Open, Minimally Invasive, and Robotic Approaches for Esophagectomy

What Is the Approach Algorithm?

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KEYWORDS

• Esophagectomy • Minimally invasive esophagectomy • Robotic assisted esophagectomy
• Esophageal cancer

KEY POINTS

- Minimally invasive esophagectomy has been described. Regardless of the approach, it is imperative to perform a safe and oncologically sound resection.
- It is important to have a general awareness of risks and advantages of each approach to esophagectomy.
- When it comes to the different approaches to esophagectomy, minimally invasive operations are seen to offer several advantages.
- Several factors can influence the optimal approach; however, the choice of approach largely depends on surgeon comfort and experience.

INTRODUCTION

Esophageal cancer has seen an overall increase in incidence over the last several decades. This pattern is more pronounced in the United States and other Western countries.[1,2] Currently, the incidence of esophageal cancer in the United States approaches 17,000 per year, with more than 15,000 deaths per year attributed to esophageal cancer. It is the eighth most common cancer worldwide, the eighteenth most common in the United States, and only second to pancreatic cancer in case fatality rate.[3,4] The treatment of esophageal cancer revolves around a complex, multimodality approach in most instances, with surgical resection a key component in appropriate patients. With the use of ever improving multimodality therapy, there has been an improvement in long-term survival for those with early or locally advanced disease.[5] This has partly been due to newer chemotherapy agents with lower toxicity profiles, as well as advanced radiotherapy techniques that have developed over the last several decades. Similarly, as other aspects of esophageal cancer treatment have evolved, so has the surgical approach to esophagectomy. Historically, open esophagectomy (OE) by either a transhiatal or transthoracic route has long been the surgical approach to resection; however, over the past several decades, minimally invasive approaches have become more popular, with a greater move

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toward transthoracic rather than transhiatal routes of resection. Regardless of the approach, the goal should remain the same, that is, performing a safe operation without compromise of oncologic principles. Here we discuss the different approaches and variables that may influence decision making.

OPERATIVE APPROACHES

Generally, esophageal resections can be characterized under 2 broad categorizations: transhiatal esophagectomy (THE) versus transthoracic esophagectomy (TTE), and OE versus minimally invasive esophagectomy (MIE). Within these 2 broad categories, subsets of technique exist.

The most common transthoracic operations, those using some component of entry into the right or left lateral chest, include the Ivor Lewis (abdomen and right chest),[6] McKeown or 3-hole (right chest, abdomen, and neck),[7] and right or left (Sweet operation) thoracoabdominal (simultaneous transcostal abdomen and right or left chest).[8] The transhiatal operations are performed through a laparotomy in conjunction with a cervical incision.

Over the last several decades, minimally invasive approaches to esophageal resection have evolved. These approaches were developed to decrease perioperative morbidity, but without compromising oncologic principles. Initially, minimally invasive approaches were used in a limited capacity for small, early stage tumors. With advancements, MIE is often used in advanced cancers as well.[9] MIE includes a large spectrum of approaches. These range from total thoracoscopic and laparoscopic approaches to a variety of hybrid approaches in which the chest approach may be done through a minimally invasive technique, but the abdominal portion remains open, or vice versa. In recent years, robotic approaches to esophagectomy are becoming more popular. Like other MIE approaches, the robot is used either during the chest or abdominal portion, or can be used during the entirety of the resection.

There are a few variables that need to be considered when choosing the approach to surgery for these patients. Ultimately, when resection is performed for malignancy, preserving oncologic principles is key. Regarding robotic resection, the literature continues to expand. Several studies have demonstrated the feasibility of a complete resection.[10–13] In the ROBOT trial, which represents a randomized controlled trial comparing robotic-assisted MIE (RAMIE) with other traditional approaches, R0 resections were comparable between RAMIE and OE, as well as median lymph nodes retrieved.[14] No difference in overall survival was noted between the 2 groups at 40 months, although longer follow-up will be needed to draw any significant differences.

OPEN VERSUS MINIMALLY INVASIVE ESOPHAGECTOMY

Minimally invasive surgical approaches have been adopted across a wide range of surgical subspecialties. As more physicians became proficient in minimally invasive techniques, several esophageal diseases have been treated in this manner over the past 20 to 30 years; thus, it is no surprise that this has been extended to esophagectomy. As mentioned, the esophagectomy was historically performed in an open fashion, either through the transhiatal or transthoracic approach. However, there are now data that show that these can all be safely performed minimally invasively.[9,15,16] Regardless of the technique or approach used, it is important for the surgeon to be aware of current data regarding morbidity, mortality, and outcomes. Although this area of research is still active area, there is a growing body of literature outlining these techniques.

