Published in final edited form as:

Ann Surg. 2017 April ; 265(4): 743–749. doi:10.1097/SLA.0000000000001702.

Traveling to a High-volume Center is Associated With Improved Survival for Patients With Esophageal Cancer

Paul J. Speicher, MD*, Brian R. Englum, MD*, Asvin M. Ganapathi, MD*, Xiaofei Wang, PhD†, Matthew G. Hartwig, MD*, Thomas A. D'Amico, MD*, and Mark F. Berry, MD‡

*Department of Surgery, Duke University Medical Center, Durham, NC

†Department of Biostatistics and Bioinformatics, Duke University Medical Center, Durham, NC

‡Department of Cardiothoracic Surgery, Stanford University Medical Center, Palo Alto, CA

Abstract

Background—An association between volume and outcomes has been observed for esophagectomy, though little is known about why or how patients choose low- or high-volume centers. The purpose of this study was to evaluate how travel burden and hospital volume influence treatment and outcomes of patients with locally advanced esophageal cancer.

Methods—Predictors of receiving esophagectomy for patients with T1-3N1M0 mid or distal esophageal cancer in the National Cancer Data Base from 2006 to 2011 were identified using multivariable logistic regression. Survival was compared using propensity score-matched groups: patients in the bottom quartile of travel distance who underwent treatment at low-volume facilities (Local) and patients in the top quartile of travel distance who underwent treatment at high-volume facilities (Travel).

Results—Of 4979 patients who met inclusion criteria, we identified 867 Local patients who traveled 2.7 [interquartile range (IQR): 1.6–4 miles] miles to centers that treated 2.6 (IQR: 1.9–3.3) esophageal cancers per year, and 317 Travel patients who traveled 107.1 (IQR: 65–247) miles to centers treating 31.9 (IQR: 30.9–38.5) cases. Travel patients were more likely to undergo esophagectomy (67.8% vs 42.9%, $P < 0.001$) and had significantly better 5-year survival (39.8% vs 20.6%, $P < 0.001$) than Local patients.

Conclusions—Patients who travel longer distances to high-volume centers have significantly different treatment and better outcomes than patients who stay close to home at low-volume centers. Strategies that support patient travel for treatment at high-volume centers may improve esophageal cancer outcomes.

Keywords

esophageal cancer; esophageal surgery; propensity matching; travel burden; volume outcomes

Reprints: Mark F. Berry, MD, 300 Pasteur Drive, Falk Cardiovascular Research Institute, Stanford, CA 94305. berry037@stanford.edu.

The other authors have no conflicts of interest to declare.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.annalsofsurgery.com).

The incidence of esophageal cancer is increasing, with an estimated 16980 new cases in the United States in 2015, and approximately 32% of esophageal cancer patients have locally advanced disease at the time of diagnosis.^{1–5} National Comprehensive Cancer Network guidelines recommend surgery as a possible treatment for most cases of esophageal cancer that do not have invasion of unresectable structures or distant metastatic disease, and several studies have suggested that complete surgical resection provides the best chance for long-term survival in patients who do not have distant disease.^{6–8} However, the treatment for locally advanced but potentially resectable esophageal cancer is highly variable in practice.⁹ In fact, surgery for locoregional disease is utilized in only 30% to 40% of resectable cases.^{8,10} The relatively low utilization of esophagectomy for esophageal cancer may be because surgical resection is historically associated with significant morbidity and mortality.^{11–15} Patients undergoing esophageal surgery have historically experienced lengthy hospital stays and prolonged overall recovery periods, which are generally more than doubled when significant complications occur.^{15–18} Minimizing perioperative morbidity is critical to increase the use of surgical resection and improve overall outcomes, so that primary nonsurgical treatment is reserved only for those who refuse surgery, have unresectable cancers, or are not thought to be surgical candidates for other reasons.¹⁹

Although esophagectomy can be achieved using a variety of surgical techniques (eg Ivor Lewis, McKeown, transhiatal, etc), surgeon and center experience has been shown to be a much more important determinant of outcomes than actual choice of procedure. Many studies have failed to demonstrate any significant differences in short- or long-term survival or quality of life between transthoracic and transhiatal esophagectomies.^{12,14,20–22} However, centers and surgeons that perform high volumes of esophageal surgery typically report mortality rates that are significantly lower for both transhiatal and transthoracic procedures than those reported in multicenter studies or national databases.^{16,23–25} The relationship between volume and outcomes for patients being treated for esophageal cancer has also been well described by multiple population-based studies.^{26–30}

