Surg Endosc (2014) 28:492–499
DOI 10.1007/s00464-013-3230-y

Outcomes following laparoscopic transhiatal esophagectomy for esophageal cancer

J. Christian Cash · Joerg Zehetner · Bobak Hedayati · Nikolai A. Bildzukewicz · Namir Katkhouda · Rodney J. Mason · John C. Lipham

Received: 12 May 2013 / Accepted: 17 September 2013 / Published online: 8 October 2013

Abstract

Background Most published minimally invasive esophagectomy techniques involve a multiple field approach, including laparoscopic and thoracoscopic esophageal mobilization. Laparoscopic transhiatal esophagectomy (LTE) should potentially reduce the complications associated with thoracotomy. This study aims to compare outcomes of LTE with open transhiatal esophagectomy (OTE) and en-bloc esophagectomy (EBE).

Methods Retrospective chart review was performed on all patients who had an LTE for cancer between July 2008 and July 2012 at our institution. Data was compared with an historic cohort of patients who underwent OTE and EBE at the same institution from July 2002 to July 2008.

Results There were 33 patients with LTE, compared with 60 patients with OTE and 139 with EBE. The presence of minor operative complications was similar ($p = 0.36$), but major complications were significantly less common in the LTE group (12, 23 and 33 %, respectively; $p = 0.04$). The median number of blood transfusions during hospitalization was significantly lower in the LTE group (0, 2.5 and 3, respectively; $p = 0.005$). Median tumor size was significantly smaller (1.5, 2.2, and 3 cm, respectively; $p = 0.03$), but the LTE group had a significantly higher percentage of patients with neoadjuvant treatment (39, 14 and 29 %, respectively; $p = 0.008$). Median lymph node yield for LTE was lower (24, 36 and 48, respectively; $p < 0.0001$), but the percentage of patients with positive nodes was similar (33, 33 and 39 %, respectively; $p = 0.69$). Mortality was equivalent among the groups (0, 2 and 4 %, respectively; $p = 0.38$). The median LOS for the LTE group was significantly lower (10, 13 and 15 days, respectively; $p < 0.0001$). Overall survival was not different between the three groups ($p = 0.65$), with median survival at 24 months of 70, 65 and 65 %, respectively.

Conclusion LTE can be performed safely with less major complications and shorter hospital stay than open esophagectomy. The reduced lymph-node harvest did not impact overall survival.

Keywords Esophageal cancer · Laparoscopic transhiatal esophagectomy · Minimally invasive

Esophagectomy is the key element in a multi-modality treatment approach that offers a potential cure for patients with esophageal cancer. Although there have been vast improvements in surgical technique since the first esophagectomy by Kelling in 1911, traditional open esophageal resection has been associated with high morbidity and mortality. Birkmeyer et al. [1] reported mortality ranging from 8 to 23 % in the US, depending on hospital volume. As the incidence of esophageal cancer has risen worldwide, so too has the debate over which technique offers the most optimal combination of minimal morbidity and mortality while retaining strict oncological principles [2]. The importance of reducing operative complications is further emphasized by the development of non-surgical treatment

Presented at the SAGES 2013 Annual Meeting, April 17–April 20, 2013, Baltimore, MD.

J. C. Cash · J. Zehetner · B. Hedayati · N. A. Bildzukewicz · N. Katkhouda · R. J. Mason · J. C. Lipham (✉)
Department of Surgery, Keck School of Medicine, University of Southern California, 1510 San Pablo St, Suite 514, Los Angeles, CA 90033, USA
e-mail: john.lipham@med.usc.edu

options for early-stage esophageal malignancy, such as endoscopic mucosal resection and ablation therapy [3, 4].

Minimally invasive esophagectomy (MIE) techniques were first reported by Cuschieri et al. [5], and in the subsequent two decades, numerous variations have been employed with heterogeneity in the reported perioperative and oncological outcomes. Systematic reviews of MIE studies have shown equivocal results, but meta-analyses have suggested that MIE has lower morbidity with no significant effect on mortality [6–8]. Recent population-based studies in the UK, conducted by Mamidanna et al. [9], showed a dramatic increase in the utilization of MIE over time, but no difference in 30-day mortality or overall morbidity, as well as a higher re-intervention rate.

The most widely employed techniques for MIE involve a multiple-field approach, including laparoscopic and thoracoscopic mobilization of the esophagus. The thoracoscopic approach offers improved visualization of the intrathoracic esophagus and a more thorough dissection of the lymph node basin. While the use of thoracoscopy has reduced the number of chest-related complications in most series, there is room for improvement as pulmonary complications are the leading cause of post-esophagectomy mortality in several series [10–14]. The laparoscopic transhiatal approach was first described by DePaula et al. [15–18] in 1995, with several subsequent reports being published regarding this technique. The transhiatal approach avoids the complications of directly accessing the thorax, although it has not been as widely adopted. One possible explanation is a perceived lack of mediastinal exposure that could potentially compromise the radial resection margins and lymphadenectomy. Although there was initial concern over the oncological feasibility of minimally invasive techniques, a systematic review by Dantoc et al. [19] reported higher median lymph node yield for MIE compared with open techniques (16 vs. 10), as well as no significant difference in 5-year survival.

