Minimally Invasive Esophagectomy for Benign Disease

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KEYWORDS

• Minimally invasive esophagectomy • Open esophagectomy • Benign conditions
• Complications

KEY POINTS

- Minimally invasive esophagectomy (MIE) can provide patients with reduced morbidity and a rapid recovery in the treatment of benign conditions.
- There are few data examining the long-term outcomes of MIE, specifically in the context of benign disease.
- At present, MIE should be performed in centers with experience in advanced minimally invasive esophageal surgery, and it requires a team approach.
- Multicenter, prospective randomized controlled trials will be required to determine the superiority of MIE compared with open esophagectomy.

INTRODUCTION

With the introduction of laparoscopic cholecystectomy in 1989, the practice of general surgery was transformed. Laparoscopic cholecystectomy provided the platform for widespread innovation and the ultimate adoption of complex minimal access procedures.[1] This transformation in surgery has been coupled with the development of advanced surgical instrumentation and applied for more complicated disease processes. Since Dallemange described the first laparoscopic fundoplication in 1991,[2] esophageal surgeons have uniformly incorporated laparoscopic approaches into practice. Clinical series have demonstrated that minimally invasive surgery for the treatment of gastroesophageal reflux disease[3–5] and achalasia[6,7] shows efficacy, with decreased recovery times compared with open approaches.

Esophagectomy is often performed in elderly patients who have many coexisting comorbidities, including pulmonary and cardiovascular disease. Open esophagectomy is associated with significant morbidity and mortality even in experienced centers.[8,9] For example, patients who develop pneumonia after esophagectomy have

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Surg Clin N Am 95 (2015) 605–614
http://dx.doi.org/10.1016/j.suc.2015.02.012 **surgical.theclinics.com**
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up to a 20% risk of death.[10] The avoidance of laparotomy and thoracotomy may have an impact on the incidence of postoperative complications, particularly respiratory failure, by reducing postoperative pain and convalescence. Based on this, there has been a great interest in minimally invasive esophagectomy (MIE), which has the theoretic advantages of being less traumatic, with a shortened postoperative recovery and fewer cardiopulmonary complications. In addition, enhanced visualization afforded by high-definition imaging and magnification may facilitate a safer approach, with a resultant reduction in blood loss and complications.

MIE has been adopted in many centers. This article describes the history of MIE in the context of benign disease, the surgical technique, and the outcomes of minimally invasive approaches compared with those of the open approach.

HISTORY OF MINIMALLY INVASIVE ESOPHAGECTOMY

MIE was developed based on the experience obtained with benign minimal access surgeries such as Nissen fundoplication, Heller myotomy, and repair of giant paraesophageal hernia. Nascent efforts consisted of hybrid operations that blended traditional open surgery with the minimally invasive approach. In 1993, Collard and colleagues[11] published the first report of MIE, and included 12 patients who underwent thoracoscopic esophageal mobilization followed by laparotomy. Several subsequent reports established the feasibility of this approach, thereby providing the foundation for development expansion. Despite these efforts, the definitive benefit of MIE over the open approach remained dubious.[12,13]

In 1995, DePaula and colleagues[14] reported a series of laparoscopic transhiatal esophagectomy. Twelve patients underwent laparoscopic transhiatal esophagectomy for end-stage achalasia. One patient required conversion to laparotomy, and no procedure-related mortality occurred. In 1997, Swanstrom and Hansen[15] reported the first experience with laparoscopic esophagectomy in the United States. Nine patients were selected based on the presence of cancer, benign strictures, and Barrett's esophagus. Eight patients underwent a transhiatal MIE with cervical anastomosis. One patient in this series underwent video-assisted thoracoscopic surgery with intrathoracic anastomosis. In 1998, Luketich and colleagues[16] reported 8 cases of minimally invasive approach to esophagectomy including a single case of combined thoracoscopic and laparoscopic esophagectomy with cervical anastomosis. Subsequently, Watson and colleagues[17] reported a minimally invasive Ivor Lewis approach in 1999, which described 2 cases of hand-assisted laparoscopic construction of the gastric conduit followed by thoracoscopic mobilization with a hand-sewn intrathoracic anastomosis. In single-institution case series, minimally invasive Ivor Lewis technique was shown to be associated with shortened postoperative hospital stay and recovery.