Despite the clear advantages associated with higher volume care, little is known about the patient decision process in choosing care at low- or high-volume centers. Ease of access to a higher-volume facility, though, likely has a major impact on that patient's choice, including the distance the patient would have to travel for care. The importance of travel burden with respect to how patients select their providers has been described previously, with 1 standard-gamble study reporting that for major cancer operations, nearly half of patients were willing to accept twice the perioperative mortality risk to avoid a theoretical 4-hour drive.³¹ Accordingly, many patients may not seek care at a high-volume hospital if several hours of travel are required, which in addition to practical issues may also isolate them from personal support systems and trusted providers for continuity-of-care.³¹ Considering these issues, we hypothesized that the need to travel long distances may mitigate the known benefits of seeking care at a high-volume facility. The purpose of this study was to specifically evaluate how travel burden and hospital volume influence treatment and outcomes of patients with locally advanced esophageal cancer using a large population-based dataset.

METHODS

Data Source

This retrospective study of patients with locally advanced T1-3N1M0 esophageal cancer in the National Cancer Data Base (NCDB) was approved by the Duke University Institutional Review Board. The NCDB is a joint venture between the American College of Surgeons Commission on Cancer and the American Cancer Society, and is estimated to capture 70% of all newly diagnosed cancers in the United States. The database collects data from more than 1500 Commission on Cancer–approved facilities in North America, and currently contains more than 30 million records. American Joint Committee on Cancer staging data are directly available, concomitant with year of diagnosis. Use of esophagectomy was determined using Facility Oncology Registry Data Standards codes.

Patient Selection

Patients with American Joint Committee on Cancer cT1-3N1M0 mid- and lower-third esophageal cancers less than 30 cm in size and diagnosed from 2006 to 2011 were included for analysis. Distance traveled is available in the NCDB and reflects the distance between the patient’s residential zip code centroid and the zip code centroid for the hospital, calculated using the Haversine formula.³² Hospital case volume was determined based on the unique facility identifier in the database. Independent predictors of esophagectomy were estimated with a multivariable logistic regression model, including age, sex, race, insurance status, Charlson comorbidity index, median census-tract income and education levels, clinical T-stage, facility volume, and distance traveled to facility.

Statistical Analysis

Patients were stratified into 2 groups based on distance traveled to receive treatment and the case volume at that facility. Patients who traveled short distances and received care at low-volume centers (Local) were defined as those treated at facilities in the lowest quartile of travel distance (<5.2 miles) and low facility volume (<5 cases/yr). Patients who traveled more substantial distances to receive treatment at high-volume centers (Travel) were defined as those treated at facilities in the highest quartile of distance traveled (>36.1 miles) and high facility volume (>20 cases/yr). Patients who did not meet these criteria were not included for analysis, as their data were not deemed to be pertinent to the central hypothesis of the study. Baseline characteristics between groups were compared with the Wilcoxon rank-sum test for continuous variables and Pearson χ^2 test for discrete variables.

To address issues of confounding and bias, propensity scores were developed which we defined as the probability of Travel versus Local, conditional on other measured covariates, which included patient age, race, insurance status, Charlson-Deyo comorbidity score, education, income, and clinical stage. Patients were matched based on propensity scores using a 1:1 nearest neighbor algorithm (*MatchIt: Nonparametric Preprocessing for Parametric Casual Inference*). Propensity measurements were estimated using a standard logistic regression model without replacement, and model discrimination was assessed using the C-index. Following propensity matching, balance was assessed between groups based on standardized differences (*Nonrandom: Stratification and matching by the propensity score*).

Survival between groups was assessed with the Kaplan-Meier method and log-rank test, and propensity-adjusted survival was tested between the matched groups with a standard product-limit estimator. As a further sensitivity analysis, survival was then compared only among patients who were treated with esophagectomy, and a similar propensity-adjusted model was created using the same measured variables as used for the primary analysis. As an additional post-hoc confirmatory analysis, Travel patients were then compared with a cohort of patients not included in the primary analysis, who were treated at high-volume centers but who traveled less than the median travel distance (13.5 miles).

A *P* value of less than 0.05 was considered statistically significant, and type I error was controlled for at the level of the comparison. Missing data were handled with complete case analysis given the substantial completeness of the study population data. All analyses were performed using R version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 4979 patients with locally advanced T1-3N1M0 esophageal cancer were identified in the NCDB from 2006 to 2011 and met inclusion criteria (Fig. 1). Baseline characteristics and endpoints for the entire patient cohort are included in Supplemental Table 1, <http://links.lww.com/SLA/A991> (online). Median patient age was 64 years, with the majority of patients having T3 disease (74.9%). The median distance traveled was 13.5 miles [interquartile range (IQR): 5.2–36.1 miles], with patients living in the Midwestern and Southern United States traveling the farthest on average (Fig. 2A). Median facility treatment volume was 4.8 cases/yr (IQR: 2.7–9.5), with facilities in the Northeast Mid-Atlantic United States having the highest average case volume per hospital (Fig. 2B). Among all patients, predictors of treatment with esophagectomy are shown in Table 1 and included younger age, male sex, white race, private insurance, and higher census-tract education levels. Higher facility volume was marginally associated with use of esophagectomy (odds ratio 1.04 per 5 annual cases, *P* < .001), whereas distance traveled was not (odds ratio 1.02, *P* = .11).

