Published in final edited form as:

J Surg Oncol. 2015 December ; 112(5): 517–523. doi:10.1002/jso.24024.

Transthoracic Versus Transhiatal Resection for Esophageal Adenocarcinoma of the Lower Esophagus: A Value-Based Comparison

Onkar V. Khullar, MD¹, Renjian Jiang, MPH², Seth D. Force, MD¹, Allan Pickens, MD¹, Manu S. Sancheti, MD¹, Kevin Ward, PhD, MPH², Theresa Gillespie, PhD^{3,4}, and Felix G. Fernandez, MD^{1,*}

¹Section of General Thoracic Surgery, Emory University School of Medicine, Atlanta, Georgia

²Rollins School of Public Health, Emory University, Atlanta, Georgia

³Department of Surgery, Emory University School of Medicine, Atlanta, Georgia

⁴Department of Hematology and Medical Oncology, Emory University School of Medicine, Atlanta, Georgia

Abstract

Background and Objective—Our objective was to compare clinical outcomes, costs, and resource use based on operative approach, transthoracic (TT) or transhiatal (TH), for resection of esophageal cancer.

Methods—This cohort analysis utilized the Surveillance, Epidemiology, and End Results—Medicare linked data from 2002 to 2009. Only adenocarcinomas of the lower esophagus were examined to minimize confounding. Medicare data was used to determine episode of care costs and resource use. Propensity score matching was used to control for identified confounders. Kaplan–Meier method and Cox-proportional hazard modeling were used to compare long-term survival.

Results—537 TT and 405 TH resections were identified. TT and TH esophagectomy had similar complication rates (46.7% vs. 50.8%), operative mortality (7.9% vs 7.1%), and 90 days readmission rates (30.5% vs. 32.5%). However, TH was associated with shorter length of stay (11.5 vs. 13.0 days, $P = 0.006$) and nearly \$1,000 lower cost of initial hospitalization ($P = 0.03$). No difference in 5-year survival was identified (33.5% vs. 36%, $P = 0.75$).

Conclusions—TH esophagectomy was associated with lower costs and shorter length of stay in an elderly Medicare population, with similar clinical outcomes to TT. The TH approach to esophagectomy for distal esophageal adenocarcinoma may, therefore, provide greater value (quality/cost).

*Correspondence to: Felix G. Fernandez, MD, The Emory Clinic, 1365 Clifton Road, NE, Suite A2215, Atlanta, Georgia 30322. Fax: +1-404-778-4346. felix.fernandez@emoryhealthcare.org.

Supporting Information: Additional supporting information may be found in the online version of this article at the publisher's web-site.

Keywords

esophageal adenocarcinoma; transhiatal esophagectomy; transthoracic esophagectomy; esophagectomy; value

Introduction

Esophageal cancer is the seventh leading cause of cancer related mortality in the United States and its incidence continues to rise [1]. The American Cancer Society's estimates for esophageal cancer in the United States for 2014 are approximately 18,170 new cases and approximately 15,450 deaths [2]. Surgical resection, often as part of a multimodality approach, remains the preferred treatment for potentially curable esophageal cancer. However, operative morbidity occurs in up to 50% of patients undergoing an esophageal resection [3,4]. In addition, operative mortality rates are notable and reported to range from 2.7% to 13.1%, with variation dependent on the data source [4–12]. As a result, esophagectomy has become the focus of nationwide surgical quality improvement efforts. For example, there are three National Quality Forum endorsed quality metrics for esophageal cancer [13]. Additionally, the American College of Surgeons National Quality Improvement Program (ACS NSQIP) tracks comparisons for esophagectomy outcomes between hospitals [14].

Unfortunately, there is no evidence-based optimal surgical approach to esophagectomy. There has been, and continues to be, considerable debate as to the most appropriate surgical approach to esophagectomy: transthoracic (TT) or transhiatal (TH). Several studies have attempted to examine this question with varying results in regards to perioperative outcomes and long-term survival [4–11]. However, these studies have not routinely included assessment of postoperative readmission and total episode of care cost. Thus, the optimal approach to surgical resection of esophageal cancer, transthoracic versus transhiatal, in regards to value remains a critical unanswered question in thoracic surgery. Value in healthcare is often defined as clinical outcomes relative to cost [15]. Outcomes should include risk adjusted evaluation of short- and long-term results, as well as patient reported outcomes. Similarly, cost should include measurement of total costs over an entire episode of care, and not simply the index hospital admission.

The objective of this study was, to perform a value-based comparison between transthoracic and transhiatal approaches to esophageal cancer using the Surveillance, Epidemiology, and End Results (SEER)-Medicare linked database. We hypothesized that transhiatal approaches are associated with equivalent long-term survival and lower operative mortality, cost and resource utilization in comparison to transthoracic approaches.

