Do robotic arms retrieve more lymph nodes during an esophagectomy?

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Contributions: (I) Conception and design: All authors; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: None; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Esophagectomy is considered as one of the surgeries in ultra-major scale that carries significant morbidity and mortality. The outcome of esophagectomy is directly related to surgeons' experience and hospital volume. Minimal invasive esophagectomy (MIE) aimed to achieve transthoracic esophagectomy and adequate lymph node dissection while reducing morbidities related to open thoracotomy. Results showed that MIE was associated with significantly lower blood loss, shorter length of stay with no difference in the number of lymph node dissected.

Keywords: Esophageal cancer; esophagectomy; robotic surgery

Received: 28 December 2019; Accepted: 23 February 2020; Published: 25 June 2020.

doi: 10.21037/aoe.2020.02.03

View this article at: http://dx.doi.org/10.21037/aoe.2020.02.03

History

The thoracoscopic esophagectomy was first described in 1993, called as en bloc esophagectomy (1). Mortality from open esophagectomy ranges from 8% to 23%, dramatically dropping to less than 2% after the minimally invasive approach (2,3).

The first transthoracic esophagectomy was performed by Melvin *et al.* (4) in 2002; Horgan *et al.*, in 2003 (5), reported the first series of 18 patients with high-grade dysplasia and esophageal cancers operated through the trans hiatal robot-assisted laparoscopic esophagectomy; Kernstine *et al.* in 2004 introduced the systematization of RAMIE (robotic assisted minimally invasive esophagectomy) (6) in 14 patients operated on; they pioneered performed three field lymphadenectomy robotic esophagectomies successfully; these authors published a larger series in 2008 (7). The comparison of RAMIE with traditional video-thoracoscopic (VAMIE) access clarified the excellent maneuverability of robotic arms and instruments, as well as a great 3-D visualization compared to conventional 2-D view.

The prone positioning was adopted in robotic access (8), allowing performing esophagectomies without selective bronchial intubation, thus decreasing dramatically the pulmonary complications, one of the most important complications of the esophagectomies performed through open and laparoscopic access (9).

Introduction

Esophageal cancer is the 6th cause of cancer mortality in the world. There were estimated more than 450,000 new cases of esophageal cancer, as well as more then 400,000 deaths related to this devastating disease. There are two most prevalent types of esophageal cancer: adenocarcinoma and squamous cell cancer. Their etiology, location in the esophagus, and natural evolution are completely different. The most important etiological factors of squamous cell cancer are tobacco and alcohol abuse, and they are predominantly located higher in the esophagus, mostly in the mid esophagus. The adenocarcinoma, which is more frequently related to gastro-esophageal reflux, occurs more frequently close to the esophagogastric transition. The main symptom, dysphagia, tend to occur late in the cancer development, and the late diagnosis defines the poor prognosis of the disease, with less than one third of the patients submitted to radical treatment; even when there is a curative-intended therapy, less than one third survive after 5 years (10).

Esophagectomy is the elected treatment for esophageal cancer, and is associated with high rate of complications and significant mortality. These rates have decreased over time, with the development of less invasive procedures, better perioperative nutritional and clinical care, and better selection of the patients for surgical treatment. Pulmonary complications had a dramatic drop after minimally invasive approaches were developed, and mainly after the adoption of the prone position. The mortality decreases after a lower rate of complications, and more patients are eligible for adjuvant therapy (11).

The esophagectomy is one of the most aggressive surgical procedures, and outcomes are closely related to the hospital volume and surgical team experience with the procedure. Open thoracotomy could have mortality higher than 10%, and more than 50% of major complications. Minimally invasive procedures through laparoscopic or robotic access provide a less aggressive surgical dissection, as well as a better instrumentation and visualization for more accurate dissection and lymph node harvest. These minimally invasive accesses are related to less bleeding and length of stay (12).