There were 867 patients identified who stayed local to be treated at a low-volume hospital, traveling a median 2.7 miles (IQR: 1.6–4 miles) to facilities with a median annual volume of 2.6 treatment cases/year (IQR: 1.9–3.3), whereas 317 patients were identified who traveled for treatment at a high-volume hospital, traveling a median 107.1 miles (IQR: 65–247 miles) to facilities with a median annual volume of 31.9 treatment cases/year (IQR: 30.9–38.5). Baseline characteristics for the 2 groups are shown in Table 2, and there were statistically significant differences between the 2 groups for all variables with the exception of sex, education, income, and insurance status. Before adjustment, Travel patients were younger, more likely to be white, more likely to have private insurance, had lower Charlson comorbidity scores, and had higher clinical T-stage. Following propensity matching, model diagnostics were assessed (C-index 0.74, differences between groups were negligible for all variables and characteristics (Table 2). Patients who traveled to high-volume centers remained substantially more likely to undergo surgery (67.8% vs 42.9%, *P* < 0.001). Among patients treated with surgery, outcomes between groups are shown in Table 3, and following adjustment Travel patients had similar rates of neoadjuvant chemotherapy and radiation therapy use, but had more lymph nodes removed during surgery (median 17 vs 10, *P* <

0.001). Hospital length of stay, as well as 30-day and 90-day mortality were not statistically different between groups; however, unplanned 30-day readmission rates were significantly lower in the Travel group (5.6% vs 7.4%, $P < 0.001$).

In unadjusted survival analysis, Travel patients had significantly better long-term survival compared to their Local counterparts (Fig. 3A, 5-year survival: 39.8% vs 20.6%, $P < 0.001$), and this advantage was maintained following adjustment with propensity matching (Fig. 3B, 5-year survival: 39.8% vs 26.0%, $P < 0.001$) as well as after additional post-hoc Cox proportional hazards adjustment for residual staging differences between groups (hazard ratio 0.61, $P < 0.001$). To address the possibility that the survival advantage seen in the Travel group compared to the Local group was attributable to the higher rates of surgery utilized in the Travel group, a sensitivity analysis was conducted among only those patients who underwent esophagectomy as part of their cancer treatment. This was done to address concerns that surgery may be associated with superior survival not only due to the presumed oncologic benefits of resection, but also because surgery may have been preferentially used in generally healthier patients. In this subset analysis of only surgical patients, survival among Local patients improved substantially over the initial cohort, although Travel patients continued to exhibit a significant 5-year survival advantage (Fig. 4A, 43.6% vs 34.5%, $P = 0.024$). Following repeat propensity matching amongst the surgically resected groups, the difference in survival no longer met statistical significance (Fig. 4B, 43.6% vs 34.9%, $P = 0.055$). Among patients who were not treated with surgery, Travel patients similarly demonstrated a significant survival advantage, although outcomes were overall inferior (32.1% vs 14.0%, $P < 0.001$). In the confirmatory analysis comparing Travel patients to the patients who were treated at high-volume centers but who traveled less than the median travel distance, there was no significant difference in overall survival [5-year survival 39.8% (95% confidence interval: 33.2–47.7) vs 34.6% (95% confidence interval: 25.0–47.8), $P = 0.49$; Supplemental Fig. 1, <http://links.lww.com/SLA/A991>].

DISCUSSION

In this study, we analyzed national treatment patterns for the management of locally advanced esophageal cancer, examining the relationship between patient travel distance and facility volume, and the subsequent effects on long-term outcomes. We specifically sought to address the question facing many patients who have a new diagnosis of esophageal cancer but who do not live near a high-volume center: is it better to stay close to home and receive care at a local low-volume center, or should the patient endure the burden associated with traveling longer distances to a high-volume center for treatment? The results of this study showed that patients who traveled to higher-volume centers were much more likely to be treated with surgery as part of their management. The 5-year survival of patients who traveled to high-volume centers was more than 50% higher than that of patients who did not travel and were treated at low-volume centers.