Materials and Methods

Data Sources

The study design is a retrospective cohort study, using the SEER-Medicare linked database to compare operative mortality, long-term survival, costs, and resource use between transthoracic and transhiatal approaches for esophagectomy in patients with esophageal

cancer. Esophageal cancer patients undergoing esophagectomy for distal esophageal adenocarcinoma in the SEER-Medicare database in the years 2002–2009 were included in the study. Medicare files linked to these patients were available through 2010. Approval for the study was obtained from the Institutional Review Board of Emory University.

The SEER database is a national registry derived from 18 tumor registries, is maintained by the National Cancer Institute (NCI), and represents approximately 28% of United States population [16]. Medicare beneficiaries within the registry have their tumor records linked to their administrative claims data, allowing for total episode of care cost assessment with certain restrictions. The quality, validity, and generalizability of the SEER-Medicare data have been described previously [17]. We utilized the Medicare Patient Entitlement and Diagnosis Summary File (PEDSF), Medicare Provider Analysis and Review (MEDPAR), Outpatient, and Physician/Supplier files for this study. The PEDSF file contains information on beneficiary enrollment and vital status. MEDPAR files contain claims related to inpatient hospitalizations and the Outpatient files contain claims related to outpatient visits. Lastly, the Physician/Supplier files contain claims related to physician services.

Patients

Among all esophageal cancer patients from 2002 through 2009 in the SEER-Medicare dataset, the following sequential exclusions were made: patients less than 65 years old, patients treated with therapy other than surgery, and patients with partial fee-for-service or concurrent health maintenance organization enrollment, or both, 1 year prior to 6 months after esophageal cancer diagnosis (Supplemental Figure). Only fee-for-service beneficiaries with continuous enrollment would have complete claims records available for analysis; therefore, all other patients were excluded. Patients who were less than 65 years old at the time of diagnosis were excluded because they do not have Medicare claims data in the year before diagnosis which would preclude the calculation of comorbidity scores from billing and diagnostic codes. Finally, we excluded all patients without adenocarcinoma of the lower esophagus, in order to reduce confounding by anatomic site and histology.

Patient, disease, and treatment information were available through the SEER registry and Medicare database. Specifically, Current Procedural Terminology (CPT) Healthcare Common Procedure Coding System (HCPCS) and International Classification of Diseases, 9th revision (ICD-9) codes were used to determine the surgical approach to esophagectomy (transthoracic vs. transhiatal), patient comorbid medical conditions, and delivery of neoadjuvant chemotherapy and radiation (Supplemental Table). Medicare claims in the year before diagnosis were used to calculate a Klabunde-modified Charlson Comorbidity Index for risk adjustment [18]. Administration of chemotherapy and/or radiation within 4 months prior to esophagectomy was considered neoadjuvant therapy, as classified in prior publications using SEER-Medicare data [19]. For analysis of patient socioeconomic status, indicators of low income or education were based on the lowest quartiles of median income and proportion with a high school education using area-based measures of socioeconomic status derived from SEER and US Census data. Tumor size, stage, and histology were all based on information collected in the SEER registry. All tumors were restaged to the American Joint Committee on Cancer (AJCC), 7th edition esophageal cancer staging system

utilizing the available tumor (T), node (N), and metastases (M) information present in the SEER registry in order to provide consistency across analyses [20].

Outcomes Measures

The primary outcome measures for this study were operative mortality, defined as death during the hospitalization for the index esophagectomy, and long-term survival. Secondary outcome measures included surgical complications, length of hospital stay (LOS), hospital readmissions, 90 days episode of care costs, and cost of initial hospitalization. Surgical complications were determined using the Guller classification system [21]. The denominator for analysis of hospital readmission was all patients discharged to home following esophageal resection for cancer. Hospital readmissions at 30 and 90 days following discharge were measured. All the MEDPAR (inpatient records) and Physician/Supplier CMS (physician office records) files recording the initial esophagectomy and its relevant service were included in the determination of index hospitalization cost. All MEDPAR, Physician/Supplier CMS, Outpatient (Outpatient service records) files ranging from the admission date of the index hospitalization through the 90th day after were included when determining 90-days Medicare episode of care costs.

Statistical Analysis

Descriptive statistics were presented as counts with percentages, means with standard deviations, or medians with IQRs. The transthoracic and transhiatal esophagectomy groups were compared with a two-sample *t*-test for continuous data and χ^2 test for categorical data. Skewed continuous data, including length of hospital stay, number of days in an intensive care unit, and 90 days Medicare costs, were compared with Wilcoxon rank-sum tests.

Propensity matching was utilized to assist in balancing the distribution of observed baseline characteristics between the surgical groups in order to control for confounding. Propensity scores were generated for patients undergoing a transthoracic or transhiatal esophagectomy, defined as the patient's probability of undergoing a transhiatal approach (vs. transthoracic) conditional on patient covariates, listed in Table II. Propensity scores were estimated by fitting a logistic regression model in which the outcome variable was transhiatal approach versus transthoracic. Patients in both groups were randomly sorted, and each patient in the transhiatal group was then matched with one patient (1:1) in the transthoracic group with the propensity score within the defined caliper width, without replacement. The caliper width was defined as 0.2 of the standard deviation of the logit of the propensity score, as this was found to minimize the mean squared error of the estimated treatment effect in various settings [22,23]. Performance of the propensity score matching (balance diagnostics) was assessed by comparing distributions of covariates in cohorts before and after the matching.