The thoracoscopic access was introduced in the early 1990s, and the robotic approach in the beginning of the 2000s. Both approaches were applied to perform trans hiatal, Ivor Lewis or McKeown techniques, and a few publications report a better outcome and less complications with the new approach (13).

In stead of being minimally invasive approaches with thin and less aggressive instruments, the thoracoscopic and robotic accesses have some differences that may lead to a shift in the outcomes of the esophagectomies: the use of rigid instruments through conventional thoracoscopy limits the surgeons' dissection capabilities; on the other hand, the robotic approach provides a 3D vision, wristed instruments that allow better dissection, increasing surgeons' dexterity (11). By reducing the surgical trauma, the consequences are less bleeding, fewer complications, shorter stay in the intensive care and in the hospital, thus decreasing mortality rates (14). There are evidences that other factor that decreases complications rates is the standardization of the procedure (15), and there have been efforts to exchange experiences and tips to define a step-by-step standard for trans hiatal and transthoracic robotic esophagectomy with lymphadenectomy (16), providing a safer introduction of robotic technology in specializes centers.

There are other advantages of the robotic access.

One of them is the real time use of near infrared fluorescence technology with indocyanine green to visualize vascularization of structures and locate lymph nodes, and may lead to decrease of leak rates in esophagectomies (15). It takes more than fifty esophagectomies to reach the learning curve of the robotic procedure, and it is an additional tool for high volume surgeons in a specialized environment (11).

Another potential advantage of the robot is that, with 3D vision, wristed thinner instruments and precise dissection with access to structures not reached through conventional thoracoscopic approach, being able to perform procedures almost impossible through the previous approaches (17,18). There are two critical areas to be reached: high mediastinal and cervical esophagus.

In the conventional approaches, the cervical dissection is always through open cervicotomy. It is feasible to docking the robot for a cervical approach, allowing triangulation and dissection with direct view of the cervical esophagus and lymph nodes (19). The recurrent laryngeal nerves lymph nodes harvest is challenging with conventional instruments, leading to a high rate of recurrences and nerve palsy, mainly in the left side, in tumors located high in the esophagus. These complications may be reduced through the robotic access (20).

Series of cases of robotic esophagectomy

Fully robotic esophageal surgery is feasible; Grimminger *et al.* performed 100 procedures using this technique: the fully robotic approach of esophagectomy with an intrathoracic gastric pull-up reconstruction allowed a superior and highly controlled lymphadenectomy compared to conventional approaches. The results were better than historical previous conventional approaches, with less ventilator support and less intensive care unit stay, lower pulmonary complications, with similar oncological lymphadenectomy and R0 outcomes (21).

Chiu *et al.* utilized a hybrid access—thoracic robotic and laparoscopic abdominal access—to perform McKeown cervical anastomosis. Long mean operative time (over than 8 hours), blood loss of about 300 mLs, with no pulmonary complication and mean hospital stay of 13 days (11).

Dunn *et al.* performed robot-assisted trans hiatal esophagectomy (RATE) in 40 patients, resulting in acceptable operative time, blood loss, and few postoperative complications (22); similar conclusions were reached by Potscher *et al.* with 33 robotic surgeries, with no conversion or intraoperative complications (14).

Robotic Ivor Lewis esophagectomy was reported by Cerfolio *et al.* in 22 patients, with hand-sewn anastomosis. There was only one anastomotic leakage and the authors report less gastric pouch ischemia and avoidance of left recurrent laryngeal nerve injury in order to indicate this technique (23).

A retrospective review was conducted to collect clinical, outcomes, and survival data for 100 consecutive patients with esophageal cancer undergoing RAMIE between March 2007 and December 2014. Postoperative complications commonly observed were nonmalignant pleural effusion (38%) and recurrent laryngeal nerve injury (33%); 30-day mortality rate was 2%. RAMIE was considered an effective and safe oncologic surgical procedure in a carefully selected group of patients with acceptable operative time, minimal blood loss and standard postoperative morbidity (22,24).