The effect of surgeon and hospital volume on perioperative outcomes has been clearly established, with some of the earliest reports examining esophagectomy in particular.^{26–30} Factors underlying how and why patients choose particular facilities, and how these decisions affect outcomes, however, have not been well studied. It is reasonable to believe

that despite the known volume-outcome benefits, some patients may choose to stay close to home to receive care at a lower-volume center to be closer to established support networks. Furthermore, increased travel burden among breast and colorectal cancer patients has been associated with numerous potential downsides, including costs, higher stages of disease at presentation, disparities in treatment approaches, and lower enrollment in clinical trials.^{33–37} Accordingly, we hypothesized that travel burden may potentially mitigate the expected benefits of seeking care at a high-volume facility. Despite these disadvantages, however, we show that travel to receive treatment at facilities with higher treatment volumes is still associated with superior long-term outcomes. These results provide further evidence in support of regionalization of care for diseases that are relatively uncommon or involve more complex management strategies.

Interestingly, while traveling to a high-volume center was associated with improved long-term survival, there were no significant differences between the Travel and Local groups regarding 30-or 90-day mortality and hospital length of stay. We did, however, observe a higher rate of unplanned readmission in the Local group, which may be a surrogate for postoperative morbidity. Although the long-term survival advantages are consistent with the existing literature,²⁹ the lack of obvious short-term differences are somewhat contradictory, but are likely the result of our study population, patient inclusion criteria, and the very limited data available in the NCDB regarding short-term outcomes and patient comorbidities.^{26,27} Rather than focusing exclusively on patients who underwent surgery, we included all patients treated for locally advanced esophageal cancer. Patients who traveled to high-volume centers were more than twice as likely to undergo esophagectomy as part of their management strategy compared to Local patients, and it is plausible that the smaller proportion of patients selected for surgery at low-volume Local centers may have been generally better candidates or less complicated cases.

On the contrary, it is possible that the substantially higher rate of esophagectomy in the Travel patients represents a selection bias regarding less-advanced disease and better general medical condition among these patients. This is unlikely, as previous studies have demonstrated a relationship between travel distance and higher stages of disease, and our own results confirm this finding with Travel patients having more advanced disease.^{36,38} Furthermore, our sensitivity analysis demonstrated that even among only the patients deemed to be surgical candidates and who underwent esophagectomy, travel to a high-volume center was associated with better long-term survival. Although it is difficult to identify the specific underlying reasons for the survival difference among all patients, patients in the Travel group who underwent esophagectomy had significantly more lymph nodes examined during surgery, which may be a surrogate for more appropriate oncologic resection.

The NCDB offers numerous advantages over other clinical and administrative databases in attempting to address questions regarding facility volume and travel distance. First and foremost, it is the only large dataset to our knowledge to include patient travel distance, facility information, cancer stage and tumor characteristics, treatment data including surgery and chemo/radiotherapy, short-term outcomes, and long-term survival data, all from a single source. The large number of patients available also provides ample statistical power to detect

small but potentially relevant differences. Lastly, results derived from the NCDB are generally applicable to the overall population of the United States, in that approximately 70% of all annual diagnoses of cancer are captured by the database.

Despite these numerous advantages, the NCDB has some important limitations. First, we were unable to identify specific reasons why patients chose to travel to a high-volume center versus staying close to home and receiving treatment at a lower-volume center, and this could potentially bias our results if the underlying unmeasured factors were confounded with survival and were not balanced between the 2 groups. The NCDB does not provide any information regarding patient's resources and ability to travel, both of which likely influence patient's decisions regarding access to care. Similarly, there is relatively limited data regarding operative approach, including the use of minimally invasive techniques, which may be more commonly employed at higher-volume centers and potentially confer better perioperative outcomes. Furthermore, preoperative functional status and patient comorbidities are lacking, all of which may be important in predicting treatment and survival. The NCDB also lacks details regarding participating in clinical trials as well as the modalities used to establish clinical stage, and if there were nonrandom differences between the groups, specifically if the Travel patients were more accurately clinically staged or more likely to participate in trials, our observed outcomes may have been biased.

In addition to specific NCDB limitations, we also chose to use overall esophageal cancer treatment center volume given the primary study question at hand; however, surgical volume has been previously associated with decreased morbidity and mortality, and we were unable to fully address this important point. Also of potential concern is our use of extreme groups while excluding a large proportion of patients who fell closer to the median of both travel distance and volume, which may have implications regarding statistical variance. This was done intentionally; however, as the purpose of this study was to examine specific situations when travel burden and volume were combined; specifically, either long-distance travel to a high-volume facility or short-distance travel to a low-volume facility.