The morbidity of the OE can exceed 50% to 70%, with mortality historically ranging from 8% to 23%.[9,15,17] However, with the advent of high-volume centers of excellence as well as minimally invasive approaches, these numbers seem to be improving. The literature has substantially grown since the first MIE described by Cuschieri and colleagues[18] in 1992. There are now several randomized trials and meta-analyses that show decreased overall morbidity (especially respiratory complications) and shorter hospital stay for MIE, with similar mortality rates.[9,17,19,20] Anastomotic leakage is an important postoperative morbidity that deserves extra attention. Multiple studies have failed to show a significant difference between open and MIE approaches.[9,15,17,19] In regards to anastomotic technique, stapled anastomosis has been shown to be superior to handsewn techniques in several studies.[21,22] Although this area of research is still active, it seems MIE has several advantages over the traditional open techniques in terms of short-term morbidity.

TRANSTHORACIC VERSUS TRANSHIATAL ESOPHAGECTOMY

When examining the different approaches to esophagectomy, they can broadly be grouped into either TTE or THE, with TTE being subdivided into Ivor Lewis or McKeown methods. In a randomized controlled trial by Omloo and colleagues,[23] the TTE was noted to be superior in several aspects, but primarily better lymph node harvest. This finding has been further validated by several other studies and a large meta-analysis.[9,19,20] Additionally, the TTE has been shown to have a lower anastomotic leak rate when compared with THE.[24] In terms of overall morbidity, THE may be superior. The study from Omloo and colleagues shows less overall morbidity and operative time when the THE approach was used, although this finding has not been routinely replicated in other studies. In a large series by Orringer and colleagues,[25] THE was performed with acceptable morbidity, although anastomotic leak and recurrent laryngeal nerve paralysis was higher compared with those generally reported for Ivor Lewis esophagectomy. The mortality rate of the 2 approaches, however, is largely the same.[9,15–17,26]

As mentioned elsewhere in this article, there are a myriad of surgical approaches to the esophagectomy, and the majority of these can be performed minimally invasively. When comparing the different types of minimally invasive approaches, the transthoracic approaches are subdivided into Ivor Lewis (MIE chest) and McKeown (MIE neck). Although the transhiatal approach can be performed laparoscopically, it is often cited as having poor visibility, often leading to inadequate lymph node dissection and difficulty with hemostasis.[27] Thus, many high-volume centers have transitioned to the transthoracic MIE. The literature comparing the MIE chest and MIE neck is scant. However, a study performed by Luketich and colleagues[9] showed decreased recurrent laryngeal nerve injury and pharyngeal dysfunction in the MIE chest group, with the remaining parameters being similar. Last, robotic approaches have been increasingly used for esophagectomy. Although there is a relative paucity of data regarding its usefulness, several studies show promising results. Early reports have shown RAMIE to offer outcomes similar to other traditional MIE approaches.[11,28,29] Additionally, it is theorized that some areas of the dissection, especially the mediastinum, may be more effectively performed with the robotic platform, given is superior optics, depth of field, and multiple degrees of freedom.[11] However, although promising, this approach needs to be further vetted.

LOCATION

Esophageal cancer may arise anywhere along the esophagus. Squamous cell cancers more commonly occurs in the proximal and middle esophagus, and adenocarcinomas arise in the mid to distal esophagus. To achieve complete (R0) resections, more proximal tumors traditionally require a cervical anastomosis. This goal can be accomplished through either a 3-hole McKeown or transhiatal approach. Either approach can also be accomplished using minimally invasive techniques. As described elsewhere in this article, cervical anastomosis does have a higher incidence of recurrent laryngeal nerve injury, anastomotic leak, and pharyngoesophageal swallowing dysfunction.

When resecting middle to distal esophageal cancers, any esophagectomy technique and approach, open or minimally invasive, can generally be used and performed. We generally recommend an Ivor Lewis approach because it minimizes the risks associated with cervical anastomosis and provides a superior en bloc lymph node resection. Whether it be open or minimally invasive often depends on the surgeon's experience and preference.