In a larger series, with 140 patients operated on (93.6% squamous cell carcinomas), the authors emphasize the importance of the learning curve and its impact in decreasing complications. After 30 cases, the number of lymph nodes increased from 25 to 45. After 60 cases, the vocal cord palsy decreased from 36% to 17%. Dramatic decrease of total operative time (496 to 433 min), length of stay (24 to 14 days) and anastomotic leakage (15% to 2%) occurred after 80 cases (25,26).

The prone position was adopted by Kim *et al.* in 21 patients with esophageal cancer, and the authors had no previous experience with the thoracoscopic approach (26). They emphasize the large number of harvest lymph nodes (38.0±14.2), and a significant decrease of the console time after 8 surgeries. This study suggests that the robotic access may have advantages in performing esophagectomy, decreasing the steep learning curve.

Guerra *et al.* (27) performed 38 robotic esophagectomies, with no conversion and R0 resections in all patients, 33 (10–89) dissected lymph nodes; morbidity of 42% and 10% mortality; after 1 year 78.9% of the patients were disease free and the overall survival was 84.2. Of the 108 patients with potentially resectable esophageal cancers operated by van der Sluis *et al.* (28), 26 was the median number of harvest lymph nodes, 42% of 5-year survival, 21 months of median disease-free, and 29 months of median overall survival. Tumor recurrence occurred in 51 patients and was locoregional only in 6 (6%) patients, systemic only in 31 (30%) patients, and combined in 14 (14%) patients. Park *et al.*, (29) reached a rate of R0 resection in 97.4% of 111 patients operated on; high number of harvest lymph nodes was achieved: 43.5±1.4 total, 24.5±1.0 mediastinal and 9.7±0.7 recurrent laryngeal nerves.

In all these reported series of cases, the robotic assisted minimally invasive esophagectomy had an acceptable oncological result, high number of R0 radical resections and appropriate lymphadenectomy, low local recurrence after proper long follow-up.

Comparison of robotic and minimally invasive esophagectomy

Open × robotic

The comparison of robotic (RAMIE) and open (OT) approaches by van der Sluis (30) in a randomized controlled trial, showed less overall surgical and pulmonary complications, lower postoperative pain, better quality of life and functional recovery of RAMIE compared to OT; on the other hand, the oncological outcomes were similar between the two approaches.

The ROBOT trial, that included patients with advanced esophageal cancer, showed evidence of superiority of RAMIE over OT. The advantages included lower complication rate, less bleeding, less pulmonary and cardiac complications, but R0 resection and number of harvest lymph nodes were similar (21).

Trans hiatal laparoscopic × robotic

Washington *et al.* (31) concluded that laparoscopic and robotic trans hiatal esophagectomies have similar oncologic results in terms of R0 resections and harvest lymph nodes; for these authors, robotic approach is oncologically noninferior to the laparoscopic (31).

Robotic transhiatal × thoracoscopic

A comparation between robotic trans hiatal esophagectomy (RTHE) and trans thoracic approach (RAMIE) concludes that there is a better post-operative quality of life with RAMIE (32).

Another study comparing the two approaches in 37 patients with distal esophageal cancer showed that RTHE scored better than RAMIE in terms of physical, emotional and social aspects, as well as for pain; after two years, RTHE group had higher scores for quality of life, pain, fatigue, dry mouth and insomnia. Symptoms as eating disorders, body composition and nutrition were similar (33).

Robotic (RAMIE) × video (VAMIE) × O (OT) thoracoscopy

Two studies with large number of patients from the National Cancer Data Base were published comparing RAMIE × VAMIE × OT (34).

One of them collected data from 9,217 patients submitted to RAMIE (581 patients; 6.3%), VAMIE (2,379 patients, 25.8%) and OT (6,257 patients, 67.9%) for unmatched and matched cohorts. In both groups the 30-day mortality was higher for RAMIE group. OT group had less dissected lymph nodes than RAMIE and VAMIE. Differences in survival were not statistically significant (48 months for RAMIE, 44 months for VAMIE and 41 months for OT. There were 569 patients in each group for the propensity-matched study, with different results: similar number of harvest lymph nodes and survival (48, 49 and 44 months, respectively) for the three groups. The authors suggest that the experience and expertise of the surgeon may have higher impact than the surgical approach for esophagectomies (34).