In this study, we compared a series of 33 laparoscopic transhiatal esophagectomies (LTEs) for esophageal cancer with a historical cohort of patients undergoing open transhiatal esophagectomy (OTE) and en-bloc esophagectomy (EBE) at the same institution to investigate perioperative outcomes, lymph node harvest, and overall survival.

Materials and methods

This study was approved by the Institutional Review Board of the University of Southern California. Charts were reviewed to identify all patients who had undergone LTE for esophageal cancer from July 2008 to July 2012. Data on these patients were collected using the hospital's electronic and paper medical record. During the study period, all esophagectomies performed by the primary surgeon were via the LTE technique, with the exclusion of those with prior major abdominal surgery. All patients undergoing completed LTE or attempted LTE converted to open were included in the analysis. The Social Security Death Index was accessed to verify the survival status for all patients.

Data were analyzed and compared with a historical cohort of esophageal cancer patients who underwent OTE and EBE at the same institution from July 2002 to July 2008. Statistical analyses were performed using Prism (GraphPad, La Jolla, CA, USA). Survival estimates were calculated according to the Kaplan–Meier method. Statistical significance was defined by $p < 0.05$.

Post-operative complications were classified as minor or major. Minor complications were those that did not require interventional procedures or reoperations. All other complications were classified as major, including any anastomotic leak; anastomotic leaks were further classified as minor or major leaks. Minor leaks were those treated with antibiotics alone and did not require interventional procedures, stenting, or reoperation, while all other leaks were classified as major.

Comorbidities were subdivided into cardiac and respiratory, as well as the presence of hypertension and diabetes. Cardiac comorbidities were defined as having any documented history of angina, myocardial infarction, coronary artery disease and valvular disease, or any history of interventional or open cardiac procedures. Respiratory comorbidities were defined as having any documented history of restrictive or obstructive lung disease, or the patient was actively smoking.

Surgical procedure

En-bloc and transhiatal esophagectomy were performed as described in previous publications [20, 21]. LTE is performed with the patient in the dorsal lithotomy position, with the operating surgeon standing between the legs and assistants on either side. Trocars are placed in the upper abdomen in a standard Nissen fundoplication configuration. The distal esophagus and all periesophageal tissue are then carefully mobilized and the dissection is extended proximally in a circumferential manner. The pericardium is skeletonized anteriorly up to the carina. In a similar manner, the aorta is skeletonized posteriorly, and the parietal pleura laterally. The right and left crura are often incised to provide better exposure of the mediastinum. After completing this portion of the mediastinal dissection, the stomach is then mobilized and a lymphadenectomy of the celiac trunk is performed. The cervical dissection is then performed and the cervical esophagus is dissected down to the proximal extent of the previous mediastinal dissection. The esophagus is then transected in the neck and removed

Table 1 Baseline characteristics and comorbidities

	LTE (%) [n = 33]	OTE (%) [n = 60]	EBE (%) [n = 139]	p Value
Age (years)	72 (50–83)	75.5 (70–80)	61 (53–71)	<0.0001
Sex				
Male	22	51	129	0.0003
Female	11	9	10	
Co-Morbidities	25 (76)	50 (83)	87 (63)	0.01
Cardiac	15 (45)	24 (40)	19 (14)	<0.0001
Respiratory	8 (24)	21 (35)	21 (15)	0.007
Hypertension	17 (52)	40 (67)	57 (41)	0.004
Diabetes	3 (9)	9 (15)	15 (11)	0.62

EBE en-bloc esophagectomy, *LTE* laparoscopic transhiatal esophagectomy, *OTE* open transhiatal esophagectomy

Table 2 Tumor staging and recurrence

	LTE (%) [n = 33]	OTE (%) [n = 60]	EBE (%) [n = 139]	p Value
Stage I	15 (45)	22 (37)	35 (25)	0.04
Stage II	6 (18)	16 (26)	45 (32)	0.24
Stage III	12 (37)	22 (37)	59 (43)	0.67
Neoadjuvant	13 (39)	7 (14)	31 (29)	0.008
Tumor size (cm)	1.5	2.2	3.0	0.03
Median lymph nodes	24	36	48	<.0001
Patients with positive nodes	11 (33)	20 (33)	54 (39)	0.65
Recurrence	8 (24)	15 (25)	38 (27)	0.90
Locoregional	5	4	14	0.24
Systemic	3	11	23	

EBE en-bloc esophagectomy, *LTE* laparoscopic transhiatal esophagectomy, *OTE* open transhiatal esophagectomy

transabdominally after the camera port is extended to accommodate the specimen. The stomach is tubularized by sequential firings of the GIA 100 mm stapler, and the staple line is over-sewn. Prior to removal, an umbilical tape is affixed to the esophagus, which is then used to pass a chest tube retrograde through the posterior mediastinum, attached to the gastric conduit, and gently withdrawn to pull the conduit up into the neck. A Kocher maneuver is not routinely performed as tubularization of the stomach generally provides enough conduit length, although, if necessary, this could be performed through the small midline incision used for specimen removal. Adequate vascular supply to the conduit is confirmed, and a single-layer, hand-sewn anastomosis is constructed. Additionally, a jejunostomy feeding tube is routinely placed. Pyloroplasty is not performed for any patients undergoing LTE.