PATHOLOGY

Barrett's Esophagus and Malignancy

Historically, Barrett's esophagus (BE) with high-grade dysplasia was an indication for esophageal resection. Today, high-grade dysplasia is frequently treated with endoscopic mucosal resection and ablation of the BE. Indications for esophagectomy in the setting of BE may include multifocal high-grade dysplasia, long segment BE, and a younger patient who may prefer to avoid routine BE surveillance with endoscopic biopsies. Shared decision making between the surgeon and patient would dictate the management in these cases, and a THE with avoidance of the chest and possible pulmonary complications may be offered. Regardless, we prefer to offer a minimally invasive Ivor Lewis approach in these cases to minimize risks of a cervical anastomosis and of laparotomy, including intraoperative cardiac compression, higher splenectomy rate, and long-term risk of ventral hernia.

For locally or regionally advanced esophageal malignancies, the goal is an R0 resection and adequate lymph node harvest for pathologic staging. Histology itself does not directly dictate the approach, but rather the likelihood of a sound oncologic resection. Stage of cancer may impact the surgeon's selection of approach. **Fig. 1** summarizes preferred surgical approaches for esophagectomy in the setting of esophageal malignancy.

Benign Disease

Although less common, occasionally an esophagectomy is warranted for benign disease. Diagnoses include severe refractory reflux disease, end-stage achalasia, severe esophageal dysmotility, and/or stricture. The approach to

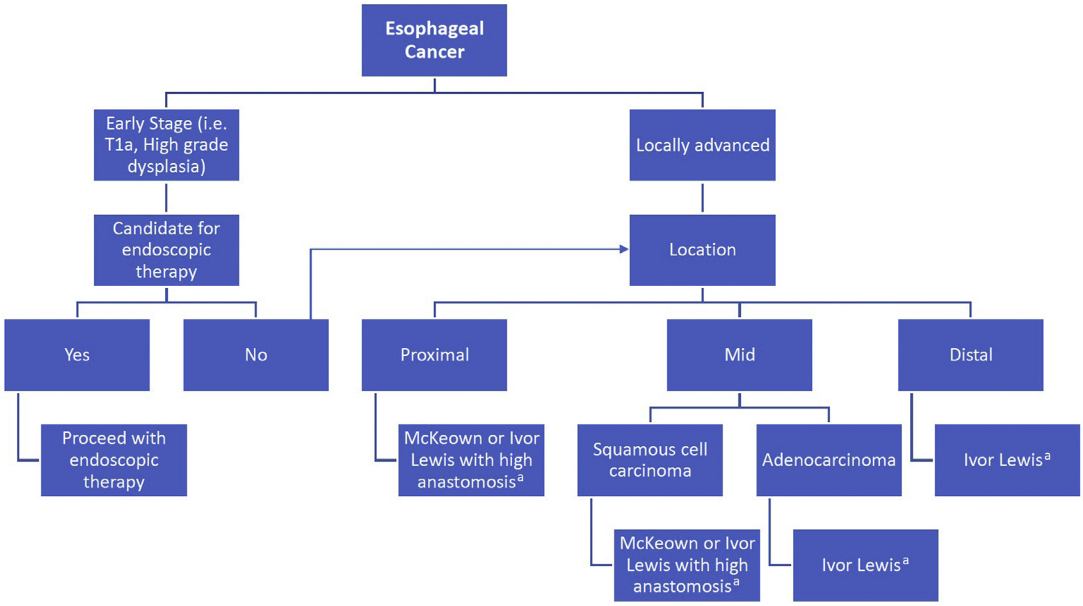

Fig. 1. Surgical approaches to esophagectomy in setting of esophageal malignancy. [a] Choicce of MIE is always preferred, but should be based on experience and comfort level of the surgeon. An open approach should be highly considered if the surgeon is not familiar or experienced with minimally invasive approaches. Strong consideration should be given to minimally invasive approaches for frail patients. Otherwise, a transhiatal or nonoperative approach should be considered.

esophagectomy should be dictated by the disease process. Patients with achalasia or esophageal dysmotility may require a cervical anastomosis to remove all the diseased esophagus. In those undergoing resections for reflux, an Ivor Lewis approach is preferred to avoid complications associated with neck anastomosis. Many patients undergoing esophagectomy for benign pathology have previously undergone one or several prior foregut operations. These may include an antireflux or paraesophageal hernia repair or a modified Heller myotomy. Previous procedures may influence the approach as a completely minimally invasive approach may be impeded by significant scar tissue. In addition, the gastric conduit may no longer be an option after several complex reoperations.[30] Esophagectomy after prior reflux studies has been shown to be associated with greater perioperative morbidity, anastomotic leak, and need for reoperation[31]; however, Chang and colleagues[30] did not report a difference in occurrence of anastomotic leak. Fig. 2 summarizes preferred surgical approaches for esophagectomy in the setting of benign disease.