After the balance diagnostics, multivariate analyses (logistic regression model for in-hospital mortality, Cox proportional hazard regression models for 5 years overall and cancer specific survival) were utilized to control covariates and examine the relationship between surgical approach and primary outcomes. Univariate analyses (two-sample *t*-test/Chi-square test/ Wilcoxon rank-sum test) were conducted to compare secondary outcomes between surgical groups. Finally, Kaplan–Meier survival curves were generated using the product limit

approach to provide overall and cancer-specific survival estimates for patients undergoing transthoracic and transhiatal esophageal resection, with differences between the strata examined by the log rank test. All statistical tests were two-sided and used $\alpha = 0.05$ level of significance. SAS Version 9.3 (Cary, NC) was used to perform all statistical analyses.

Results

A total of 942 patients in the SEER-Medicare dataset underwent esophageal resection for an adenocarcinoma of the lower esophagus between the years 2002 and 2009 and met all other inclusion criteria (Supplemental Figure). The demographics and clinical details of patients undergoing transthoracic or transhiatal esophagectomy are summarized in Table I. Patients were predominantly Caucasian males with a mean age of approximately 73. Nearly 80% of operations were performed at teaching hospitals, with approximately one quarter of operations performed at NCI designated hospitals. Nearly 40% of patients in each treatment approach group received neoadjuvant chemotherapy and/or radiation. The distribution of tumor stage was not different between transthoracic and transhiatal resections; however, there was a higher percentage of patients with unknown tumor grade in the transhiatal cohort (16.1% vs. 10.4%, $P = 0.02$). More than half the patients in both cohorts had a modified Charlson comorbidity score of zero. Finally, a higher percentage of patients in the transthoracic group (23.3% vs. 15.3%, $P = 0.02$) resided in communities with lower levels of education. In order to control for these baseline differences, 392 patients in the transhiatal group were matched to an equivalent number in transthoracic group with propensity score matching. 13 non-matched patients in TH group were excluded from the matched cohort. Table II demonstrates that balance of covariates was achieved between groups.

Analysis of Primary Outcomes

The effect of extent of resection on the primary outcomes (in-hospital mortality, overall survival, and cancer-specific survival) are shown in Table III. No difference was identified. Observed operative (in-hospital) mortality rates associated with esophagectomies were substantial at 7.9% for TT and 7.1% for TH. Kaplan–Meier analysis of long-term overall and cancer specific survival in the propensity matched cohort is shown in Figure 1. Overall survival in patients undergoing a transthoracic esophagectomy was 67.9% at 1 year, 52.6% at 2 years, 46.3% at 3 years, 40.6% at 4 years, and 33.5% at 5 years following surgery (Fig. 1A). Similarly, survival in patients undergoing a transhiatal esophagectomy was 67.1% at 1 year, 55.6% at 2 years, 46.4% at 3 years, 38.8% at 4 years, and 36.0% at 5 years following surgery, with no difference identified.

Long-term cancer specific survival was similarly compared between the two approaches, again with no significant difference identified (Fig. 1B). Cancer specific survival in patients undergoing a transthoracic esophagectomy was 77.1% at 1 year, 62.2% at 2 years, 55.7% at 3 years, 52.1% at 4 years, and 47.0% at 5 years following surgery. In comparison, cancer specific survival in patients undergoing a transhiatal esophagectomy was 72.3% at 1 year, 62.9% at 2 years, 58.1% at 3 years, 52.2% at 4 years, and 52.2% at 5 years following surgery.

Analysis of Perioperative Secondary Outcomes

Secondary/perioperative outcomes in patients following esophagectomy are detailed in Table IV. Several differences between the cohorts were identified. The extent of lymph node evaluation with surgery, as measured by the median number of lymph nodes sampled, was superior for transthoracic compared to transhiatal esophagectomies by two additional lymph nodes sampled ($P = 0.003$). Median hospital LOS was 1.5 days shorter after TH esophagectomy ($P = 0.006$). Similarly, median intensive care unit stay was 2.0 days shorter after TH ($P = 0.003$).

While complications were frequent in esophagectomy patients, occurring in 46.7% of TT and 50.8% of TH resections, no difference between the two cohorts was identified. The most common type of complication was pulmonary in each group (25%). Operative reintervention rates were 3.1% for TT resection and 3.6% for TH. No statistical differences were found percentage of patients discharged to home or hospital readmissions. 90 days hospital readmission was frequent and occurred in over 30% of patients. Finally, while cost data for both cohorts was skewed, a significant difference of nearly \$1,000 was identified in the cost of initial hospitalization ($P = 0.03$), with no difference identified in the remainder of the 90 days episode of care of costs. While the overall 90 days episode of care costs was \$4,000 less in the transhiatal cohort, this difference did not reach statistical significance ($P = 0.06$).