Results

Between July 2008 and July 2012, a total of 33 consecutive LTE were performed for patients with squamous cell carcinoma or adenocarcinoma of the esophagus. The results were compared with a cohort of 60 patients who underwent OTE and 139 patients who underwent EBE for the same pathology from July 2002 to July 2008. The median age was significantly different between the groups, with EBE having the youngest patients ($p < 0.0001$) [Table 1]. The majority of patients in all groups were men, although the male predominance was significantly less in the LTE group ($p = 0.0003$). Prevalence of comorbidities was significantly higher in the LTE and OTE groups than EBE ($p = 0.01$), with a higher incidence in all subgroups except prevalence of diabetes.

When pathological staging was analyzed, the EBE group had fewer stage I tumors; otherwise, there were no significant differences in staging of the groups (Table 2). Median tumor size was significantly smaller in the LTE group compared with the OTE and EBE groups ($p = 0.03$), but there was also a significantly higher percentage of patients who received neoadjuvant therapy in the LTE group ($p = 0.008$). Of patients in the LTE group receiving neoadjuvant treatment, 23 % had a complete pathological response (3/13). Additionally, the percentage of patients with positive nodes was similar among all groups ($p = 0.65$), although the number of lymph nodes resected was lower for the LTE group (24) than the OTE and EBE groups ($p < 0.0001$). Recurrence was similar among all groups ($p = 0.9$), with no significant differences between the ratios of systemic and locoregional recurrence between the groups ($p = 0.24$).

The LTE group had a conversion rate of 6.1 % (2/33), with one conversion being due to the inability to clearly identify the left gastric vessels due to adherent tissue obscuring proper visualization. The other conversion was due to difficulty with port placement and maintaining proper insufflation secondary to a previous abdominal wall reconstruction with mesh after TRAM (Transverse Rectus Abdominis Myocutaneous) flap for breast reconstruction.

The average operative time was similar among the LTE and OTE groups (274 and 275.5 min, respectively), and significantly shorter than the EBE group (415 minutes; $p < 0.0001$) [Fig. 1]. The presence of minor operative complications among the three groups was similar ($p = 0.36$), but major complications were significantly less common in the LTE group ($p = 0.04$) [Table 3]. There was no difference in the incidence of pulmonary complications ($p = 0.57$) or anastomotic leaks ($p = 0.72$). The LTE group did not require any re-operations compared with 10 and 16 % in the OTE and EBE groups, respectively, although this difference was not statistically significant ($p = 0.56$). The median LOS was significantly lower for

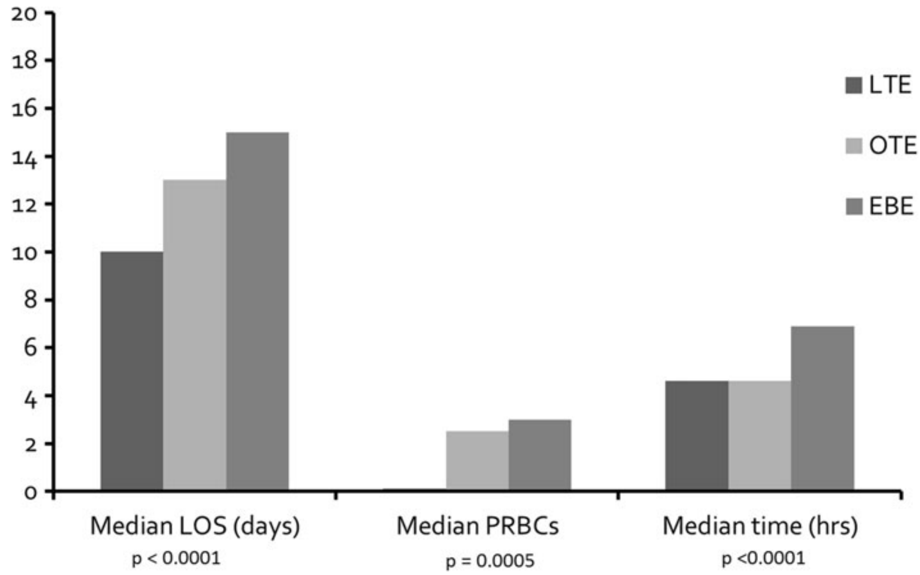

Fig. 1 Perioperative outcomes. *EBE* en-bloc esophagectomy, *LTE* laparoscopic transhiatal esophagectomy, *OTE* open transhiatal esophagectomy

Table 3 Morbidity and mortality

	LTE (%) [$n = 33$]	OTE (%) [$n = 60$]	EBE (%) [$n = 139$]	p Value
Morbidity				
Minor	9 (27)	23 (38)	40 (29)	0.36
Major	4 (12)	14 (23)	46 (33)	0.04
Leak	3 (9)	8 (13)	20 (14)	0.72
Minor	2	5	13	–
Major	1	3	7	–
Chest	2 (6)	5 (8.3)	16 (11.5)	0.57
Reoperations	0	6 (10)	22 (16)	0.56
Mortality	0	1 (2)	6 (4)	0.39

EBE en-bloc esophagectomy; *LTE* laparoscopic transhiatal esophagectomy; *OTE* open transhiatal esophagectomy