LYMPH NODE RESECTION

Although the extent of lymphadenectomy has been an area of controversy for years, several studies have demonstrated that long-term survival may be directly related to this parameter.[32] Hulscher and colleagues[32] have shown an improved lymph node resection through a transthoracic approach, and suggested a survival advantage with improved lyphadencectomy. This outcome is likely from better exposure and improved node dissection in the mediastinum. With regard to open versus minimally invasive transthoracic approach, Luketich and colleagues[9] reported a comparable number of median lymph nodes removed. Other larger studies have reported similar findings.[33,34] Ye and colleagues[35] have reported an increased extent of lymphadenectomy in higher stage squamous cell carcinoma. As far as RAMIE approaches, several series have demonstrated an improved lymph node resection compared with an open approach.[14,28,36–38]

ONCOLOGIC OUTCOMES

For OE, studies have not routinely shown significant differences in long-term survival between transhiatal and transthoracic approches.[39,40] In a large randomized study by Hulscher and colleagues[32] comparing TTE and THE, R0 resection was similar. Significantly more lymph nodes were resected in the TTE arm. The recurrence rate and

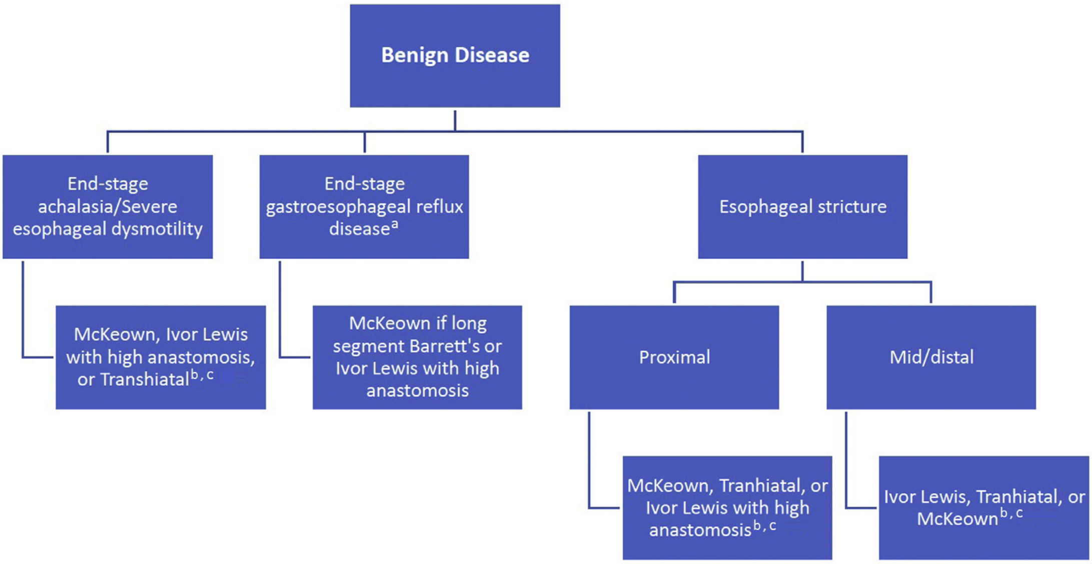

Fig. 2. Surgical approaches to esophagectomy in setting of benign disease. [a] Patients with multiple failed anti-reflux surgeries that are not amendable to redo fundoplication or Roux-en-Y. [b] Choice of MIE is always preferred, but should be based on experience and comfort level of the surgeon. An open approach should be highly considered if the surgeon is not familiar or experienced with minimally invasive approaches. Strong consideration should be given to minimally invasive approaches for frail patients. [c] If unable to perform a minimally invasive procedure, a transhiatal approach would be preferred to avoid morbidity associated with a thoracotomy.

median disease-free survival were similar. There was a trend toward a better 5-year survival in the TTE group, but it was not statistically significant.