The other study based on The National Cancer Database included 5,553 (7.8% RAMIE, 28.4% VAMIE, 63.8% OT) patients with Stage 0 to III esophageal cancer (12). The results of the comparisons for length of stay, 30-day readmissions, mortality and overall survival rates had no statistically significant differences between the three groups. There was a trend for better results of RAMIE in total and upper mediastinal lymph nodes dissection, and better 5-year disease-free and overall survival after more complete mediastinal lymphadenectomy (34).

Thoracoscopic × robotic

Revisions comparing similar group of patients with esophageal cancer operated with minimally invasive thoracoscopic esophagectomy (MIE) or robotic assisted surgery (RAMIE) to performing McKeown procedures (13,35), demonstrate comparable surgical time, bleeding and harvest lymph nodes; no significant difference in complications and mortality between the groups, as well as for R0 resection, or time spent in intensive care and in the hospital. These revisions conclude that the two approaches are comparable. The robot has some differences with thoracoscopic approach better optics, a stable camera, thinner and wristed instruments allowing to perform more difficult dissections in tight spaces, as well as the comfort of the sitting operation set. The disadvantages of the robot are higher fixed and maintenance costs than conventional thoracoscopy, the specialized training required and the separation of the surgeon from the patient.

Robotic (RAMIE) × video (VAMIE)

Regarding RAMIE compared to VAMIE, some studies demonstrated similar complication rates between the two groups (17,36), but ICU stay was significantly shorter and there was a trend in improved lymphadenectomy in RAMIE (37).

A meta-analysis including 1,862 patients (931 in each group) showed no difference for R0 resection rate, conversion to open, 30-day mortality rate, 90-day mortality rate, In-hospital mortality rate, postoperative complications, number of harvested lymph nodes, operation time, and length of stay in hospitals. RAMIE had significant less blood loss and lower rate of vocal cord palsy rate than VAMIE group (38).

The important advances in VAMIE over the past 20 years have led to better surgical outcomes by experienced surgical groups, but the lymphadenectomy still represents a challenge for VAMIE, particularly the left side lymph node harvest in the left recurrent laryngeal nerve, because of technical limitations (difficult dissection in small surgical field with rigid instruments and bidimensional vision); randomized studies showed advantages of RAMIE in decreasing vocal cord palsy after the recurrent nerve lymphadenectomy (20).

Suda *et al.* (39) compared RAMIE to VAMIE in 36 patients with squamous esophageal cancer. VAMIE had higher incidence of vocal cord palsy and hoarseness compared to RAMIE, attributing these findings to a better visualization and ergonomics, and safer dissection with the robotic approach.

Chao *et al.* (20,40,41) published series of McKeown esophagectomies and bilateral recurrent laryngeal nerve lymph node dissection, comparing the RAMIE *vs.* VAMIE approaches in patients with squamous esophageal cancer. The only difference between the two groups was in the recurrent nerves lymphadenectomy, mainly in the left side, with similar pulmonary complications and vocal cord palsy.

Deng *et al.* (17,42), included 84 consecutive patients in a randomized prospective study comparing RAMIE and VAMIE, with 42 patients in each group. Results were similar in both groups regarding complications and length of stay; otherwise, RAMIE surgeries were longer, but had better results for bleeding and lymph node harvest in the three fields—total number of lymph nodes (21.9×17.8), right recurrent laryngeal nerve lymph nodes (2.1×1.2) and abdominal lymph nodes (10.8×7.7) than VAMIE (17,42). Similar results were achieved for Kim *et al.* (43); RAMIE had higher number of right RLN lymph nodes compared to VAMIE (2.1 and 1.2) with same rate of RLN palsy.