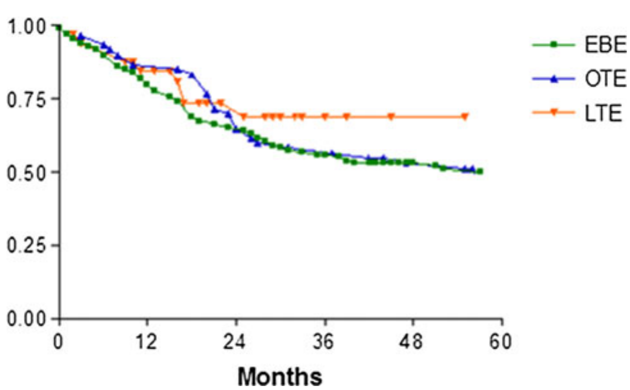

Fig. 2 Kaplan–Meier survival curve. *EBE* en-bloc esophagectomy, *LTE* laparoscopic transhiatal esophagectomy, *OTE* open transhiatal esophagectomy

the LTE group at 10 days compared with the OTE and EBE groups at 13 days and 15 days, respectively ($p < 0.0001$). Median PRBC transfusion during hospitalization was significantly lower for the LTE group at 0, compared with 2.5 and 3 in the OTE and EBE groups, respectively ($p = 0.0005$) [Fig. 1].

Median follow-up was 26 months (range 2–55 months) for the LTE group, 64 months for the OTE group, and 62 months for the EBE group. Using the Kaplan–Meier method, overall survival was not significantly different between the groups, with a median survival at 24 months of 70, 65, and 65 %, respectively ($p = 0.65$) [Fig. 2].

Discussion

The number of centers employing MIE continues to rise, as well as the overall percentage of patients undergoing MIE compared with open repair [22]. As a result, the optimal approach to esophageal resection for malignancy remains an area of active debate [23]. In their selected series of LTE compared with combined laparoscopic and thoracoscopic two-field esophagectomy, Benzoni et al. [24] showed shorter operative times, shorter intensive care unit and overall stay, and a trend towards better survival in the LTE group, although this was limited by a small number of patients. Because of the difficulty of randomization, only one trial has been published to date. This study compared open transthoracic with minimally invasive transthoracic esophagectomy, showing lower rates of pulmonary complications and shorter hospital stay in the MIE group, with equivalent lymph node yield between the two arms [25]. To date, there has not been a randomized trial comparing LTE with either open or minimally invasive techniques. Our objective was to compare our series of patients undergoing LTE with a historical cohort who underwent open transhiatal and EBE at our institution.

The age of patients undergoing LTE and OTE was significantly higher than those undergoing EBE. This was likely due to selection bias against older patients in the EBE group, given the higher prevalence of comorbidities among an older population and the high morbidity associated with this operation. This is reinforced by the finding that the LTE and OTE groups had significantly higher comorbidities overall, and previous studies have suggested that a transhiatal approach may be beneficial for this group of patients [26]. The male predominance in our series is consistent with other reported series. The LTE group also encompassed the first 33 consecutive patients undergoing this procedure, however they were not selected as all esophagectomies performed by the primary surgeon during the study period were via LTE approach.

The LTE group also showed a significantly shorter operative time than the EBE group, and operative times are comparable to those reported in other recent series of laparoscopic and laparoscopic hand-assisted transhiatal esophagectomies [15, 26–28]. Maas et al. showed similar operative times when comparing LTE and OTE (300 vs. 280; $p = 0.11$) [26]. LTE also has the potential for shorter operative times compared with other MIE techniques utilizing thoracoscopy since these require intraoperative repositioning of the patient.

Blood loss for LTE was also less, as evidenced by a significantly lower need for perioperative blood transfusion, which is also in keeping with other reported series that showed lower incidence of intraoperative blood transfusions and lower median volume of products transfused when comparing MIE with open procedures [6]. The need for transfusion was analyzed instead of estimated intraoperative blood loss as we feel that these estimates are subjective and inaccurate, and instead wanted to focus on blood loss significant enough to warrant transfusion. With improved visualization during a laparoscopic transhiatal approach, blood loss is minimized as there is less 'blind' dissection associated with the open transhiatal approach.

Depending on the type of MIE employed, conversion rates between 3 and 18 % have been reported in the literature [29, 30]. Our conversion rate of 6.1 % is lower than that reported in other recent series [17, 26, 31]. Although previous reports described problems with bleeding due to blunt dissection associated with the transhiatal approach, we experienced no such issues with hemostasis as our conversions were due to aberrant anatomical considerations. Luketich et al. [32] reported a conversion rate of 4.5 % in their large series, with reasons for conversion from laparoscopy most commonly cited as adhesions, inadequate conduit length, tumor bulkiness, or need to better assess margins. Other series have excluded patients from LTE based on prior upper abdominal surgery [33] but none in our group were excluded for this reason, although one conversion was due to difficulty maintaining pneumoperitoneum due to a prior complex abdominal wall reconstruction. The significantly shorter length of stay for LTE is consistent with other reports of MIE [15, 34]. Initial studies showed a shorter LOS for hand-assisted LTE compared with OTE (9.1 vs. 11.6; $p = 0.037$) [35], with a similar reduction shown in more recent series of LTE [26, 33]. In their review, Decker et al. [36] reported median LOS of 11.5 days for all MIE techniques versus 15–19 days for conventional approaches. The transhiatal approach can potentially reduce complications by avoiding the atelectasis associated with thoracoscopy or thoracotomy. Although minor post-operative complications were similar among groups, major operative complications were significantly lower in the laparoscopic group. Hulscher et al. [37] showed lower rates of pulmonary complications with the transhiatal approach in a randomized trial, presumably by obviating the need for single-lung ventilation and direct thoracic access. Other studies have reported lower rates of pulmonary complications with MIE [38–40]. Maas et al. also showed a lower incidence, although not significant, of pulmonary and cardiac complications in their comparison of LTE and OTE [26]. Other comparative studies have shown 8–10 % complication rates for open and 7–8 % for LTE [41, 42]. We had a trend toward lower pulmonary complications in our series and feel this may approach statistical significance with a larger series.