In this study we found that patients who travel longer distances to high-volume centers have significantly different treatment patterns than patients who stay close to home at low-volume centers. Patients who travel to high-volume centers are much more likely to be treated with surgical resection, and the patients who travel to high-volume centers get a survival benefit independent from simply being more likely to undergo surgery. In light of the decreased incidence of esophageal cancer in comparison to more common entities such as lung, breast, or colorectal cancer, regionalization of this fairly uncommon disease is important.⁵ Although further studies that investigate why or why not patient would choose to travel to a high-volume center are necessary, strategies that support regionalization of care, and specifically patient travel for treatment at high-volume centers, may improve esophageal cancer outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The data used in this study are derived from a de-identified National Cancer Data Base file. The American College of Surgeons has executed a Business Associate Agreement that includes a data use agreement with each of its Commission on Cancer accredited hospitals. The American College of Surgeons and the Commission on Cancer have not verified and are not responsible for the analytic or statistical methodology employed, or the conclusions drawn from these data by the investigators.

Disclosures: Institutional funding was the primary funding source for this study. In addition, this work was supported by the NIH-funded Cardiothoracic Surgery Trials Network (M.F.B. and M.G.H.), 5U01HL088953-05. One of the authors (T.A.D.) serves as a consultant for Scanlan International, Inc.

References

1. Dubecz A, Gall I, Solymosi N, et al. Temporal trends in long-term survival and cure rates in esophageal cancer: a SEER database analysis. *J Thorac Oncol.* 2012; 7:443–447. [PubMed: 22173700]
2. Enzinger PC, Mayer RJ. Esophageal cancer. *N Engl J Med.* 2003; 349:2241–2252. [PubMed: 14657432]
3. Pennathur A, Luketich JD. Resection for esophageal cancer: strategies for optimal management. *Ann Thorac Surg.* 2008; 85:S751–S756. [PubMed: 18222210]
4. Rice TW, Rusch VW, Ishwaran H, et al. Cancer of the esophagus and esophagogastric junction: data-driven staging for the seventh edition of the American Joint Committee on Cancer/International Union Against Cancer Cancer Staging Manuals. *Cancer.* 2010; 116:3763–3773. [PubMed: 20564099]
5. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2015. *CA Cancer J Clin.* 2015; 65:5–29. [PubMed: 25559415]
6. 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]
7. Kelsen DP, Winter KA, Gunderson LL, et al. Long-term results of RTOG trial 8911 (USA Intergroup 113): a random assignment trial comparison of chemotherapy followed by surgery compared with surgery alone for esophageal cancer. *J Clin Oncol.* 2007; 25:3719–3725. [PubMed: 17704421]
8. Paulson EC, Ra J, Armstrong K, et al. Underuse of esophagectomy as treatment for resectable esophageal cancer. *Arch Surg.* 2008; 143:1198–1203. [PubMed: 19075172]
9. Smith GL, Smith BD, Buchholz TA, et al. Patterns of care and locoregional treatment outcomes in older esophageal cancer patients: the SEER-Medicare Cohort. *Int J Radiat Oncol Biol Phys.* 2009; 74:482–489. [PubMed: 19289262]
10. Dubecz A, Sepesi B, Salvador R, et al. Surgical resection for locoregional esophageal cancer is underutilized in the United States. *J Am Coll Surg.* 2010; 211:754–761. [PubMed: 20980174]
11. Bailey SH, Bull DA, Harpole DH, et al. Outcomes after esophagectomy: a ten-year prospective cohort. *Ann Thorac Surg.* 2003; 75:217–222. [PubMed: 12537219]
12. 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]
13. Ra J, Paulson EC, Kucharczuk J, et al. Postoperative mortality after esophagectomy for cancer: development of a preoperative risk prediction model. *Ann Surg Oncol.* 2008; 15:1577–1584. [PubMed: 18379852]
14. 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]
15. 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. [PubMed: 19258071]