Indication for Minimally Invasive Esophagectomy in Benign Disease

Unlike MIE in the treatment of esophageal cancer, patients who undergo this procedure for benign disease tend to have a superior functional status and few comorbidities. In addition, the debilitation and malnutrition associated with induction therapy are typically absent. As a result, the outcomes of MIE tend to be improved in patients with benign disease compared with those undergoing resection for malignancy. The potential indications for MIE in the face of benign disease include

End-stage achalasia—patients present with anatomic obstruction and aspiration secondary to esophageal redundancy and dilation in the face of a prior complete myotomy

Severe gastroesophageal reflux disease with associated esophageal motility disorder—patients suffer from volume regurgitation, dysphagia. and chest pain with poor esophageal clearance

Failed antireflux surgery—most patients have undergone 2 to 3 prior antireflux surgeries and are not candidates for roux en y esophagojejunostomy because of functional obstruction proximal to the esophagogastric junction (ie, peristaltic failure)

Severe esophageal motility disorder unresponsive to prior medical and surgical therapy

1. These patients typically have a spastic motility disorder and present with severe dysphagia and regurgitation secondary to functional obstruction and bolus escape with retrograde bolus propagation.
2. Most of these patients have had a prior long myotomy with continued chest pain and dysphagia.

Refractory peptic stricture (rare in the era of proton pump inhibitor therapy)—it is important to screen these patients for gastrinoma and pill-induced injury

Idiopathic inflammatory disorders of the esophagus

Large benign tumors of the esophagus such as leiomyoma—the need for MIE in these patients is rare

Caustic injury to esophagus with refractory stricture

The selection of MIE approach (ie, transhiatal, inversion, Ivor Lewis) should be guided by the type and location of benign disease. For example, a patient with a transmural inflammatory process would not be a good candidate for a minimally invasive inversion esophagectomy, because the periesophageal fibrosis and thickening would preclude a safe stripping technique and increase the chances of hemorrhage and injury to vital structures.

Current Approaches to Minimally Invasive Esophagectomy

The laparoscopic transhiatal (inversion) esophagectomy (LIE) is a modification based on the open inversion technique with vagal preservation described by Akiyama and colleagues[18] in 1994. The LIE is an entirely laparoscopic approach, whereby a vein stripper is attached to the distal esophagus through a cervical esophagotomy, and distal-to-proximal inversion (outside in) of the esophagus is performed by drawing back on the vein stripper, thereby facilitating the transhiatal dissection from below. Attaching to the proximal esophagus, delivering the vein stripper through a laparoscopic port, and drawing from below also can be used to facilitate proximal-to-distal inversion. The esophagus is then placed into a specimen bed and delivered through a 12 mm port site.

This approach provides enhanced mediastinal working space and visualization with the countertraction between the esophagus and its surrounding mediastinal attachments and directed dissection as the esophagus is inverted. Advantages of this approach include the elimination of the need for single-lung ventilation or patient repositioning during the procedure. Perry and colleagues[19] reported a series of 40 consecutive patients who underwent LIE. Four patients (10%) required laparotomy because of adhesions (2 patients), severe kyphosis (1 patient), and a tracheal tear occurred during the mediastinal dissection (1 patient). Median intensive care unit (ICU) and hospital stays were 2 days and 9 days, respectively. There was no operative mortality. The rates of recurrent nerve injury and anastomotic leak were 10% and 27.5%, respectively. The LIE may be particularly useful for patients with end-stage benign esophageal diseases such as achalasia and complicated gastroesophageal reflux disease.

For patients with inflammatory esophageal diseases, long-segment strictures, and benign tumors, the exposure, need for mediastinal dissection, and pliability of the esophageal body may preclude a safe operation.