Discussion

With increasing focus on value based care and a national focus on quality metrics for esophageal cancer care, it will be necessary to determine the optimal surgical approach for esophagectomy [13,14]. Value in health care is often defined as improved outcomes relative to decreased costs [15]. In other words, it is not enough to decrease cost while ignoring patient outcomes; both need to be considered. Further, it is important to consider the total cost of an episode of care, and not just operative cost or initial hospital cost while ignoring costs of complications and readmissions. A more invasive operation (TT) may result in greater patient morbidity which may negate the benefits of the superior tumor clearance that may be gained with this approach. Which operative approach most effectively balances short-term risk of morbidity and mortality with long-term survival from esophageal cancer and overall cost is a critical knowledge gap at present in the field of thoracic oncologic surgery and thus was the focus of this study.

In order to evaluate these variables, we conducted a retrospective cohort study utilizing the SEER-Medicare database. Our objective was to analyze outcomes and total cost after esophagectomy in a national cohort in order to determine which surgical approach, transthoracic or transhiatal, provided the greatest value. We limited our analysis to only patients with adenocarcinoma of the lower esophagus to ensure equivalency between the two cohorts, allowing us to obtain an accurate representation of the inherent value of these two approaches. Prior studies regarding esophagectomy have not conclusively demonstrated one operative approach to esophagectomy to be safer or to result in lower patient mortality [5–11]. However, these studies are outdated, lacked sufficient power, did not evaluate overall survival, or could not evaluate total episode of care costs. Our study supports the existing literature with a larger sample size and more contemporary cohort, while

considering these other variables. Overall, we found no significant differences in regards to clinical outcomes between transthoracic and transhiatal esophagectomy; however, differences in costs and resource use were identified.

Operative mortality and readmission to the hospital within 30 and 90 days of discharge, surrogates of post-operative complications following surgery, were no different between the two surgical approaches. However, hospital length of stay and ICU days were significantly longer for TT approaches. On the other hand, TT approaches to esophagectomy were associated with greater numbers of lymph nodes removed at the time of surgery. Despite this, after controlling for potential known confounding factors, long-term overall and cancer specific survival rates were not different between the two approaches. One may hypothesize that the optimal approach to surgical resection depends on unique patient and tumor characteristics. However, such conclusions cannot be drawn from the current dataset, as more clinical detail and a large study sample would be necessary to perform such subgroup analysis.

Operative mortality following esophagectomy has been a topic of extensive study, given the high risk nature of this operation. Prior comparisons of operative mortality based on surgical approach have yielded conflicting results. Several prior database analyses all found no difference in operative mortality between TT and TH approaches, with mortality rates ranging from 3% to 10% [5–8]. This is consistent with our results, which identified a 7–8% in hospital mortality rate. The lowest reported operative mortality in a large series comes from the Society of Thoracic Surgeons General Thoracic Surgery Database, which reported an operative mortality of 2.7% in esophagectomies performed by board certified thoracic surgeons with no comparison of operative approach [12]. On the other hand, a large meta-analysis comprised of 52 studies, did find higher short term mortality for TT compared to TH resections (OR 1.48; CI 1.20–1.83) [24].

The operative approach for esophagectomy for esophageal cancer that maximizes long-term survival has similarly not been determined. A single prospective, randomized controlled trial comparing TT (n = 114) and TH (n= 106) approaches for esophageal adenocarcinomas located in the distal esophagus, which evaluated overall survival, has been completed to date [4]. This study found a trend towards improved survival with TT resections (5 years overall survival: TT 39%, TH 29%; 95%CI: –3% to 23%). On the other hand, previous analysis of SEER-Medicare data from an earlier era (1992–2002) by Chang et al. found no difference in overall survival between the two cohorts, after adjusting for baseline differences. Similarly, in a meta-analysis of 26 studies including 3,643 patients, no operative approach was associated with improved long-term survival [24]. Results of our analysis again found no difference in regards to in-hospital mortality, overall, or cancer-specific survival. This result is in agreement with the existing literature on surgical therapy for esophageal cancer, which does not strongly support one operative approach over the other as being associated with improved long term survival or operative mortality.

In order to determine optimal value, however, we must look beyond survival alone. Hospital postoperative LOS is frequently used as a surrogate of perioperative complications and a measure of surgical quality. We did identify a one and a half day longer median LOS after

TT esophagectomy, along with no difference in perioperative complications. Chang et al. found no difference in LOS between the two (20.7 days with TT and 21.4 days with TH), though again in an older cohort [5]. In separate analyses of NSQIP data, both Papenfuss et al. and Bhayani et al. found no differences in LOS between TT and TH esophagectomies [6,11]. However, in the previously mentioned meta-analysis, Boshier et al. did find an advantage for TH esophagectomy, with hospital LOS on average 4 days less [24]. Overall, it can likely be concluded that in a contemporary cohort hospital LOS is slightly shorter after TH esophagectomy. As we did not identify a difference in perioperative complications, it is possible that the longer LOS may be caused by modifiable practice patterns such as pain management, unnecessary or prolonged ICU admissions, timing of swallow evaluations, and diet management. This unfortunately cannot be discerned without greater clinical detail than is provided by the SEER-Medicare database, and will need to be the focus of future studies evaluating value after esophagectomy.