16. Atkins BZ, Shah AS, Hutcheson KA, et al. Reducing hospital morbidity and mortality following esophagectomy. *Ann Thorac Surg.* 2004; 78:1170–1176. [PubMed: 15464465]
17. Dimick JB, Wainess RM, Upchurch GR Jr, et al. National trends in outcomes for esophageal resection. *Ann Thorac Surg.* 2005; 79:212–216. [PubMed: 15620945]
18. Swanson SJ, Batirel HF, Bueno R, et al. Transthoracic esophagectomy with radical mediastinal and abdominal lymph node dissection and cervical esophagogastronomy for esophageal carcinoma. *Ann Thorac Surg.* 2001; 72:1918–1924. [PubMed: 11789772]
19. Berry MF. Esophageal cancer: staging system and guidelines for staging and treatment. *J Thorac Dis.* 2014; 6(Suppl 3):S289–S297. [PubMed: 24876933]
20. 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]
21. Goldmine M, Maddern G, Le Prise E, et al. Oesophagectomy by a transhiatal approach or thoracotomy: a prospective randomized trial. *Br J Surg.* 1993; 80:367–370. [PubMed: 8472154]
22. 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]
23. Davies AR, Forshaw MJ, Khan AA, et al. Transhiatal esophagectomy in a high volume institution. *World J Surg Oncol.* 2008; 6:88. [PubMed: 18715498]
24. Luketich JD, Pennathur A, Awais O, et al. Outcomes after minimally invasive esophagectomy: review of over 1000 patients. *Ann Surg.* 2012; 256:95–103. [PubMed: 22668811]
25. Orringer MB, Marshall B, Chang AC, et al. Two thousand transhiatal esophagectomies: changing trends, lessons learned. *Ann Surg.* 2007; 246:363–372. [PubMed: 17717440]
26. Begg CB, Cramer LD, Hoskins WJ, et al. Impact of hospital volume on operative mortality for major cancer surgery. *JAMA.* 1998; 280:1747–1751. [PubMed: 9842949]
27. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med.* 2002; 346:1128–1137. [PubMed: 11948273]
28. Birkmeyer JD, Sun Y, Goldfaden A, et al. Volume and process of care in high-risk cancer surgery. *Cancer.* 2006; 106:2476–2481. [PubMed: 16634089]
29. Birkmeyer JD, Sun Y, Wong SL, et al. Hospital volume and late survival after cancer surgery. *Ann Surg.* 2007; 245:777–783. [PubMed: 17457171]
30. Killeen SD, O'Sullivan MJ, Coffey JC, et al. Provider volume and outcomes for oncological procedures. *Br J Surg.* 2005; 92:389–402. [PubMed: 15786424]
31. Finlayson SR, Birkmeyer JD, Tosteson AN, et al. Patient preferences for location of care: implications for regionalization. *Med Care.* 1999; 37:204–209. [PubMed: 10024124]
32. Robusto CC. The cosine-haversine formula. *Am Math Monthly.* 1957; 64:38–40.
33. Avis NE, Smith KW, Link CL, et al. Factors associated with participation in breast cancer treatment clinical trials. *J Clin Oncol.* 2006; 24:1860–1867. [PubMed: 16622260]
34. Baldwin LM, Cai Y, Larson EH, et al. Access to cancer services for rural colorectal cancer patients. *J Rural Health.* 2008; 24:390–399. [PubMed: 19007394]
35. Celaya MO, Rees JR, Gibson JJ, et al. Travel distance and season of diagnosis affect treatment choices for women with early-stage breast cancer in a predominantly rural population (United States). *Cancer Causes Control.* 2006; 17:851–856. [PubMed: 16783613]
36. Massarweh NN, Chiang YJ, Xing Y, et al. Association between travel distance and metastatic disease at diagnosis among patients with colon cancer. *J Clin Oncol.* 2014; 32:942–948. [PubMed: 24516014]
37. Schroen AT, Brenin DR, Kelly MD, et al. Impact of patient distance to radiation therapy on mastectomy use in early-stage breast cancer patients. *J Clin Oncol.* 2005; 23:7074–7080. [PubMed: 16192590]
38. Scoggins JF, Fedorenko CR, Donahue SM, et al. Is distance to provider a barrier to care for medicaid patients with breast, colorectal, or lung cancer? *J Rural Health.* 2012; 28:54–62. [PubMed: 22236315]

FIGURE 1.
Patient selection and inclusion/exclusion criteria.

FIGURE 2. Geomapping of national trends in esophageal cancer care in the United States by geographical region regarding: (A) median travel distance to treatment facility and (B) median annual facility case volume.

FIGURE 3.

Kaplan-Meier survival curves for patients treated for esophageal cancer, stratified by whether patients travel to high-volume centers versus stay local to receive care at low-volume centers: (A) unadjusted and (B) following propensity matching.

FIGURE 4.

Kaplan-Meier survival curves among the subset of patients treated with esophagectomy, stratified by patients who travel to high-volume centers versus patients who stay local and receive surgery at low-volume centers: (A) unadjusted and (B) following propensity matching.

Independent Predictors of Treatment With Esophagectomy Among All Patients With Locally Advanced (T1–3N1M0) Esophageal Cancer, Regardless of Distance Traveled and Facility Volume