Higher leak rates with cervical anastomoses are widely reported [38, 43], although a few have reported higher leak rates with thoracic anastomosis [30]. We only perform cervical anastomosis in conjunction with LTE as we believe the potential increased risk of leak is offset by the ease in managing cervical leaks compared with the often catastrophic consequences of thoracic leaks and associated mediastinitis. Our series showed no difference in leak rates and are consistent with others reported in the literature ranging from 7 to 13% [36], including those of Luketich et al. [32] and Orringer et al. [44] in their large series.

A population-based study by Mamidanna et al. showed an increased re-intervention rate among MIE compared with open (21 vs. 17.6 %; $p = 0.006$) [9]. Conversely, our comparison showed statistically significant lower rates of major complications (requiring interventional procedures or re-operation) and a trend toward lower incidence of re-operations.

Studies have reported that performing the lower and middle portions of the mediastinal lymphadenectomy via the hiatus allows it to be approached along the appropriate anatomical layers, with good surgical views of the posterior and left mediastinum [45]. A recent meta-analysis reported high overall median LN yield (16 vs. 10; $p = 0.02$) for MIE compared with open [46] as well as another recent series (20 vs. 9; $p < 0.0001$) [47]. Another study comparing LTE with laparoscopic and thoracoscopic two-field esophagectomy showed higher LN yields for LTE [24]. In contrast, our series showed a lower LN yield for LTE compared with open groups, similar to the lower yield reported for LTE by Luketich et al. [48] in their series and a recent review showing lower yield for transhiatal approaches overall [36].

Although the number of lymph nodes resected in the LTE group was significantly different than in the other groups, our median of 24 exceeds the yield of 16 required for a complete lymphadenectomy reported in various studies [19, 49, 50], and is higher than that reported in other series [15, 31, 34]. These variances could be due to surgical protocol or the quality of pathological examination. Other LTE series have reported similar LN yields and our yield approximates that reported by a recent large series of over 1,000 MIE patients [27, 32].

Our higher incidence of neoadjuvant therapy in the LTE group is consistent with that in recent published literature. A systematic review reported no overall difference in stage of patients undergoing open versus MIE but a significantly greater use of neoadjuvant therapy among patients undergoing MIE [19]. Our general institutional policy is to refer patients for neoadjuvant treatment if more than two lymph nodes are identified on EUS; however, a significant portion of our patients are referred from outside our institution, so there was not uniformity regarding the neoadjuvant regimen received. In patients undergoing MIE, the presence or absence of neoadjuvant treatment did not affect operative time, blood loss, or LN yield [34, 51].

Our preponderance of early-stage patients in the LTE group mirrors that in the Decker et al. series, who reported transhiatal MIE, including more early-stage patients than transthoracic MIE (36 vs. 21 % for stage 0 or I) [36]. Other recent series have also reported staging disparities between comparison groups, but this should not preclude any comparison of oncological outcomes [8, 52, 53]. Our institution previously reported increased survival for patients with higher stage (T3N1) tumors for patients undergoing EBE compared with OTE, which could explain the higher incidence of stage III cancer in our EBE group compared with the OTE group [54].

MIE has been shown to provide appropriate locoregional control. Our comparison shows no difference in recurrence rates based on operative technique, which is consistent with a report by Thomson et al. showing that operative approach was not a prognostic factor for recurrence (local, regional, or distant) [55]. The necessary radicality of LN dissection is controversial [56–58]. Our institution previously reported a survival benefit for patients with 23 or more LN resected [59], although it is unclear whether this benefit is due to stage migration or eradication of occult metastatic disease. Other reports have called into question this conclusion, and a randomized trial by Omloo et al. [60] showed no survival benefit for open TTE compared with open THE, although the open TTE had greater LN yield.

Recent studies have suggested that a less invasive and radical operation is not necessarily a less curative one. A meta-analysis by Hulscher et al. [37] showed similar 5-year survival rates for those undergoing transthoracic compared with transhiatal esophagectomy. In a randomized trial by the same group, there was no significant difference in the median survival, disease-free survival, and quality-adjusted survival between the groups [61]. The authors commented that long follow-up is needed to determine whether the possible survival benefit outweighs the increased morbidity associated with the transthoracic approach [37]. Reports from our institution [21, 54] have shown improved survival and decreased local recurrence with more radical LN resections in selected series, but reports comparing MIE with open techniques have shown at least equivalent survival. A recent meta-analysis showed no difference in overall 5-year survival between open and MIE, and MIE showed better survival in earlier time periods [46], as did a recent series [6]. Survival at 24 months was equivalent among all groups in our series, which is consistent with the literature, and reinforces our hypothesis that less radical lymph node dissections will not negatively impact survival. Maas et al. showed no difference in overall and disease-free survival at 3 and 5 years in their study comparing LTE and OTE, and others have suggested that survival may be improved with MIE, but the majority of recent publications and our own experience suggests MIE in general and LTE specifically has at least equivalent survival compared with open techniques [15, 24, 26].