Given the importance of readmissions as a quality of care metric, readmission rates should be considered in conjunction with other outcomes when determining value. Hospital readmissions following an esophagectomy for esophageal cancer have previously been shown to be a common occurrence, ranging from 5% to 25%, though these reports did not differentiate surgical approaches [25–28]. In our study, rehospitalization after discharge to home was found to occur frequently. However, there was also no difference between the two cohorts. Interestingly, 90 days readmission was higher in our analysis than previously reported, suggesting that to fully evaluate value it is necessary to evaluate a full 90 days episode of care.

Finally, in order to fully evaluate value we must consider cost. When evaluating value, it is necessary to consider the total cost of the entire episode of care and not just for the index admission [15]. Other studies have previously examined and associated cost after esophagectomy with age, LOS, and various complications [29–31]. However, to date no studies have compared the cost of these two approaches. Further, these prior studies only looked at the cost of the index admission. As discussed, over 30% of patients will be readmitted within 90 days after esophagectomy, which must be included in any cost analysis. We, therefore, utilized 90 days episode of care payments from Medicare in order to capture the cost of readmission. In our analysis, the median cost of the initial hospitalization was nearly \$1,000 higher in the TT cohort, while no difference was identified the remainder of the 90 days episode of care costs. This is consistent with our findings of longer LOS after TT esophagectomy, but no difference in readmission. Given that we found no difference in overall morbidity or mortality with either approach, this increased cost is likely due to longer LOS. Additional focus on reducing LOS, as discussed earlier, could potentially eliminate this cost difference.

As this is a retrospective cohort study analyzing data from a national cancer registry (SEER) linked to a large administrative dataset (CMS), this analysis has several limitations inherent to these databases. As the CMS dataset is collected for billing, and not clinical purposes, it is potentially subject to misclassification of data. Additionally, our analysis is restricted to patients aged 65 or older with Medicare insurance, and may not be representative of a younger cohort of patients, those with private insurance, or those treated exclusively by

board certified thoracic surgeons. Along those lines, 37% of patients in the propensity matched cohorts of this analysis received induction therapy, which we believe is reflective of the care in the Medicare population. However, in practices where a larger percentage of patients receive induction therapy, these results may not be representative. Further, the SEER registry lacks clinical detail regarding specific comorbid medical conditions (other than the Charlson index) or detailed information on post-operative complications, such as anastomotic leaks. In addition, the SEER registry does not separate pathologic (true or post treatment) stage of the tumor and clinical (pretreatment) stage, instead utilizing a combined stage. Thus, it is difficult to interpret preoperative decision making, subjecting the analysis to selection bias. Further, we are unable to discern the exact approach utilized in the transthoracic cohort (Ivor Lewis vs. McKeown vs. thoracoabdominal) given the available data. Only distal esophageal adenocarcinoma patients were included in an attempt to create a homogenous cohort; however, given this limitation there is still some potential heterogeneity within the transthoracic cohort. Additionally, no ICD-9 or CPT codes were in use for minimally invasive esophagectomies during the time frame of this study (2002–2009). The number of patients undergoing this approach was likely limited; however, these could not be accounted for. Further, episode of care costs estimated in this study do not include home health, durable medical equipment or hospice costs. Finally, the SEER registry lacks data regarding patient reported outcomes, which should be considered when fully considering value.

Use of SEER-Medicare data does, however, provide several strengths to this analysis over other studies. Foremost, the patient population with esophageal cancer that is examined here is a nationally representative cohort of older patients taken from the SEER-Medicare data. Further, data from the SEER registry provides detailed tumor information not available in most clinical registries. Administrative data from CMS allows for accurate determination of resource utilization endpoints, including: length of hospital stay, discharge to an intermediate care facility, or readmission to the hospital. Also, given the use of this large, national registry, this study represents the largest series of which we are aware examining esophagectomy for esophageal cancer that considers operative mortality, resource utilization, and long-term survival. As a result, excellent power was available for all analyses performed.