The thoracoscopic and laparoscopic approaches were initially performed using the McKeown approach, with thoracoscopic esophageal mobilization performed initially, followed by laparoscopy for gastric conduit preparation and feeding jejunostomy placement, and finally the esophagogastrostomy was then performed in the neck. Outstanding thoracoscopic visualization of intrathoracic structures facilitates the safe mobilization of a thoracic esophagus and the radical dissection of lymphatic tissue when performed for malignancy. In 2003, Luketich and colleagues[20] reported the results of 222 consecutive patients who underwent this approach. The operation was successfully completed in 93% of patients. There were no emergent conversions to laparotomy for hemorrhage. The rates of hospital mortality and anastomotic dehiscence were 1.4% and 11.7%, respectively. Median ICU time and hospital stay were 1 day and 7 days, respectively. Using the gastroesophageal reflux disease health-related quality of life (GERD-HRQL), the quality of life was preserved based on pre and postoperative scores on relatively short-term follow-up. However, the potential pitfall with this approach is related to the cervical dissection and risk for recurrent nerve injury, pharyngeal dysfunction, and a higher anastomotic dehiscence rate. Because of this, an alternative method is to use a completely thoracoscopic–laparoscopic Ivor Lewis approach with a proximal intrathoracic anastomosis (TLE), in which laparoscopic gastric conduit creation followed by thoracoscopic mobilization and removal of thoracic esophagus, gastric pull-up, and construction of an esophagogastric anastomosis are performed. In 2006, Bizekis and colleagues[21] reported a series of TLE in 50 patients for cancer. Twenty-five patients (50%) received preoperative chemotherapy or chemoradiation. There was 1 nonemergent conversion to laparotomy. The rates of operative mortality and anastomotic dehiscence were both 6%. Four patients (8%) developed pneumonia postoperatively. There were no recurrent nerve injuries. It is important to emphasize that most data are obtained in populations with malignancy, and to date, there have been no large series examining the long-term outcomes of MIE as a treatment for benign disease.

Preoperative Preparation

Optimal outcomes depend on obtaining a complete preoperative risk assessment with the mitigation of modifiable risks (eg, coronary artery stenosis, active tobacco use, uncontrolled diabetes, cardiac dysrhythmia, celiac artery stenosis). The possibility of conversion to thoracotomy or laparotomy should be discussed preoperatively. Cardiac clearance and pulmonary function testing should be obtained to assess the risk for cardiopulmonary complications such as myocardial infarction and pneumonia. Smoking cessation is critically important, and assistance with quitting should be provided. All patients should meet with the dietician before and after surgery to discuss caloric optimization and postoperative diet. Prophylactic anticoagulation in conjunction with sequential compression devices is routinely employed. For thoracoscopic procedures, a double-lumen endotracheal tube is placed, and proper location is confirmed with bronchoscopy after patient positioning into the left lateral decubitus position.

SURGICAL TECHNIQUE

The technical details of LIE[22] and TLE[23] have been described previously. The characteristics and indications for each procedure are summarized in **Table 1**. Both procedures are complicated and ideally require 2 experienced surgeons to deliver a

Table 1
Characteristics of minimally invasive laparoscopic transhiatal (inversion) esophagectomy and Ivor Lewis esophagectomy

	Laparoscopic Transhiatal (Inversion) Esophagectomy	Thoracoscopic–Laparoscopic Ivor Lewis Esophagectomy
Approach	Laparoscopic	Thoracoscopic and laparoscopic
Single-lung ventilation	No	Yes
Patient position	Supine	Supine to left lateral decubitus
Laparoscopic ports	6-port technique	5-port technique
Thoracoscopic ports	N/A	5-port technique
Anastomosis	Neck	High chest
Advantage	No need for patient repositioning/single-lung ventilation/thoracoscopy	Rare recurrent laryngeal nerve injury, low anastomotic leak/stricture rates, less gastric conduit required, good intrathoracic visualization
Disadvantage	Limited mediastinal working space, higher anastomotic leak/stricture, pharyngeal dysfunction, requires longer gastric conduit length	Need for single-lung ventilation, potentially fatal intrathoracic anastomotic leak

successful outcome in an appropriate time frame. Important technical tips that need to be emphasized include