Park *et al.* (44) made a similar study in a total of 105 patients with squamous carcinoma of the esophagus. Results were similar for operative time, surgical outcomes and late survival, with similar 5-year results (69% and 59%). Advantage of RAMIE for lymphadenectomy in the three fields—total number (37.3±17.1 *vs.* 28.7±11.8), upper mediastinum (10.7±9.7 *vs.* 6.3±9.3) and abdomen (12.2±8.7 *vs.* 7.8±7.1); nevertheless, the better lymph node harvest showed no impact on long term survival (27).

The robotic approach provides a surgical cervical approach through direct vision and triangulation for lymph node dissection, otherwise impossible in open procedures and virtually impossible through conventional laparoscopic approach (44). This access enables lymph node retrieval otherwise impossible through open or thoracoscopic approach for patients who had positive documented lymph node involvement (45,46), despite having higher complication and mortality rates for radical surgery with curative intention, but oncologic results comparable to more distal cancers (46).

Comments

Esophagectomy still remains a surgical challenge nowadays, with significant morbimortality rates. It is a complex surgery, frequently leading to cervical, thoracic and abdominal access in the same procedure, demanding long hours to be accomplished. Skilled surgeon, well trained surgical team, anesthetic careful attention, specialized intensive unit facility and careful attention through a long-term hospital stay are needed to decrease complication rates.

The employment of less aggressive techniques, through thoracoscopic approach in steady of open thoracotomy in the last two decades had a tremendous impact in metabolic response to surgical trauma, leading to increase safety and efficacy of the surgeries, and significantly decreasing minor and major complications and mortality. The prone position without selective ventilation determined even better pulmonary complication rates. VAMIE is non inferior do OT, and intensive care unit and hospital stay have decreased overtime. Oncologic outcomes of VAMIE are similar or better to open esophagectomy (13,47).

More recently, the robotic approach was introduced in order to overcome the limitations of the conventional thoracoscopic approach:

(I) Bidimensional view and unstable camera, that make more difficult the visualization of the operative field, mainly when aggressive lymph node dissection is required.
(II) Rigid instruments that limit the surgical dexterity and determine cumbersome procedures, especially in the thorax, particularly in the upper esophagus.
(III) Limited access to proper triangulation and dissection in the thoracic region with the conventional thoracoscopy.
(IV) Inability to access the cervical region through minimal access with the rigid and large instruments.

There are still controversies about the advantages of the robot in surgery. The recent acquisition of the technology, its limited use because of high cost environment, the natural resistance of the surgeons to adopt new technologies that demand hard training and waist of long time to accomplish are some of the factors that affect acceptance of the robotic platform.

In urology there is almost a consensus about the use of the robot for prostatic cancer treatment. It is possibly one of the most important unanimities in surgery, and has shifted the urologists practice direct from open to robotic surgery, as laparoscopic urologic procedures are demanding and technically challenging because of the limitations of the laparoscopic access and the limitations of the available instruments.

The adoption in others specialties is variable, with an important increase in gynecologic surgeries, mainly hysterectomies. In general surgery the robotic platform has been used for almost all procedures, from abdominal wall defects to hepatectomy, with variable acceptance rates in different hospitals, regions and countries. In thoracic surgery there has been a slow growing of the use of the robot, similar to the introduction of the thoracoscopic approach to this particular specialty.

There are some radical authors claiming that the robot represents a technology looking forwards applications that will never come, much more than a real shift for better surgical results and patients' outcomes (13,47).

There are some very important differences (and advantages) between the laparoscopic and robotic platforms; some of them can be overcome by the conventional laparoscopic set, but others probably not.

The first difference is the 3D visualization camera system. In the current da Vinci model the operative field is seen through a console, as if the surgeon was "inside" the cavity and very close to the structures. Most of the future robotic platforms will not use this technology, with the 3D vision system made through monitors with eye tracking system or the conventional glasses to create the 3D imaging. Some of the current laparoscopic sets already adopted this concept.