TABLE 1

Predictor	Descriptive Statistics		Multivariable Predictors			
	No Surgery (n = 2418)	Surgery (n = 2561)	Odds of Surgery	Lower 95% CI	Upper 95% CI	P
Age (OR per decade)	68 (60, 76)	62 (55, 68)	0.60	0.56	0.65	<0.001
Female sex	565 (23.4%)	361 (14.1%)	0.65	0.55	0.76	<0.001
Race/ethnicity						
White	2067 (86.7%)	2388 (94.7%)	Ref	Ref	Ref	Ref
Black	242 (10.2%)	91 (3.6%)	0.38	0.29	0.49	<0.001
Other	75 (3.1%)	42 (1.7%)	0.52	0.34	0.79	0.002
Insurance status						
Private	716 (29.6%)	1367 (53.4%)	Ref	Ref	Ref	Ref
Medicare	1497 (61.9%)	1084 (42.3%)	0.72	0.62	0.84	<0.001
Medicaid	54 (2.2%)	27 (1.1%)	0.34	0.21	0.56	<0.001
Government other	76 (3.1%)	30 (1.2%)	0.13	0.08	0.21	<0.001
Uninsured	75 (3.1%)	53 (2.1%)	0.45	0.31	0.67	<0.001
Charlson comorbidity index						
0	1786 (73.9%)	1932 (75.4%)	Ref	Ref	Ref	Ref
1	463 (19.1%)	502 (19.6%)	1.11	0.95	1.30	0.18
2	169 (7%)	127 (5%)	0.81	0.62	1.05	0.11
Education above median	1299 (55.5%)	1615 (64.7%)	1.27	1.09	1.47	0.002
Income above median	1296 (55.4%)	1531 (61.3%)	1.08	0.93	1.24	0.33
Clinical T stage						
T1	179 (7.4%)	116 (4.5%)	Ref	Ref	Ref	Ref
T2	443 (18.3%)	511 (20%)	1.62	1.20	2.19	0.002
T3	1796 (74.3%)	1934 (75.5%)	1.46	1.11	1.92	0.007
Facility volume (OR per 5 cases/yr)	4 (2.5, 7.3)	6.7 (3.6, 13.4)	1.04	1.03	1.05	<0.001
Distance traveled (OR per 50 miles)	9.7 (4.1, 25.4)	18.7 (7.6, 48.5)	1.02	1.00	1.04	0.11

CI indicates confidence interval; OR, odds ratio.

Baseline Characteristics, Stratified by Patients Who Travel to High-volume Centers Versus Patients Who Stay Local at Low-volume Centers; Unadjusted and Following Adjustment With Propensity Matching

TABLE 2

Characteristic	Unadjusted			PS-matched		
	Local (n = 867)	Travel (n = 317)	P	Local (n = 317)	Travel (n = 317)	St. Diff.*
Patient characteristics						
Age, yrs (IQR)	66 (58–75)	63 (56–70)	<0.001	61 (55–69)	63 (56–70)	0.20
Female	194 (22.4%)	54 (17%)	0.055	51 (16.1%)	54 (17%)	0.83
Race/ethnicity			<0.001			0.96
White	722 (84.4%)	299 (96.5%)		300 (96.8%)	299 (96.5%)	2.4%
Black	102 (11.9%)	5 (1.6%)		5 (1.6%)	5 (1.6%)	
Other	31 (3.6%)	6 (1.9%)		5 (1.6%)	6 (1.9%)	
Charlson comorbidity score			0.028			0.65
0	630 (72.7%)	252 (79.5%)		244 (77%)	252 (79.5%)	7.7%
1	183 (21.1%)	55 (17.4%)		64 (20.2%)	55 (17.4%)	
2+	54 (6.2%)	10 (3.2%)		9 (2.8%)	10 (3.2%)	
Education above median	476 (54.9%)	191 (60.3%)	0.12	203 (64%)	191 (60.3%)	0.37
Income above median	453 (52.2%)	152 (47.9%)	0.21	149 (47%)	152 (47.9%)	0.87
Insurance			0.18			0.99
Uninsured	25 (2.9%)	3 (1.2%)		4 (1.3%)	3 (1.2%)	1.2%
Insured	832 (97.1%)	254 (98.8%)		303 (98.7%)	254 (98.8%)	
Clinical stage			<0.001			0.80
T1N1	66 (7.6%)	13 (4.1%)		12 (3.8%)	13 (4.1%)	18.2%
T2N1	197 (22.7%)	47 (14.8%)		53 (16.7%)	47 (14.8%)	
T3N1	604 (69.7%)	257 (81.1%)		252 (79.5%)	257 (81.1%)	
Facility characteristics						
Distance to cancer center (IQR)	2.7 (1.6–4)	107.1 (65–247)	<0.001	2.7 (1.7–4.1)	107.1 (65.5–247.4)	<0.001
Treatment facility			<0.001			<0.001
Community program	154 (17.8%)	0 (0%)		64 (20.2%)	0 (0%)	
Comprehensive community program	554 (63.9%)	0 (0%)		203 (64%)	0 (0%)	
Research/academic program	159 (18.3%)	317 (100%)		50 (15.8%)	317 (100%)	

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Characteristic	Unadjusted			PS-matched			St. Diff.*
	Local (n = 867)	Travel (n = 317)	P	Local (n = 317)	Travel (n = 317)	P	
Facility volume (cases/yr)	2.6 (1.9, 3.3)	31.9 (30.9, 38.5)	<0.001	2.4 (1.8, 3.3)	31.9 (30.9, 38.5)	<0.001	
Treatment specifics							
Surgical resection	283 (32.6%)	215 (67.8%)	<0.001	136 (42.9%)	215 (67.8%)	<0.001	

PS indicates propensity score.