- Attention should be paid to preserve the right gastroepiploic arcade while mobilizing the stomach during division of the gastrocolic ligament and elevation of antrum away from the pancreatic bed. Every effort should be made to dissect all lymphatic tissue en bloc with surgical specimen throughout the procedure. the authors include the common hepatic lymph nodes along with the celiac nodes when performing MIE for malignancy.
- For benign diseases, the left gastric artery can be preserved in continuity with the right gastric artery. This maneuver may enhance arterial inflow to the neoesophagus. The pyloroantral area must be mobilized (including Kocher maneuver) until the pylorus can be elevated to the right crus in a tension-free manner.
- Circumferential mediastinal dissection should be performed as far proximally as can be safely visualized through the hiatus. This action facilitates the dissection of diaphragmatic hiatus from the chest, and the retrieval of the surgical specimen with neoesophagus pull-up into the chest.
- The authors favor a narrow (5 cm wide) neoesophagus because of its superior long-term functional benefits such as improved emptying and less reflux. During the creation of gastric conduit, the first assistant grasps the tip of the fundus along the greater curvature and stretches it toward the spleen, while a second grasper is placed on the antral area and a slight downward retraction is applied. This maneuver facilitates a straight application stapler, thus preventing spiraling and subsequent ischemia of the conduit.
- A key initial step in the chest part of TLE is to place a retracting suture through the central tendon of the diaphragm, which is brought out through the anterior chest wall via a 1 mm incision. This suture retracts the diaphragm inferiorly and anteriorly, and allows excellent visualization of the crural diaphragm and esophagogastric junction.

- The dissection of proximal esophagus above the azygos vein arch should be maintained on the esophageal wall to prevent injury of the recurrent laryngeal nerve.
- All aortoesophageal vessels and any lymphatic branches arising from the thoracic duct should be meticulously clipped prior to division to prevent unexpected bleeding and chylothorax.
- With the TLE approach, the esophagus is divided proximal to the level of the azygos arch.
- The proximal esophagus is divided at the level of the azygos arch, ensuring that the site of division is proximal to squamocolumnar junction in patients with long-segment Barrett esophagus.
- The gastric conduit needs to be positioned without redundancy or tension. With the TLE approach, the authors use a 28 or 25 mm circular stapler for the esophagogastrostomy. First, a gastrotomy is created parallel to the staple line at the most proximal aspect of the neoesophagus; the stapler is introduced into the chest through a 5 cm minithoracotomy made at the surgeon right hand port. The stapler is then introduced into the lumen of the neoesophagus, and the pin is deployed along the greater curvature after assessing for tension. After esophagogastrostomy, the opening in the gastrotomy is closed with an endoscopic stapler.
- After the stapler is removed at the completion of anastomosis, it is important to verify that the stapler contains 2 complete tissue rings, as this indicates that a complete circumferential anastomosis has been established.
- With the Ivor Lewis approach, the neoesophagus should be sutured to the right crus from the thoracic side to prevent small bowel herniation from the abdominal cavity.