Our data should be interpreted carefully as there are inherent shortcomings with any retrospective series. Our follow-up time is limited, and our controls were not conducive to case-matching. Randomized trials comparing the differing modalities of MIE should be undertaken to further define the roles of these techniques in esophageal cancer treatment.

Conclusion

LTE has several advantages over open techniques for esophageal cancer resection. Operative mortality and reoperations are equivalent to open techniques, with lower major complication rates, less blood loss and shorter LOS. LTE provides excellent exposure and yields an appropriate lymph node harvest and oncological resection with equivalent recurrence and survival rates. LTE should be considered as a preferred approach to esophagectomy.

Disclosures Drs. Cash, Zehetner, Bildzukewicz, Katkhouda, Mason and Lipham and Mr. Hedayati have no conflicts of interest or financial ties to disclose.

Funding No sources of funding were provided for this manuscript.

References

1. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, Welch HG, Wennberg DE (2002) Hospital volume and surgical mortality in the United States. N Engl J Med 346:1128–1137
2. Enzinger PC, Mayer RJ (2003) Esophageal cancer. N Engl J Med 349:2241–2252
3. Foroulis CN, Thorpe JA (2006) Photodynamic therapy (PDT) in Barrett's esophagus with dysplasia or early cancer. Eur J Cardiothorac Surg 29:30–34
4. Ell C, May A, Pech O, Gossner L, Guenter E, Behrens A, Nachbar L, Huijsmans J, Vieth M, Stolte M (2007) Curative endoscopic resection of early esophageal adenocarcinomas (Barrett's cancer). Gastrointest Endosc 65:3–10
5. Cuschieri A, Shimi S, Banting S, Vander Velpen G (1992) Technical aspects of laparoscopic splenectomy: hilar segmental devascularization and instrumentation. J R Coll Surg Edinb 37:414–416
6. Sundaram A, Geronimo JC, Willer BL, Hoshino M, Torgersen Z, Juhasz A, Lee TH, Mittal SK (2012) Survival and quality of life after minimally invasive esophagectomy: a single-surgeon experience. Surg Endosc 26:168–176
7. Sihag S, Wright CD, Wain JC, Gaissert HA, Lanuti M, Allan JS, Mathisen DJ, Morse CR (2012) Comparison of perioperative outcomes following open versus minimally invasive Ivor Lewis oesophagectomy at a single, high-volume centre. Eur J Cardiothorac Surg 42:430–437
8. Braghetto I, Csendes A, Cardemil G, Burdiles P, Korn O, Valladares H (2006) Open transthoracic or transhiatal esophagectomy versus minimally invasive esophagectomy in terms of morbidity, mortality and survival. Surg Endosc 20:1681–1686
9. Mamidanna R, Bottle A, Aylin P, Faiz O, Hanna GB (2012) Short-term outcomes following open versus minimally invasive esophagectomy for cancer in England: a population-based national study. Ann Surg 255:197–203
10. Law S, Wong KH, Kwok KF, Chu KM, Wong J (2004) Predictive factors for postoperative pulmonary complications and mortality after esophagectomy for cancer. Ann Surg 240:791–800
11. Gao Y, Wang Y, Chen L, Zhao Y (2011) Comparison of open three-field and minimally-invasive esophagectomy for esophageal cancer. Interact Cardiovasc Thorac Surg 12:366–369
12. Ferri LE, Law S, Wong KH, Kwok KF, Wong J (2006) The influence of technical complications on postoperative outcome and survival after esophagectomy. Ann Surg Oncol 13:557–564
13. Atkins BZ, Shah AS, Hutcheson KA, Mangum JH, Pappas TN, Harpole DH Jr, D'Amico TA (2004) Reducing hospital morbidity and mortality following esophagectomy. Ann Thorac Surg 78:1170–1176 discussion 1170-1176
14. Agostini P, Cieslik H, Rathinam S, Bishay E, Kalkat MS, Rajesh PB, Steyn RS, Singh S, Naidu B (2010) Postoperative pulmonary complications following thoracic surgery: are there any modifiable risk factors? Thorax 65:815–818