* Standardized differences of less than 10% are considered negligible, and less than 20% are typically considered acceptable.

TABLE 3

Treatment Specifics and Outcomes Among Patients Treated With Esophagectomy, Stratified by Patients Who Travel to High-volume Centers Versus Patients Who Stay Local at Low-volume Centers; Unadjusted and Following Propensity Matching

Characteristic	Unadjusted		PS Matched	
	Local (n = 283)	Travel (n = 215)	Local (n = 215)	Travel (n = 215)
Treatment specifics				
Days to definitive surgery (IQR)	118.5 (97.8–140.2)	119 (99–151)	117 (97–141)	119 (99–151)
		0.45		0.44
Neoadjuvant XRT	211 (74.6%)	171 (79.5%)	164 (76.3%)	171 (79.5%)
		0.23		0.49
Neoadjuvant chemo	219 (77.4%)	179 (83.3%)	170 (79.1%)	179 (83.3%)
		0.13		0.32
Adjuvant XRT	33 (11.7%)	11 (5.1%)	28 (13%)	11 (5.1%)
		0.02		0.007
Adjuvant chemo	51 (18%)	24 (11.2%)	38 (17.7%)	24 (11.2%)
		0.046		0.19
Surgical endpoints				
Pathologic T stage				
				0.001
0/CR	28 (9.9%)	43 (20%)	21 (9.8%)	43 (20%)
T1	21 (7.4%)	31 (14.4%)	15 (7.0%)	31 (14.4%)
T2	53 (18.7%)	34 (15.8%)	32 (14.9%)	34 (15.8%)
T3	112 (39.6%)	77 (35.8%)	96 (44.7%)	77 (35.8%)
T4	3 (1.1%)	2 (0.9%)	3 (1.4%)	2 (0.9%)
In situ	1 (0.4%)	0 (0%)	1 (0.5%)	0 (0%)
TX	65 (23%)	28 (13%)	47 (21.9%)	28 (13%)
				0.072
Pathologic N stage				
				0.026
0/CR	103 (36.4%)	103 (47.9%)	82 (38.1%)	103 (47.9%)
N1	117 (41.3%)	74 (34.4%)	88 (40.9%)	74 (34.4%)
N2	5 (1.8%)	8 (3.7%)	3 (1.4%)	8 (3.7%)
N3	4 (1.4%)	4 (1.9%)	3 (1.4%)	4 (1.9%)
NX	54 (19.1%)	26 (12.1%)	39 (18.1%)	26 (12.1%)
Nodes examined (IQR)	10 (4–17)	17 (11–25)	10 (4.5–17)	17 (11–25)
		<0.001		<0.001
Positive margins	20 (7.5%)	16 (7.8%)	17 (8.4%)	16 (7.8%)
		0.99		0.98
Surgical margins				
				0.52
R0	247 (92.5%)	188 (92.2%)	185 (91.6%)	188 (92.2%)
R1	11 (4.1%)	12 (5.9%)	9 (4.5%)	12 (5.9%)

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Characteristic	Unadjusted		PS Matched	
	Local (n = 283)	Travel (n = 215) P	Local (n = 215)	Travel (n = 215) P
R2	1 (0.4%)	0 (0%)	1 (0.5%)	0 (0%)
Positive NOS	8 (3%)	4 (2%)	7 (3.5%)	4 (2%)
Short-term outcomes				
30-Day mortality	15 (5.3%)	8 (3.7%)	9 (4.2%)	8 (3.7%)
90-Day mortality	34 (12.1%)	15 (7.3%)	22 (10.3%)	15 (7.3%)
30-Day readmission		0.071		0.015
No	241 (85.2%)	198 (92.1%)	178 (80.1%)	198 (92.1%)
Unplanned	20 (7.1%)	12 (5.6%)	16 (7.4%)	12 (5.6%)
Planned	4 (1.4%)	0 (0%)	4 (1.9%)	0 (0%)
Planned and unplanned	1 (0.4%)	0 (0%)	1 (0.5%)	0 (0%)
Unknown	17 (6%)	5 (2.3%)	16 (7.4%)	5 (2.3%)
Hospital LOS (IQR)	10 (7–14)	9 (7–13)	10 (7–14)	9 (7–13)
		0.63		0.89

CR indicates complete response; LOS, length of stay; NOS, not otherwise specified; PS, propensity score; XRT, radiation therapy.