POSTOPERATIVE MANAGEMENT

All patients who undergo MIE are placed in the intensive care unit (ICU), and every effort is made to extubate the patient immediately following surgery. Prior to extubation, therapeutic bronchoscopy is performed to clear the airway as much as possible to minimize atelectasis and mucous plugging. A nasogastric tube is place intraoperatively, and the patient should be maintained in a 45° head-up position to prevent aspiration and improve functional residual capacity. Prophylactic anticoagulation with heparin in conjunction with sequential compression devices is critical to prevent deep vein thrombosis (DVT) and pulmonary embolism. Aggressive pulmonary toileting and early ambulation should be implemented to maximize pulmonary function and prevent DVT. Electrolytes should be monitored and corrected to prevent postoperative arrhythmia. On postoperative day 2, continuous tube feeding is started at 10 mL/h, and the rate of tube feeding is advanced to goal over the following day. Prior to discharge, tube feeding is changed to cyclic (3 PM–9 AM), thereby enabling patients to maintain daily activities without a connection to tube feeding. On day 5, a water-soluble contrast examination should be obtained to inspect the anastomosis for leak, anatomic features, and emptying. Patients are then initiated on 30 to 60 mL of clear fluids by mouth every 1 to 2 hours. The patients are discharged with sips of liquid, cyclic tube feeding at goal rate, and a Jackson-Pratt (JP) drain (placed at the level of the anastomosis); they should be seen in the clinic after 2 weeks with a chest radiograph and blood work.

Prevention of Anastomotic Leak

Anastomotic dehiscence remains a potentially life-threatening complication associated with MIE. A prospective, randomized study by Bhat and colleagues[24]

demonstrated that a pedicled omental transposition to reinforce the esophagogastrostomy significantly reduced the incidence of dehiscence, thus decreasing the morbidity and mortality of the procedure.

Several methods to improve the microcirculation of the neoesophagus have been investigated. Akiyama and colleagues[25] performed preoperative angiographic embolization of the left gastric, right gastric, and splenic arteries in a group of patients, followed 2 days later by esophagogastrectomy with gastric tubularization and esophagogastrostomy. In the control group, esophagectomy was performed without preoperative embolization. There was improved circulation in the embolization group compared with the control group (33% vs 67%, respectively) as measured by laser flowmetry. Anastomotic dehiscence rates were higher in the control group. Supercharging of the neoesophagus by vascular anastomoses has been investigated as another approach. Nagawa and colleagues[26] performed intraoperative anastomoses between the left gastroepiploic and transverse cervical arteries, resulting in no anastomotic dehiscence compared with the 10% to 25% dehiscence rate previously experienced by the group using unaugmented techniques. The drawback to this procedure is that it required multiple surgical teams with experience in microvascular anastomoses. In their practice, the authors have used preoperative gastric ischemic conditioning by laparoscopic ligation of left gastric vessels 2 weeks prior to esophagectomy, potentially decreasing the rate of dehiscence and stricture[27–29] in high-risk patients. Combining a minimally invasive approach with these methods for prevention of anastomotic leak, the outcomes of MIE would improve further.

Is Minimally Invasive Esophagectomy Superior to Open Esophagectomy?

No randomized controlled trials comparing MIE with open esophagectomy have been conducted. Several retrospective studies have shown MIE to be equivalent or improved compared with the open approach.[20,30,31] In a case–control study comparing LIE (n = 21) with open transhiatal esophagectomy (n = 21),[30] LIE was associated with less blood loss and shorter hospital stay without increasing the operative time, morbidity, or mortality related to esophagectomy. In the report of 222 consecutive patients who underwent combined thoracoscopic–laparoscopic esophagectomy, Luketich and colleagues[20] demonstrated a low mortality rate (1.4%) and short hospital stay (7 days) compared with most open series published.[9,32] Pham and colleagues[31] reported the results of a retrospective study comparing TLE (n = 44) with open Ivor Lewis esophagectomy (n = 46). TLE was associated with less blood loss and wound problems. However, TLE required longer operative times, and there was no significant difference in hospital stay, 30-day mortality, or cardiopulmonary complications.

A meta-analysis by Biere and colleagues[33] demonstrated no significant difference for major morbidity or pulmonary complications between the groups, although there was a trend toward mortality rate reduction in the MIE group. A meta-analysis by Nagpal and colleagues[34] showed that MIE was associated with less blood loss, shorter operative time and length of hospital stay, and lower respiratory complications compared with open esophagectomy. As such, a quicker recovery and a reduction in morbidity can be achieved with MIE, but outcomes of MIE remain variable. For example, in a recent report of 1033 MIEs using the combined laparoscopic and thoracoscopic approach,[35] Luketich and colleagues demonstrated an overall mortality rate of 1.7% and a median length of stay of 8 days. Patients spent a median of 2 days in the ICU. However, the mortality rate after 30 days was not reported. Multicenter, prospective randomized trials comparing MIE with open esophagectomy will be required to determine if MIE is superior to open esophagectomy. Esophagectomy remains one of the most complicated and technically demanding procedures

performed in the field of surgery, and the outcomes are tightly linked to case volume and experience of surgeons and hospitals.[36]