Wristed instruments developed for the robotic system, too, can be designed for using in the laparoscopic surgery, with some few differences.

However, the most important concept of the robotic system, that made a shift in surgery, was the separation of the surgeons' hands of the instruments, creating an environment with countless opportunities to insert softwares to help improving the surgical practice. The surgeon is sitting in a much more ergonomic positioning, decreasing the fatigue and dexterity loss during a long-lasting surgery. The camera and instruments are under direct control of the surgeon, and there is not the fulcrum effect of laparoscopy; in this system the tip of the instrument moves in the opposite position of the surgeons' arm, and there is a magnification of the tremor. In the robotic system, the instruments have seven degrees of freedom, trembling control. The use of dyes to highlight structures or fluids, special lens, softwares to help controlling the instruments and scale motions, future "intelligent" instruments to identify structures and tissues, use of big data to help identifying structures and make real time decisions during the surgical procedure, machine learning and many other possibilities that creativity will develop, allowing to perform new procedures impossible through the current open and video systems.

This whole new system will help to make easier very difficult and complex surgeries (32). Regarding to esophageal surgery, the stable and three-dimensional image allowing a very close observation of the operative field, enables a more precise dissection of the esophagus and surrounding tissues, helping to preserve the important delicate mediastinal structures that need to be preserved (48). This is particularly important in the mediastinum, where the steady camera and ten times magnified field of view makes safer the manipulation of delicate structures that are always moving because of the continuous movements caused by breathing and pulsatile movements of the heart and aorta (33). The use of dyes, the current near-infrared fluorescence imaging fluorescence angiography with indocyanine green, helps to identify the gastric conduit vascularization, localize lymph nodes and vascular structures, thus preventing unintended injuries, helping to overcome the learning curve for these operations. There is a great potential for future use of this technology by developing softwares to identify structures or even malignancies (49).

There are various known disadvantages of the current robotic system. The high cost of the system, the maintenance and instruments with limited number of uses, prevent a rapid spread of the adoption of the system. The platform is cumbersome and limits the movements of bedside surgeon and auxiliaries; at least in the beginning of the experience, the required docking and undocking add operative time to the surgery (47).

There are growing evidences that the advantages of conventional thoracoscopy over open esophagectomy—reduced surgical trauma, less bleeding, shorter intensive care unit and hospital stay, decreasing in morbidity and mortality—may be overcome by the robotic approach (32). Robotic assistance in esophagectomy has been described performing procedures similar to the thoracoscopic approach and probably new surgeries eventually will be available because of the versatility of the robotic system (13,50).

An all robotic trans hiatal associated to a cervical approach has been described to decrease postoperative pulmonary complications maintaining the lymphadenectomy; its short-term outcomes are promising (51). Others combinations, as prone positioning and use of four arms helping completeness of mediastinal dissection (50).

There is no consensus about advantages of robotic surgery over conventional thoracoscopy. The available literature is limited, with a relatively small number of cases, and a diversity of techniques are utilized, and eventually definitive conclusions regarding the benefits of robotic assistance are difficult to establish; it is true the conclusion that the two techniques are at least equivalent regarding to immediate postoperative results (13,50).

Lymphadenectomy is key part of oncological radical esophagectomy, and advantages on lymph node harvest of RAMIE over VAMIE remains unclear. There are other factors influencing the results, such as an exact preparation of the patient, surgeons' expertise and adequate environment (14).