Many series have shown MIE to be oncologically comparable with OE.[41] In a meta-analysis performed by Gottlieb-Vedi and colleagues,[42] long-term survival after MIE was similar and potentially even be better than OE. As far as adequacy of resection, in one of the largest series to date on MIE, Luketich and colleagues[9] reported an R0 resection in 98% of patients.[9] Lymph node resection, as mentioned elsewhere in this article, is similar to open approach.[33,34] In patients who underwent neoadjuvant therapy, MIE approaches are equivalent to open approaches in regard to perioperative outcomes.[43]

There are few data on long-term cancer survival after RAMIE. As far as adequacy of resection, Puntambekar and associates[44] reported a 97.6% R0 resection with a hybrid robotic-assisted 3-hole esophagectomy. As for the Ivor Lewis RAMIE, several series have reported a complete resection from 90% to 100%.[10–13] Although the ROBOT trial, a randomized controlled trial comparing a robotic versus a traditional approach, did not focus on survival outcomes, several oncologic outcomes were extrapolated. R0 resections were comparable between RAMIE and OE (93% vs 96%; P = .35). At median follow-up of 40 months, overall survival and disease-free survival were not statistically significantly different between the RAMIE and OE arms.[14] Recurrence rates in this series were also consistent with published data on OE.[45] As mentioned elsewhere in this article, several studies have reported an improved lymph node resection compared with an open approach.[14,28,36,37,46] Increased lymph node resection may potentially offer some benefit in regard to overall cancer survival, although further studies would need to be completed to confirm any oncologic advantage.

QUALITY OF LIFE

Improved quality of life after esophagectomy can be a predictor of long-term survival.[47,48] Global health, social, and emotional functioning improve more frequently after MIE compared with OE.[49] In a randomized study from the Netherlands, MIE was associated with better quality of life at 1 year after resection.[50] In the ROBOT trial, compared with OE, the RAMIE arm had improved functional recovery at 14 days, less postoperative pain, and overall better quality of life based on assessment tools.[14] Other studies also reported less pain after RAMIE.[46,51]

EXPERIENCE AND APPROACH SELECTION

A large influence on surgical approach to esophagectomy is based on experience and comfort level. For many surgeons, their surgical approach is dictated by how they were trained. Historically, during the era of open surgery, surgeons would decide between an Ivor Lewis, McKeown, or transhiatal approach based on their experience with each. This circumstance also was and remains prevalent with minimally invasive techniques. Many surgeons still choose to do an OE, which may often be due to their lack of experience with minimally invasive surgery. Standard MIE requires advanced skill in thoracoscopy and laparoscopy, which not all surgeons may have been exposed to in training. This is also the case in RAMIE. Although robotic surgery has been present for more than a decade, its use as an alternative approach to esophagectomy is still relatively a younger adaptation.

Previous studies have evaluated the learning curve in regards to MIE. Guo and colleagues[52] reported that 30 cases were needed to gain proficiency, with even lower morbidity at 60 cases. Other studies reported similar findings.[53] Although earlier studies focused on parameters directly related to the surgery, specifically operative time, more recent studies evaluated the effects of the learning curve on anastomotic leakage, mortality, and survival. Van Workum and colleagues[54] reported that 10% of leaks were attributed to the learning curve phase. Several studies also identified increased mortality associated with learning curve.[55,56] These findings stress the importance of rigid structured training and proctorship when first endeavoring in MIE.

When it comes robotics, some investigators argue that the learning curve is decreased compared with standard minimally invasive approach owing to the sophistication of the robotic technology.[11,57] Several studies have attempted to define proficiency in robotic esophagectomies. Hernandez and cowrokers[58] reported near proficiency around 20 cases, at which point operative time was significantly decreased. Other studies also noted that proficiency was can be achieved early on.[44,59] It is important to note, however, that obtaining proficiency has many variables, including previous experience in esophagectomy and robotic surgery. Also, the extent of the robotic portion of the esophagectomy may vary between studies. In a study by Sarkaria and colleagues[13] regarding learning curve in completely robotic RAMIE, significant decrease in operative times were noted between 30 and 45 cases with the nadir between cases 40 and 45. Conversion rates decreased from 13 in the first 50 to 2 in the next 50 cases. The study ensured a dedicated operating room team that included 2 constant attending surgeons and specific anesthesiologists. In a more recent study, van der Sluis and colleagues[60] concluded that proficiency in completely RAMIE consisted of 70 procedures. This study was also performed under structured proctoring. Zhang and colleagues[61] reported a learning curve of 26 cases to gain proficiency for robotic-assisted esophageal dissection and 14 for stomach mobilization. This study was performed by a single surgical team that had vast experience in open and thoracolaparoscopic esophagectomy.