SUMMARY

MIE can provide patients with reduced morbidity and a rapid recovery in the treatment of benign conditions. There is few data examining the long-term outcomes of MIE specifically in the context of benign disease. At present, MIE should be performed in centers with experience in advanced minimally invasive esophageal surgery, and it requires a team approach. Multicenter, prospective randomized controlled trials will be required to determine the superiority of MIE compared with open esophagectomy. Further investigation will be required to determine the effect of MIE on quality of life and long-term outcomes in the treatment of benign conditions.

REFERENCE

1. Vierra M. Minimally invasive surgery. Annu Rev Med 1995;46:147–58.
2. Dallemagne B, Weerts JM, Jehaes C, et al. Laparoscopic Nissen fundoplication: preliminary report. Surg Laparosc Endosc 1991;1(3):138–43.
3. Ackroyd R, Watson DI, Majeed AW, et al. Randomized clinical trial of laparoscopic versus open fundoplication for gastro-oesophageal reflux disease. Br J Surg 2004;91(8):975–82.
4. DeMeester TR, Bonavina L, Albertucci M. Nissen fundoplication for gastroesophageal reflux disease. Evaluation of primary repair in 100 consecutive patients. Ann Surg 1986;204(1):9–20.
5. Hunter JG, Trus TL, Branum GD, et al. A physiologic approach to laparoscopic fundoplication for gastroesophageal reflux disease. Ann Surg 1996;223(6):673–85 [discussion: 685–7].
6. Khajanchee YS, Kanneganti S, Leatherwood AE, et al. Laparoscopic Heller myotomy with Toupet fundoplication: outcomes predictors in 121 consecutive patients. Arch Surg 2005;140(9):827–33 [discussion: 833–4].
7. Patti MG, Pellegrini CA, Horgan S, et al. Minimally invasive surgery for achalasia: an 8-year experience with 168 patients. Ann Surg 1999;230(4):587–93 [discussion: 593–4].
8. Millikan KW, Silverstein J, Hart V, et al. A 15-year review of esophagectomy for carcinoma of the esophagus and cardia. Arch Surg 1995;130(6):617–24.
9. Orringer MB, Marshall B, Iannettoni MD. Transhiatal esophagectomy: clinical experience and refinements. Ann Surg 1999;230(3):392–400 [discussion: 400–3].
10. Atkins BZ, Shah AS, Hutcheson KA, et al. Reducing hospital morbidity and mortality following esophagectomy. Ann Thorac Surg 2004;78(4):1170–6 [discussion: 1170–6].
11. Collard JM, Lengele B, Otte JB, et al. En bloc and standard esophagectomies by thoracoscopy. Ann Thorac Surg 1993;56(3):675–9.
12. Akaishi T, Kaneda I, Higuchi N, et al. Thoracoscopic en bloc total esophagectomy with radical mediastinal lymphadenectomy. J Thorac Cardiovasc Surg 1996;112(6):1533–40 [discussion: 1540–1].
13. Robertson GS, Lloyd DM, Wicks AC, et al. No obvious advantages for thoracoscopic two-stage oesophagectomy. Br J Surg 1996;83(5):675–8.
14. DePaula AL, Hashiba K, Ferreira EA, et al. Laparoscopic transhiatal esophagectomy with esophagogastroplasty. Surg Laparosc Endosc 1995;5(1):1–5.
15. Swanstrom LL, Hansen P. Laparoscopic total esophagectomy. Arch Surg 1997;132(9):943–7 [discussion: 947–9].