In conclusion, transthoracic, and transhiatal approaches to esophagectomy for distal esophageal adenocarcinoma are associated with similar operative mortality and long-term patient survival. However, costs and LOS appear to be lower with TH approaches. Therefore, a TH approach to esophagectomy may provide greater value than a TT approach in this population. Potential trade-offs, invasiveness of approach versus extent of lymphadenectomy, should be discussed with patients as part of the decision making process. Measurement of patient reported outcomes are likely to further inform the selection of operative approach for esophageal cancer in the future. However, until we have robust patient reported outcomes post-esophagectomy to complete the evaluation of value after esophagectomy, we advise that thoracic surgeons employ the operative approach with which they have the greatest comfort and proficiency.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. This study used the linked SEER-Medicare database. The interpretation and reporting of these data are the sole responsibility of the authors. The authors acknowledge the efforts of the Applied Research Program, National Cancer Institute; the Office of Research, Development, and Information, CMS; Information Management Services, Inc; and the Surveillance, Epidemiology, and End Results (SEER) program tumor registries in the creation of the SEER-Medicare database.

Grant sponsor: National Center for Advancing Translational Sciences of the National Institutes of Health; Grant number: UL1TR000454.

References

1. Thrift AP, Whiteman DC. The incidence of esophageal adenocarcinoma continues to rise: Analysis of period and birth cohort effects on recent trends. *Ann Oncol.* 2012; 23:3155–3162. [PubMed: 22847812]
2. American Cancer Society. What are the key statistics about cancer of the esophagus?. Available at: <http://www.cancer.org/cancer/esophaguscancer/detailedguide/esophagus-cancer-key-statistics?docSelected=esophagus-cancer-what-is-cancer-of-the-esophagus>
3. Lagarde SM, Reitsma JB, Maris AK, et al. Preoperative prediction of the occurrence and severity of complications after esophagectomy for cancer with use of a nomogram. *Ann Thorac Surg.* 2008; 85:1938–1945. [PubMed: 18498798]
4. 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; 347:1662–1669. [PubMed: 12444180]
5. Chang AC, Ji H, Birkmeyer NJ, et al. Outcomes after transhiatal and transthoracic esophagectomy for cancer. *Ann Thorac Surg.* 2008; 85:424–429. [PubMed: 1822237]
6. Bhayani NH, Gupta A, Dunst CM, et al. Esophagectomies with thoracic incisions carry increased pulmonary morbidity. *JAMA Surg.* 2013; 148:733–738. [PubMed: 23784203]
7. Rentz J, Bull D, Harpole D, et al. Transthoracic versus transhiatal esophagectomy: A prospective study of 945 patients. *J Thorac Cardiovasc Surg.* 2003; 125:1114–1120. [PubMed: 12771885]
8. Connors RC, Reuben BC, Neumayer LA, et al. Comparing outcomes after transthoracic and transhiatal esophagectomy: A 5-year prospective cohort of 17,395 patients. *J Am Coll Surg.* 2007; 205:735–740. [PubMed: 18035255]
9. Kutup A, Nentwich MF, Bollschweiler E, et al. What should be the gold standard for the surgical component in the treatment of locally advanced esophageal cancer: Transthoracic versus transhiatal esophagectomy. *Ann Surg.* 2014; 260:1016–1022. [PubMed: 24950288]
10. Merkow RP, Bilimoria KY, McCarter MD, et al. Short-term outcomes after esophagectomy at 164 American College of Surgeons National Surgical Quality Improvement Program hospitals: Effect of operative approach and hospital-level variation. *Arch Surg.* 2012; 147:1009–1016. [PubMed: 23165615]
11. Papenfuss WA, Kukar M, Attwood K, et al. Transhiatal versus transthoracic esophagectomy for esophageal cancer: A 2005–2011 NSQIP comparison of modern multicenter results. *J Surg Oncol.* 2014; 110:298–301. [PubMed: 24891305]
12. Wright CD, Kucharczuk JC, O'Brien SM, et al. Predictors of major morbidity and mortality after esophagectomy for esophageal cancer: A Society of Thoracic Surgeons General Thoracic Surgery Database risk adjustment model. *J Thorac Cardiovasc Surg.* 2009; 137:587–595. discussion 596. [PubMed: 19258071]
13. National Quality Forum. NQF 0360, 0361, 0469. Available at: <http://www.qualityforum.org/home.aspx>