There is a conflicting literature about the advantages of the robot in lymph node harvest: some publications show advantage and other, no difference. Studies comparing the two techniques, such as the publication of Weksler *et al.* (34) found the same number of lymph nodes (mean number: 23 and 23, respectively) comparing 11 patients with RAMIE and 26 VAMIE patients. Suda *et al.* (39) in two groups with 16 RAMIE and 20 VAMIE patients, found a comparable lymph node yield between RAMIE and VAMIE (mean number: 37.5 and 39, respectively). Yerokun *et al.* (52), in a group of 340 patients (170 RAMIE patients and 170 VAMIE patients), also found equivalency (mean number: 16 and 16, respectively). Other authors found advantages of the robot. Park *et al.* (53) in a comparative study including 62 RAMIE and 43 VAMIE patients, found significantly larger number of dissected lymph nodes in the RAMIE group, in the total number of lymph nodes (37.3 *vs*. 28.7), upper mediastinum (10.7 *vs*. 6.3), and abdominal (12.2 *vs*. 7.8), compared to the VAMIE group. Chao *et al.* (40), with 34 patients on each group, found no significant difference of total dissected lymph nodes (37.2 and 36.2) but RAMIE yielded significantly more left recurrent left nerve lymph nodes than VAMIE (5.3 and 3.4). Similar results were obtained in the comparisons made by Kim *et al.* (26) in terms of recurrent nerve nerves lymphadenectomy (RAMIE 2.1 and VAMIE 1.2) without increasing rate of RLN paralysis, and also Motoyama *et al.* (54) described advantage of RAMIE over VAMIE in dissecting lymph nodes from around the left recurrent laryngeal nerve (6 in the RAMIE group and 4 in the VAMIE group).

Robotic surgery is a developing technology that will probably allow the performance of safer and more complete surgeries, with less trauma and postoperative complications (13).

Conclusions

Esophagectomy is difficult, complex, time-consuming and it is associated with significant morbidity and mortality. The adoption of minimally invasive techniques is an attempt to, without compromising the safety and efficacy of the procedure, decrease surgical morbidity and mortality. Many papers regarding safety and efficacy of MIE were published over the past 20 years validating that short and long-term results of conventional thoraco-laparoscopic minimally invasive esophagectomy are similar to open esophagectomy. The role of robotic assistance is to be established with an increasing number of randomized trials about RAMIE compared to VAMIE and long-term oncological data (45,55). While direct clinical benefits to the patient may be difficult to clarify, benefits to the surgeon in terms of ease of the surgical performance and potential decrease in chronic work-related trauma and injuries may be significant (56).

RAMIE is superior to open esophagectomy in terms of postoperative complications, length of hospital stays, and quality of life, but the benefits of RAMIE over conventional VAMIE are not well established and the cost-effectiveness of RAMIE is a real issue (55). For some authors, the best approach is the one on which surgeons with different experiences and skills deliver consistently good outcomes in the least invasive access possible (57). Some potential advantages of robotic assistance might lead to improvements in postoperative overcomes. One of them is the possibility to perform a safe hand-sewn instead of a stapled intrathoracic anastomosis, but the advantages in terms of leaks and strictures must be established. Another potential advantage is clearly the fine and safe dissection along the recurrent laryngeal nerves performed during RAMIE and the upper thoracic inlet, allowing to operate on tumors and remove lymph nodes located in the upper mediastinum. Even more important, the computerized platform can be improved by introducing new technologies and software, even towards an image guided surgery (55).

In conclusion, robot-assisted resection for esophageal cancer is feasible, but a real benefit has not yet been demonstrated due to the limited. The limitations and disadvantages of the robot have been and will continue to being overcome by new softwares and technologies, and there is consistent evidences that robotic assistance is here to stay (58) but the careful review of the current available literature shows that there are no data to support actual advantage of robotic-assisted over standard minimally invasive esophagectomy (59).

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Fernando A. M. Herbella, Rafael M. Laurino Neto, and Rafael C. Katayama) for the series “How Can We Improve Outcomes for Esophageal Cancer?” published in *Annals of Esophagus*. The article has undergone

external peer review.

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/aoe.2020.02.03). The series "How Can We Improve Outcomes for Esophageal Cancer?" was commissioned by the editorial office without any funding or sponsorship. The authors have no other 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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doi: 10.21037/aoe.2020.02.03
Cite this article as: Domene CE, Volpe P. Do robotic arms retrieve more lymph nodes during an esophagectomy? Ann Esophagus 2020;3:13.