SUMMARY

Esophagectomy is a complex operation, and several different approaches have been historically described. The major approaches include transhiatal or transthoracic, with the latter being primarily subdivided into the Ivor Lewis, McKeown, and thoracoabdominal operations. All of these procedures can be performed minimally invasively, and with or without robotic assistance. Although minimally invasive operations may offer several advantages in the perioperative period, the decision to perform an open or minimally operation must be tempered primarily by surgeon comfort and experience with any given approach. Regardless of which approach is chosen, it is paramount to focus primarily on a safe and oncologically sound resection.

DISCLOSURE

The authors have nothing to disclose.

REFERENCES

1. Blot WJ, McLaughlin JK. The changing epidemiology of esophageal cancer. Semin Oncol 1999; 26(5 Suppl 15):2–8.
2. Pohl H, Welch HG. The role of overdiagnosis and reclassification in the marked increase of esophageal adenocarcinoma incidence. J Natl Cancer Inst 2005;97(2):142–6.
3. Ferlay J, Soerjomataram I, Dikshit R, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. Int J Cancer 2015;136(5):E359–86.
4. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2015. CA Cancer J Clin 2015;65(1):5–29.
5. Rustgi AK, El-Serag HB. Esophageal carcinoma. N Engl J Med 2014;371(26):2499–509.
6. Lewis I. The surgical treatment of carcinoma of the oesophagus; with special reference to a new

operation for growths of the middle third. Br J Surg 1946;34:18–31.
7. McKeown KC. Total three-stage oesophagectomy for cancer of the oesophagus. Br J Surg 1976; 63(4):259–62.
8. Sweet RH. Carcinoma of the esophagus and the cardiac end of the stomach immediate and late results of treatment by resection and primary esophagogastric anastomosis. J Am Med Assoc 1947; 135(8):485–90.
9. Luketich JD, Pennathur A, Awais O, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg 2012;256(1):95–103.
10. Hodari A, Park KU, Lace B, et al. Robot-assisted minimally invasive Ivor Lewis esophagectomy with real-time perfusion assessment. Ann Thorac Surg 2015;100(3):947–52.
11. Okusanya OT, Sarkaria IS, Hess NR, et al. Robotic assisted minimally invasive esophagectomy (RAMIE): the University of Pittsburgh Medical Center initial experience. Ann Cardiothorac Surg 2017;6(2): 179–85.
12. Sarkaria IS, Rizk NP. Robotic-assisted minimally invasive esophagectomy: the Ivor Lewis approach. Thorac Surg Clin 2014;24(2):211–22, vii.
13. Sarkaria IS, Rizk NP, Grosser R, et al. Attaining proficiency in robotic-assisted minimally invasive esophagectomy while maximizing safety during procedure development. Innovations (Phila) 2016; 11(4):268–73.
14. van der Sluis PC, van der Horst S, May AM, et al. Robot-assisted minimally invasive thoracolaparoscopic esophagectomy versus open transthoracic esophagectomy for resectable esophageal cancer: a randomized controlled trial. Ann Surg 2019; 269(4):621–30.
15. Levy RM, Trivedi D, Luketich JD. Minimally invasive esophagectomy. Surg Clin North Am 2012;92(5): 1265–85.