14. American College of Surgeons. American College of Surgeons National Surgical Quality Improvement Program®. Available at: <https://www.facs.org/quality-programs/acs-nsqip>
15. Porter ME. What is value in health care? N Engl J Med. 2010; 363:2477–2481. [PubMed: 21142528]
16. SEER Program. Overview of the SEER Program. <http://seer.cancer.gov/about/overview.html>
17. Warren JL, Klabunde CN, Schrag D, et al. Overview of the SEER-Medicare data: Content, research applications, and generalizability to the United States elderly population. Med Care. 2002; 40:IV–3–18.
18. Klabunde CN, Potosky AL, Legler JM, et al. Development of a comorbidity index using physician claims data. J Clin Epidemiol. 2000; 53:1258–1267. [PubMed: 11146273]
19. Abrams JA, Buono DL, Strauss J, et al. Esophagectomy compared with chemoradiation for early stage esophageal cancer in the elderly. Cancer. 2009; 115:4924–4933. [PubMed: 19637343]
20. Edge, SB. American Joint Committee on Cancer: “AJCC cancer staging manual”. New York: Springer; 2010.
21. Guller U, Hervey S, Purves H, et al. Laparoscopic versus open appendectomy: Outcomes comparison based on a large administrative database. Ann Surg. 2004; 239:43–52. [PubMed: 14685099]
22. Rosenbaum PR, Rubin DB. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. Am Stat. 1985; 39:33–38.
23. Austin PC. Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. Pharm Stat. 2011; 10:150–161. [PubMed: 20925139]
24. Boshier PR, Anderson O, Hanna GB. Transthoracic versus transhiatal esophagectomy for the treatment of esophagogastric cancer: A meta-analysis. Ann Surg. 2011; 254:894–906. [PubMed: 21785341]
25. Goodney PP, Stukel TA, Lucas FL, et al. Hospital volume, length of stay, and readmission rates in high-risk surgery. Ann Surg. 2003; 238:161–167. [PubMed: 12894006]
26. Varghese TK Jr, Wood DE, Farjah F, et al. Variation in esophagectomy outcomes in hospitals meeting Leapfrog volume outcome standards. Ann Thorac Surg. 2011; 91:1003–1009. discussion 1009–1010. [PubMed: 21440116]
27. Li C, Ferri LE, Mulder DS, et al. An enhanced recovery pathway decreases duration of stay after esophagectomy. Surgery. 2012; 152:606–614. discussion 614–606. [PubMed: 22943844]
28. Fernandez FG, Khullar O, Force SD, et al. Hospital readmission is associated with poor survival after esophagectomy for esophageal cancer. Ann Thorac Surg. 2015; 99:292–297. [PubMed: 25442987]
29. Short MN, Aloia TA, Ho V. The influence of complications on the costs of complex cancer surgery. Cancer. 2014; 120:1035–1041. [PubMed: 24382697]
30. Carrott PW, Markar SR, Kuppusamy MK, et al. Accordion severity grading system: Assessment of relationship between costs, length of hospital stay, and survival in patients with complications after esophagectomy for cancer. J Am Coll Surg. 2012; 215:331–336. [PubMed: 22683069]
31. Stahl CC, Hanseman DJ, Wima K, et al. Increasing age is a predictor of short-term outcomes in esophagectomy: A propensity score adjusted analysis. J Gastrointest Surg. 2014; 18:1423–1428. [PubMed: 24866369]

Fig. 1. Kaplan–Meier survival curves for overall (**A**) and cancer-specific (**B**) survival among propensity score matched cohort.

Table I
Clinical Characteristics of Patients Undergoing Esophagectomy for Adenocarcinoma of the Lower Esophagus

	Transthoracic N = 537, N (%)	Transhiatal N = 405, N (%)	P-value
Mean age (SD)	72.7 (5.1)	73.5 (5.3)	0.03
Male	475 (88.5)	360 (88.9)	0.84
Race: Caucasian	525 (97.7)	397 (98.0)	0.001
Residence ^a			0.13
Metropolitan	431 (80.3)	344 (84.9)	
Urban	95 (17.7)	50 (12.3)	
Rural	11 (2.05)	<11 (<2.7)	
Education: <25% high school graduates	125 (23.3)	62 (15.3)	0.02
Income: >25% below poverty level	27 (5.0)	19 (4.7)	0.81
Married	417 (77.7)	305 (75.3)	0.40
Comorbidity score			0.79
0	331 (57.9)	247 (61.0)	
1	148 (27.6)	105 (25.9)	
2	45 (8.4)	32 (7.9)	
3+	33 (6.2)	21 (5.2)	
Type of admission			0.14
Elective	476 (88.8)	375 (92.6)	
Emergency	22 (4.1)	11 (2.7)	
Urgent	38 (7.1)	19 (4.7)	
Induction therapy (chemotherapy and/or radiation)	215 (40.0)	150 (37.0)	0.35
Stage ^a			0.14
I	175 (32.6)	158 (39.0)	
II	172 (32.0)	119 (29.4)	
III	165 (30.7)	106 (26.2)	
IV	14 (2.6)	<11 (<2.7)	
Unknown	<11 (<2.7)	<11 (<2.7)	
Grade			0.02
Poor or undifferentiated	250 (46.5)	189 (46.7)	
Well to moderate	231 (43.0)	151 (37.3)	
Unknown	65 (10.4)	65 (16.1)	
Teaching hospital (Yes)	424 (79.0)	319 (78.8)	0.81
NCI ^b designated hospital (Yes)	126 (23.5)	107 (26.4)	0.30

^a Cells with size <11 were suppressed with accordance to SEER Data Use Agreement.

^b NCI: National Cancer Institute.