15. Montenovo MI, Chambers K, Pellegrini CA, Oelschlager BK (2011) Outcomes of laparoscopic-assisted transhiatal esophagectomy for adenocarcinoma of the esophagus and esophagogastric junction. Dis Esophagus 24:430–436
16. DePaula AL, Hashiba K, Ferreira EA, de Paula RA, Grecco E (1995) Laparoscopic transhiatal esophagectomy with esophagogastroplasty. Surg Laparosc Endosc 5:1–5
17. Bonavina L, Incarbone R, Bona D, Peracchia A (2004) Esophagectomy via laparoscopy and transmediastinal endodissection. J Laparoendosc Adv Surg Tech A 14:13–16
18. Swanstrom LL, Hansen P (1997) Laparoscopic total esophagectomy. Arch Surg 132:943–947 discussion 947-949
19. Dantoc MM, Cox MR, Eslick GD (2012) Does minimally invasive esophagectomy (MIE) provide for comparable oncologic outcomes to open techniques? A systematic review. J Gastrointest Surg 16:486–494
20. Orringer MB (1984) Transhiatal esophagectomy without thoracotomy for carcinoma of the thoracic esophagus. Ann Surg 200:282–288
21. Hagen JA, DeMeester SR, Peters JH, Chandrasoma P, DeMeester TR (2001) Curative resection for esophageal adenocarcinoma: analysis of 100 en bloc esophagectomies. Ann Surg 234:520–530 discussion 530-521
22. Lazzarino AI, Nagpal K, Bottle A, Faiz O, Moorthy K, Aylin P (2010) Open versus minimally invasive esophagectomy: trends of utilization and associated outcomes in England. Ann Surg 252:292–298
23. Dunst CM, Swanstrom LL (2010) Minimally invasive esophagectomy. J Gastrointest Surg 14(Suppl. 1):S108–S114
24. Benzoni E, Terrosu G, Bresadola V, Uzzau A, Intini S, Noce L, Cedolini C, Bresadola F, De Anna D (2007) A comparative study of the transhiatal laparoscopic approach versus laparoscopic gastric mobilisation and right open transthoracic esophagectomy for esophageal cancer management. J Gastrointestin Liver Dis 16:395–401
25. Biere SS, van Berge Henegouwen MI, Maas KW, Bonavina L, Rosman C, Garcia JR, Gisbertz SS, Klinkenbijl JH, Hollmann MW, de Lange ES, Bonjer HJ, van der Peet DL, Cuesta MA (2012) Minimally invasive versus open oesophagectomy for patients with oesophageal cancer: a multicentre, open-label, randomised controlled trial. Lancet 379:1887–1892
26. Maas KW, Biere SS, Scheepers JJ, Gisbertz SS, van-der-Peet DL, Cuesta MA (2012) Laparoscopic versus open transhiatal esophagectomy for distal and junction cancer. Rev Esp Enferm Dig 104:197–202
27. Parker M, Bowers SP, Goldberg RF, Pfluke JM, Stauffer JA, Asbun HJ, Smith CD (2011) Transcervical videoscopic esophageal dissection during two-field minimally invasive esophagectomy: early patient experience. Surg Endosc 25:3865–3869
28. Aujesky R, Neoral C, Kral V, Bohanes T, Vrba R, Vomackova K (2009) Video-assisted laparoscopic resection of the esophagus for carcinoma after neoadjuvant therapy. Hepatogastroenterology 56:1035–1038
29. Song SY, Na KJ, Oh SG, Ahn BH (2009) Learning curves of minimally invasive esophageal cancer surgery. Eur J Cardiothorac Surg 35:689–693
30. Nguyen NT, Hinojosa MW, Smith BR, Chang KJ, Gray J, Hoyt D (2008) Minimally invasive esophagectomy: lessons learned from 104 operations. Ann Surgery 248:1081–1091
31. Santin BJ, Price P (2011) Laparoscopic transhiatal esophagectomy at a low-volume center. JSLS 15:41–46
32. Luketich JD, Pennathur A, Awais O, Levy RM, Keeley S, Shende M, Christie NA, Weksler B, Landreneau RJ, Abbas G, Schuchert MJ, Nason KS (2012) Outcomes after minimally invasive esophagectomy: review of over 1000 patients. Ann Surg 256:95–103
33. Scheepers JJ, Veenhof AA, van der Peet DL, van Groeningen C, Mulder C, Meijer S, Cuesta MA (2008) Laparoscopic transhiatal resection for malignancies of the distal esophagus: outcome of the first 50 resected patients. Surgery 143:278–285