16. Luketich JD, Nguyen NT, Weigel T, et al. Minimally invasive approach to esophagectomy. JSLS 1998;2(3):243–7.
17. Watson DI, Davies N, Jamieson GG. Totally endoscopic Ivor Lewis esophagectomy. Surg Endosc 1999;13(3):293–7.
18. Akiyama H, Tsurumaru M, Ono Y, et al. Esophagectomy without thoracotomy with vagal preservation. J Am Coll Surg 1994;178(1):83–5.
19. Perry KA, Enestvedt CK, Diggs BS, et al. Perioperative outcomes of laparoscopic transhiatal inversion esophagectomy compare favorably with those of combined thoracoscopic-laparoscopic esophagectomy. Surg Endosc 2009;23(9):2147–54.
20. Luketich JD, Alvelo-Rivera M, Buenaventura PO, et al. Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surg 2003;238(4):486–94 [discussion: 494–5].
21. Bizekis C, Kent MS, Luketich JD, et al. Initial experience with minimally invasive Ivor Lewis esophagectomy. Ann Thorac Surg 2006;82(2):402–6 [discussion: 406–7].
22. Jobe BA, Kim CY, Minjarez RC, et al. Simplifying minimally invasive transhiatal esophagectomy with the inversion approach: lessons learned from the first 20 cases. Arch Surg 2006;141(9):857–65 [discussion: 865–6].
23. Kent MS, Schuchert M, Fernando H, et al. Minimally invasive esophagectomy: state of the art. Dis Esophagus 2006;19(3):137–45.
24. Bhat MA, Dar MA, Lone GN, et al. Use of pedicled omentum in esophagogastric anastomosis for prevention of anastomotic leak. Ann Thorac Surg 2006;82(5):1857–62.
25. Akiyama S, Kodera Y, Sekiguchi H, et al. Preoperative embolization therapy for esophageal operation. J Surg Oncol 1998;69(4):219–23.
26. Nagawa H, Seto Y, Nakatsuka T, et al. Microvascular anastomosis for additional blood flow in reconstruction after intrathoracic esophageal carcinoma surgery. Am J Surg 1997;173(2):131–3.
27. Holscher AH, Schneider PM, Gutschow C, et al. Laparoscopic ischemic conditioning of the stomach for esophageal replacement. Ann Surg 2007;245(2):241–6.
28. Varela E, Reavis KM, Hinojosa MW, et al. Laparoscopic gastric ischemic conditioning prior to esophagogastrectomy: technique and review. Surg Innov 2008;15(2):132–5.
29. Enestvedt CK, Hosack L, Winn SR, et al. VEGF gene therapy augments localized angiogenesis and promotes anastomotic wound healing: a pilot study in a clinically relevant animal model. J Gastrointest Surg 2008;12(10):1762–70 [discussion: 1771–2].
30. Perry KA, Enestvedt CK, Pham T, et al. Comparison of laparoscopic inversion esophagectomy and open transhiatal esophagectomy for high-grade dysplasia and stage I esophageal adenocarcinoma. Arch Surg 2009;144(7):679–84.
31. Pham TH, Perry KA, Dolan JP, et al. Comparison of perioperative outcomes after combined thoracoscopic-laparoscopic esophagectomy and open Ivor-Lewis esophagectomy. Am J Surg 2010;199(5):594–8.
32. Bailey SH, Bull DA, Harpole DH, et al. Outcomes after esophagectomy: a ten-year prospective cohort. Ann Thorac Surg 2003;75(1):217–22 [discussion: 222].
33. Biere SS, Cuesta MA, van der Peet DL. Minimally invasive versus open esophagectomy for cancer: a systematic review and meta-analysis. Minerva Chir 2009;64(2):121–33.
34. Nagpal K, Ahmed K, Vats A, et al. Is minimally invasive surgery beneficial in the management of esophageal cancer? A meta-analysis. Surg Endosc 2010;24(7):1621–9.

35. Luketich JD, Pennathur A, Levy RM, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg 2012;256:95–103.
36. 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.