Table II
Clinical Characteristics of Patients Undergoing Esophagectomy for Adenocarcinoma of the Lower Esophagus in Propensity Matched Cohort (Balance Diagnostics for Propensity Match)

	Transthoracic N = 392 N (%)	Transhiatal N = 392 N (%)	P-value
Mean age (SD)	73.2 (5.3)	73.3 (5.2)	0.72
Male	349 (89.0)	346 (88.3)	0.74
Race: Caucasian	384 (98.0)	382 (97.5)	0.88
Residence ^a			0.92
Metropolitan	331 (84.4)	327 (83.4)	
Urban	50 (12.8)	54 (13.8)	
Rural	<11 (2.8)	<11 (<2.8)	
Education: <25% high school graduates	62 (15.8)	59 (15.1)	0.77
Income: >25% below poverty level	19 (4.9)	21 (5.4)	0.75
Married	298 (76.0)	298 (76.0)	1.00
Comorbidity score			0.69
0	238 (60.7)	244 (62.2)	
1	101 (25.8)	88 (22.5)	
2	32 (8.2)	35 (8.9)	
3+	21 (5.4)	25 (6.4)	
Type of admission			0.93
Elective	362 (92.4)	361 (92.1)	
Emergency	11 (2.8)	10 (2.6)	
Urgent	19 (4.9)	21 (5.4)	
Induction therapy (chemotherapy and/or radiation)	146 (37.2)	147 (37.5)	0.94
Stage ^a			0.98
I	147 (37.5)	149 (38.0)	
II	117 (29.9)	121 (30.9)	
III	106 (27.0)	100 (25.5)	
IV	<11 (2.8)	<11 (2.8)	
Unknown	<11 (2.8)	<11 (2.8)	
Grade			0.86
Poor or undifferentiated	187 (47.7)	188 (48.0)	
Well to moderate	151 (38.5)	155 (39.5)	
Unknown	54 (13.8)	49 (12.5)	
Teaching hospital (yes)	308 (78.6)	311 (79.3)	0.79
NCI ^b designated hospital (Yes)	102 (26.0)	98 (25.0)	0.74

^a Cells with size <11 were suppressed with accordance to SEER Data Use Agreement.

^b NCI: National Cancer Institute.

Table III
Impact of Surgical Approach on In-Hospital Mortality, Overall Survival, and Cancer-Specific Survival in the Propensity Matched Cohort^a

		Effect estimate	95% confidence limits	P-value
In-hospital mortality (rate ratio)	TT (Ref.)	1.00	—	—
	TH	0.88	0.51–1.53	0.65
Overall survival (hazard ratio)	TT (Ref.)	1.00	—	—
	TH	0.94	0.77–1.14	0.50
Cancer-specific survival (hazard ratio)	TT (Ref.)	1.00	—	—
	TH	0.98	0.78–1.24	0.89

^a Covariates that have been controlled in both logistic model and Cox-PH survival models are: Neo-adjuvant treatment, gender, race, age at diagnosis, marital status, education level, poverty level, charlson comorbidity index, admission type, grade, stage, urban residence, teaching hospital, NCI designated hospital, total number of beds.

Table IV
Perioperative Clinical Outcomes of Patients Undergoing Esophagectomy for Esophageal Cancer in Propensity Matched Cohort

	Transthoracic N = 392 N(%)	Transhiatal N = 392 N(%)	P-value
Median number of lymph nodes examined (IQR)	11.0 (15.0)	9.0 (10.0)	0.003
Median length of hospital stay (days) (IQR)	13.0 (13.0)	11.5 (9.0)	0.006
Median intensive care unit stay (days) (IQR)	7.0 (10.0)	5.0 (10.0)	0.003
Hospital death	31 (7.9)	28 (7.1)	0.68
Intraoperative complication	22 (5.6)	25 (6.4)	0.65
Mechanical wound complication	19 (4.9)	24 (6.1)	0.43
Infection	26 (6.6)	27 (6.9)	0.89
Pulmonary complication	99 (25.3)	99 (25.3)	1.00
Gastrointestinal complication	37 (9.4)	49 (12.5)	0.17
Cardiovascular complication	53 (13.5)	65 (16.6)	0.23
Systemic complication ^a	11 (2.8)	<11 (<2.8)	0.22
Reinterventions	12 (3.1)	14 (3.6)	0.69
Any complication	183 (46.7)	199 (50.8)	0.25
Median 90 day medicare cost (IQR)	\$45,861.5 (41,266.1)	\$41,576.2 (30,598.3)	0.06
Median initial hospitalization cost (IQR)	\$32,533.1 (21,945.9)	\$31,658.8 (15,382.5)	0.03
Median remainder of 90 day cost (IQR)	\$8,916.33 (17,605.7)	\$9,365.7 (16,288.8)	0.49
Discharge to home	266 (67.9)	271 (69.1)	0.70
Hospital readmission at 30 days after discharge ^b	44 (16.5)	50 (18.5)	0.56
Hospital readmission at 90 days after discharge ^b	81 (30.5)	88 (32.5)	0.61

IQR, Interquartile range.

^a Cells with size <11 were suppressed with accordance to SEER Data Use Agreement.

^b Out of patients discharged to home.