16. van den Berg JW, Luketich JD, Cheong E. Oesophagectomy: the expanding role of minimally invasive surgery in oesophageal cancer. Best Pract Res Clin Gastroenterol 2018;36-37:75–80.
17. Levy RM, Pennathur A, Luketich JD. Randomized trial comparing minimally invasive esophagectomy and open esophagectomy: early perioperative outcomes appear improved with a minimally invasive approach. Semin Thorac Cardiovasc Surg 2012; 24(3):153–4.
18. Cuschieri A, Shimi S, Banting S. Endoscopic oesophagectomy through a right thoracoscopic approach. J R Coll Surg Edinb 1992;37(1):7–11.
19. Biere SS, van Berge Henegouwen MI, Maas KW, et al. Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 2012;379(9829):1887–92.
20. Heger P, Blank S, Goossen K, et al. Thoracoabdominal versus transhiatal surgical approaches for adenocarcinoma of the esophagogastric junction-a systematic review and meta-analysis. Langenbecks Arch Surg 2019;404(1):103–13.
21. Kumar T, Krishanappa R, Pai E, et al. Completely linear stapled versus handsewn cervical esophagogastric anastomosis after esophagectomy. Indian J Surg 2018;80(2):134–9.
22. Pines G, Buyeviz V, Machlenkin S, et al. The use of circular stapler for cervical esophagogastric anastomosis after esophagectomy: surgical technique and early postoperative outcome. Dis Esophagus 2009; 22(3):274–8.
23. Omloo JM, Lagarde SM, Hulscher JB, et al. Extended transthoracic resection compared with limited transhiatal resection for adenocarcinoma of the mid/distal esophagus: five-year survival of a randomized clinical trial. Ann Surg 2007;246(6): 992–1000 [discussion: 1000–1].
24. Ryan CE, Paniccia A, Meguid RA, et al. Transthoracic anastomotic leak after esophagectomy: current trends. Ann Surg Oncol 2017;24(1): 281–90.
25. Orringer MB, Marshall B, Iannettoni MD. Transhiatal esophagectomy: clinical experience and refinements. Ann Surg 1999;230(3):392–400 [discussion: 400–3].
26. Biere SS, van Berge Henegouwen MI, Bonavina L, et al. Predictive factors for post-operative respiratory infections after esophagectomy for esophageal cancer: outcome of randomized trial. J Thorac Dis 2017; 9(Suppl 8):S861–7.
27. Levy RM, Wizorek J, Shende M, et al. Laparoscopic and thoracoscopic esophagectomy. Adv Surg 2010; 44:101–16.
28. Meredith KL, Maramara T, Blinn P, et al. Comparative perioperative outcomes by esophagectomy surgical technique. J Gastrointest Surg 2019. [Epub ahead of print].
29. van der Sluis PC, van Hillegersberg R. Robot assisted minimally invasive esophagectomy (RAMIE) for esophageal cancer. Best Pract Res Clin Gastroenterol 2018;36-37:81–3.
30. Chang AC, Lee JS, Sawicki KT, et al. Outcomes after esophagectomy in patients with prior antireflux or hiatal hernia surgery. Ann Thorac Surg 2010;89(4): 1015–21 [discussion: 1022–3].
31. Shen KR, Harrison-Phipps KM, Cassivi SD, et al. Esophagectomy after anti-reflux surgery. J Thorac Cardiovasc Surg 2010;139(4):969–75.
32. Hulscher JB, van Sandick JW, de Boer AG, et al. Extended transthoracic resection compared with limited transhiatal resection for adenocarcinoma of the esophagus. N Engl J Med 2002;347(21): 1662–9.
33. Seesing MFJ, Gisbertz SS, Goense L, et al. A propensity score matched analysis of open