34. Ben-David K, Sarosi GA, Cendan JC, Howard D, Rossidis G, Hochwald SN (2012) Decreasing morbidity and mortality in 100 consecutive minimally invasive esophagectomies. Surg Endosc 26:162–167
35. Bernabe KQ, Bolton JS, Richardson WS (2005) Laparoscopic hand-assisted versus open transhiatal esophagectomy: a case-control study. Surg Endosc 19:334–337
36. Decker G, Coosemans W, De Leyn P, Decaluwe H, Nafteux P, Van Raemdonck D, Lerut T (2009) Minimally invasive esophagectomy for cancer. Eur J Cardiothorac Surg 35:13–20 discussion 20-11
37. Hulscher JB, van Sandick JW, de Boer AG, Wijnhoven BP, Tijssen JG, Fockens P, Stalmeier PF, ten Kate FJ, van Dekken H, Obertop H, Tilanus HW, van Lanschot JJ (2002) Extended transthoracic resection compared with limited transhiatal resection for adenocarcinoma of the esophagus. N Engl J Med 347:1662–1669
38. Schoppmann SF, Prager G, Langer FB, Riegler FM, Kabon B, Fleischmann E, Zacherl J (2010) Open versus minimally invasive esophagectomy: a single-center case controlled study. Surg Endosc 24:3044–3053
39. Parameswaran R, Blazeby JM, Hughes R, Mitchell K, Berrisford RG, Wajed SA (2010) Health-related quality of life after minimally invasive oesophagectomy. Br J Surg 97:525–531
40. Lee JM, Cheng JW, Lin MT, Huang PM, Chen JS, Lee YC (2011) Is there any benefit to incorporating a laparoscopic procedure into minimally invasive esophagectomy? The impact on perioperative results in patients with esophageal cancer. World J Surg 35:790–797
41. Van den Broek WT, Makay O, Berends FJ, Yuan JZ, Houdijk AP, Meijer S, Cuesta MA (2004) Laparoscopically assisted transhiatal resection for malignancies of the distal esophagus. Surg Endosc 18:812–817
42. Dapri G, Himpens J, Cadiere GB (2008) Minimally invasive esophagectomy for cancer: laparoscopic transhiatal procedure or thoracoscopy in prone position followed by laparoscopy? Surg Endosc 22:1060–1069
43. Urschel JD (1995) Esophagogastrostomy anastomotic leaks complicating esophagectomy: a review. Am J Surg 169:634–640
44. Orringer MB, Marshall B, Chang AC, Lee J, Pickens A, Lau CL (2007) Two thousand transhiatal esophagectomies: changing trends, lessons learned. Ann Surg 246:363–372 discussion 372-364
45. Shiozaki A, Fujiwara H, Murayama Y, Komatsu S, Kuriu Y, Ikoma H, Nakanishi M, Ichikawa D, Okamoto K, Ochiai T, Kokuba Y, Otsuji E (2012) Perioperative outcomes of esophagectomy preceded by the laparoscopic transhiatal approach for esophageal cancer. Dis Esophagus. doi:10.1111/j.1442-2050.2012.01439.x
46. Dantoc M, Cox MR, Eslick GD (2012) Evidence to support the use of minimally invasive esophagectomy for esophageal cancer: a meta-analysis. Arch Surg 147:768–776
47. Berger AC, Bloomenthal A, Weksler B, Evans N, Chojnacki KA, Yeo CJ, Rosato EL (2011) Oncologic efficacy is not compromised, and may be improved with minimally invasive esophagectomy. J Am Coll Surg 212:560–566 discussion 566-568
48. Luketich JD, Alvelo-Rivera M, Buenaventura PO, Christie NA, McCaughan JS, Litle VR, Schauer PR, Close JM, Fernando HC (2003) Minimally invasive esophagectomy: outcomes in 222 patients. Ann Surgery 238:486–494 discussion 494-485
49. Qureshi I, Nason KS, Luketich JD (2008) Is minimally invasive esophagectomy indicated for cancer? Expert Rev Anticancer Ther 8:1449–1460
50. Gemmill EH, McCulloch P (2007) Systematic review of minimally invasive resection for gastro-oesophageal cancer. Br J Surg 94:1461–1467
51. Yamasaki M, Miyata H, Fujiwara Y, Takiguchi S, Nakajima K, Kurokawa Y, Mori M, Doki Y (2011) Minimally invasive esophagectomy for esophageal cancer: comparative analysis of open and hand-assisted laparoscopic abdominal lymphadenectomy with gastric conduit reconstruction. J Surg Oncol 104:623–628
52. Smithers BM, Gotley DC, Martin I, Thomas JM (2007) Comparison of the outcomes between open and minimally invasive esophagectomy. Ann Surg 245:232–240
53. Godiris-Petit G, Munoz-Bongrand N, Honigman I, Cattan P, Sarfati E (2006) Minimally invasive esophagectomy for cancer: prospective evaluation of laparoscopic gastric mobilization. World J Surg 30:1434–1440
54. Johansson J, DeMeester TR, Hagen JA, DeMeester SR, Peters JH, Oberg S, Bremner CG (2004) En bloc vs transhiatal esophagectomy for stage T3 N1 adenocarcinoma of the distal esophagus. Arch Surg 139:627–631 discussion 631-623
55. Thomson IG, Smithers BM, Gotley DC, Martin I, Thomas JM, O'Rourke P, Barbour AP (2010) Thoracoscopic-assisted esophagectomy for esophageal cancer: analysis of patterns and prognostic factors for recurrence. Ann Surg 252:281–291
56. Rizk N, Venkatraman E, Park B, Flores R, Bains MS, Rusch V, American Joint Committee on Cancer staging s (2006) The prognostic importance of the number of involved lymph nodes in esophageal cancer: implications for revisions of the American Joint Committee on Cancer staging system. J Thorac Cardiovasc Surg 132:1374–1381
57. Pennathur A, Zhang J, Chen H, Luketich JD (2010) The "best operation" for esophageal cancer? Ann Thorac Surg 89:S2163–S2167
58. Lerut T, Nafteux P, Moons J, Coosemans W, Decker G, De Leyn P, Van Raemdonck D, Ectors N (2004) Three-field lymphadenectomy for carcinoma of the esophagus and gastroesophageal junction in 174 R0 resections: impact on staging, disease-free survival, and outcome: a plea for adaptation of TNM classification in upper-half esophageal carcinoma. Ann Surg 240:962–972 discussion 972-964
59. Peyre CG, Hagen JA, DeMeester SR, Altorki NK, Ancona E, Griffin SM, Holscher A, Lerut T, Law S, Rice TW, Ruol A, van Lanschot JJ, Wong J, DeMeester TR (2008) The number of lymph nodes removed predicts survival in esophageal cancer: an international study on the impact of extent of surgical resection. Ann Surg 248:549–556
60. Omloo JM, Lagarde SM, Hulscher JB, Reitsma JB, Fockens P, van Dekken H, Ten Kate FJ, Obertop H, Tilanus HW, van Lanschot JJ (2007) 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 246:992–1000 discussion 1000-1001
61. Hulscher JB, Van Sandick JW, Offerhaus GJ, Tilanus HW, Obertop H, Van Lanschot JJ (2001) Prospective analysis of the diagnostic yield of extended en bloc resection for adenocarcinoma of the oesophagus or gastric cardia. Br J Surg 88:715–719