOW reports that he is a consultant for Intuitive, Ethicon, Medtronic, and Boston Scientific. Institution has research grant with Intuitive for robot. He also received payment for expert testimony for case reviews. The other author has no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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