versus minimally invasive transthoracic esophagectomy in the Netherlands. Ann Surg 2017; 266(5):839–46.
34. Yibulayin W, Abulizi S, Lv H, et al. Minimally invasive oesophagectomy versus open esophagectomy for resectable esophageal cancer: a meta-analysis. World J Surg Oncol 2016;14(1):304.
35. Ye B, Zhong CX, Yang Y, et al. Lymph node dissection in esophageal carcinoma: minimally invasive esophagectomy vs open surgery. World J Gastroenterol 2016;22(19):4750–6.
36. Espinoza-Mercado F, Imai TA, Borgella JD, et al. Does the approach matter? Comparing survival in robotic, minimally invasive, and open esophagectomies. Ann Thorac Surg 2019;107(2):378–85.
37. Mori K, Yamagata Y, Aikou S, et al. Short-term outcomes of robotic radical esophagectomy for esophageal cancer by a nontransthoracic approach compared with conventional transthoracic surgery. Dis Esophagus 2016;29(5):429–34.
38. Sarkaria IS, Rizk NP, Finley DJ, et al. Combined thoracoscopic and laparoscopic robotic-assisted minimally invasive esophagectomy using a four-arm platform: experience, technique and cautions during early procedure development. Eur J Cardiothorac Surg 2013;43(5):e107–15.
39. Hulscher JB, Tijssen JG, Obertop H, et al. Transthoracic versus transhiatal resection for carcinoma of the esophagus: a meta-analysis. Ann Thorac Surg 2001;72(1):306–13.
40. Rindani R, Martin CJ, Cox MR. Transhiatal versus Ivor-Lewis oesophagectomy: is there a difference? Aust N Z J Surg 1999;69(3):187–94.
41. Verhage RJ, Hazebroek EJ, Boone J, et al. Minimally invasive surgery compared to open procedures in esophagectomy for cancer: a systematic review of the literature. Minerva Chir 2009;64(2):135–46.
42. Gottlieb-Vedi E, Kauppila JH, Malietzis G, et al. Long-term survival in esophageal cancer after minimally invasive compared to open esophagectomy: a systematic review and meta-analysis. Ann Surg 2019;270(6):1005–17.
43. Tapias LF, Mathisen DJ, Wright CD, et al. Outcomes with open and minimally invasive Ivor Lewis esophagectomy after neoadjuvant therapy. Ann Thorac Surg 2016;101(3):1097–103.
44. Puntambekar S, Kenawadekar R, Kumar S, et al. Robotic transthoracic esophagectomy. BMC Surg 2015;15:47.
45. van Hagen P, Wijnhoven BP, Nafteux P, et al. Recurrence pattern in patients with a pathologically complete response after neoadjuvant chemoradiotherapy and surgery for oesophageal cancer. Br J Surg 2013; 100(2):267–73.
46. Sarkaria IS, Rizk NP, Goldman DA, et al. Early quality of life outcomes after robotic-assisted minimally invasive and open esophagectomy. Ann Thorac Surg 2019;108(3):920–8.
47. Safieddine N, Xu W, Quadri SM, et al. Health-related quality of life in esophageal cancer: effect of neoadjuvant chemoradiotherapy followed by surgical intervention. J Thorac Cardiovasc Surg 2009;137(1): 36–42.
48. van Heijl M, Sprangers MA, de Boer AG, et al. Preoperative and early postoperative quality of life predict survival in potentially curable patients with esophageal cancer. Ann Surg Oncol 2010;17(1): 23–30.
49. Taioli E, Schwartz RM, Lieberman-Cribbin W, et al. Quality of life after open or minimally invasive esophagectomy in patients with esophageal cancer-a systematic review. Semin Thorac Cardiovasc Surg 2017;29(3):377–90.
50. Maas KW, Cuesta MA, van Berge Henegouwen MI, et al. Quality of life and late complications after minimally invasive compared to open esophagectomy: results of a randomized trial. World J Surg 2015; 39(8):1986–93.
51. Sugawara K, Yoshimura S, Yagi K, et al. Long-term health-related quality of life following robot-assisted radical transmediastinal esophagectomy. Surg Endosc 2020;34(4):1602–11.
52. Guo W, Zou YB, Ma Z, et al. One surgeon's learning curve for video-assisted thoracoscopic esophagectomy for esophageal cancer with the patient in lateral position: how many cases are needed to reach competence? Surg Endosc 2013;27(4): 1346–52.
53. Lin J, Kang M, Chen C, et al. Thoracolaparoscopy oesophagectomy and extensive two-field lymphadenectomy for oesophageal cancer: introduction and teaching of a new technique in a high-volume centre. Eur J Cardiothorac Surg 2013;43(1): 115–21.
54. van Workum F, Stenstra M, Berkelmans GHK, et al. Learning curve and associated morbidity of minimally invasive esophagectomy: a retrospective multicenter study. Ann Surg 2019;269(1):88–94.
55. Mackenzie H, Markar SR, Askari A, et al. National proficiency-gain curves for minimally invasive gastrointestinal cancer surgery. Br J Surg 2016; 103(1):88–96.
56. Markar SR, Mackenzie H, Lagergren P, et al. Surgical proficiency gain and survival after esophagectomy for cancer. J Clin Oncol 2016;34(13): 1528–36.
57. Kumar A, Asaf BB. Robotic thoracic surgery: the state of the art. J Minim Access Surg 2015;11(1): 60–7.
58. Hernandez JM, Dimou F, Weber J, et al. Defining the learning curve for robotic-assisted esophagogastrectomy. J Gastrointest Surg 2013;17(8):1346–51.

59. Kim DJ, Hyung WJ, Lee CY, et al. Thoracoscopic esophagectomy for esophageal cancer: feasibility and safety of robotic assistance in the prone position. J Thorac Cardiovasc Surg 2010;139(1):53–9.e51.
60. van der Sluis PC, Ruurda JP, van der Horst S, et al. Learning curve for robot-assisted minimally invasive thoracoscopic esophagectomy: results from 312 cases. Ann Thorac Surg 2018;106(1):264–71.
61. Zhang H, Chen L, Wang Z, et al. The learning curve for robotic McKeown esophagectomy in patients with esophageal cancer. Ann Thorac Surg 2018;105(4):1024–30.