Title
A Decade Analysis of Trends and Outcomes of Partial Versus Total Esophagectomy in the United States

Journal
Annals of Surgery, 258(3)

ISSN
0003-4932

Authors
Jafari, Mehraneh D
Halabi, Wissam J
Smith, Brian R
et al.

Publication Date
2013-09-01

DOI
10.1097/sla.0b013e3182a1b11d

Peer reviewed

A Decade Analysis of Trends and Outcomes of Partial Versus Total Esophagectomy in the United States

Mehraneh D. Jafari, MD,∗ Wissam J. Halabi, MD,∗ Brian R. Smith, MD,∗ Vinh Q. Nguyen, PhD,† Michael J. Phelan, PhD,† Michael J. Stamos, MD,∗ and Ninh T. Nguyen, MD∗

Objective: To examine the trends and outcomes of partial esophagectomy with an intrathoracic anastomosis compared with total esophagectomy with a cervical anastomosis.
Background: Controversy exists regarding the optimal surgical approach in the management of esophageal cancer.
Methods: Using the Nationwide Inpatient Sample database, yearly trends of patients with esophageal cancer who underwent partial and total esophagectomy were analyzed. Multivariate logistic regression analysis was used to analyze serious morbidity and in-hospital mortality between partial and total esophagectomy. In addition, outcomes were analyzed according to hospital volume, with low-volume centers defined as those with fewer than 10 cases per year and high-volume centers as those with 10 or more cases per year.
Results: Between 2001 and 2010, 15,190 esophagectomies were performed for cancer. There was an overall increase in the number of esophagectomy procedures performed (1402 to 1975), with a concomitant reduction in the mortality rate (8.3% to 4.2%), particularly for partial esophagectomy. Partial esophagectomy was the predominant operation (76%). Most operations were performed at low-volume centers (62%), with a recent shift of cases to high-volume center. Compared with total esophagectomy, partial esophagectomy was associated with a shorter length of hospital stay (16 ± 6 vs 19 ± 9 days; $P < 0.05$), a lower in-hospital mortality rate (5.8% vs 8.3%; $P < 0.05$), and a lower hospital charge ($119,339 vs $138,496; $P < 0.05$). On multivariate regression analysis, total esophagectomy was associated with higher serious morbidity (odds ratio, 1.39; $P < 0.01$) and in-hospital mortality (odds ratio, 1.67; $P = 0.03$). There were no significant differences in risk-adjusted outcomes between low-volume centers and high-volume center.
Conclusions: The number of esophagectomies performed for esophageal cancer has increased over the past decade accompanied by an overall reduction in mortality, particularly for the partial esophagectomy approach. The predominant operation in the United States continues to be partial esophagectomy with an intrathoracic anastomosis, which was associated with lower morbidity and in-hospital mortality than total esophagectomy. Hospital volume at a threshold of 10 cases per year was not a predictor of outcome.

Keywords: annual volume, esophageal cancer, partial esophagectomy, total esophagectomy, transthoracic anastomosis

There has been a substantial increase in the incidence of esophagealcancer, with an estimated 17,990 cases in 2013.[1,2] This increase has been attributed to a rise in the

incidence of adenocarcinoma of the esophagus as a result of an increase in the prevalence of gastroesophageal reflux disease, Barrett esophagus, and obesity.[1] Esophagectomy continues to be the mainstay treatment for localized esophageal cancer.[3] Because of the high morbidity and mortality associated with esophagectomy, there continues to be debate on the best surgical approach for esophagectomy and on the value of using a hospital's annual volume as an indicator of quality.

Since the development of transhiatal esophagectomy (THE), there has been continued debate regarding its role in comparison with transthoracic esophagectomy (TTE).4 A recent meta-analysis in 2011, comprising 52 studies with 5905 patients, found that TTE was associated with more respiratory complications, wound infections, and perioperative mortality, whereas anastomotic leak and recurrent nerve palsy were higher in the transhiatal group.[5] There was no significant difference in 5-year survival between the 2 groups. Two additional meta-analyses in 1999 and 2001 similarly concluded that TTE was associated with higher pulmonary morbidity and mortality rates than THE.[6,7] Mortality associated with esophagectomy has been steadily declining over the past 2 decades. Using the Nationwide Inpatient Sample (NIS), Dimick and colleagues[8] found a modest but significant decline in the mortality rate from 13.6% to 10.5% during the study period from 1988 to 2000. A recent report from the national Medicare data similarly reported a steady reduction in the risk-adjusted mortality rate for esophagectomy from 10.0% in 1999–2000 to 8.9% in 2007–2008.[9] The improvement in outcome may be attributed to advancement in surgical techniques such as adoption of minimally invasive surgical techniques and recent improvement in the perioperative management of complications such as the use of esophageal stenting in management of intrathoracic leaks. In addition, there are many studies substantiating a relationship between the annual esophagectomy volume and improved perioperative outcomes, thus emphasizing that esophagectomy should be selectively referred to high-volume centers (HVCs).[9–13]

With the recent evolution of minimally invasive surgical techniques, advance endoscopic management of complications, and the push for selective referral of esophagectomy to HVCs, this study aimed to analyze contemporary data on the surgical treatment of esophageal cancer in the Unites States over the past decade, 2001–2010, examining for (1) trends in use of different surgical techniques for esophagectomy (partial vs total), (2) trends in performance of esophagectomy at HVCs, (3) the impact of annual hospital volume on outcome, and (4) comparison of risk-adjusted outcomes between partial and total esophagectomy.

METHODS

The NIS, part of the Healthcare Cost and Utilization Project, is the largest all-payer inpatient care database in the United States, gathering information from nearly 8 million hospital stays each year across the country. The data set approximates a 20% stratified sample of American community, nonmilitary, nonfederal hospitals, resulting in a sampling frame that comprises approximately 95% of all hospital discharges in the United States. Data elements within the NIS are drawn from hospital discharge abstracts that allow determination of all procedures performed during a given hospitalization. Approval for the use of the NIS patient-level data in this study was obtained from the

institutional review board of the University of California, Irvine Medical Center, and the NIS.

We analyzed the discharge data on all patients who underwent esophagectomy for the treatment of esophageal cancer between January 1, 2001, and December 31, 2010, using appropriate diagnostic and procedural codes as specified by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). The principal ICD-9-CM diagnosis codes for esophageal cancer included 150.0–150.5, 150.8, and 150.9. The principal ICD-9-CM procedure codes for partial esophagectomy with an intrathoracic anastomosis were 42.41, 42.5, 42.51, and 42.52 and for total esophagectomy were 42.42 and 42.11. Partial esophagectomy was defined as an operation that required an intrathoracic anastomosis. Total esophagectomy was defined as either a 3-field McKeown approach or a THE requiring a cervical anastomosis. The annual number of esophageal resection was calculated for each hospital. Volume was evaluated by using the unique hospital identification number for each hospital within the NIS. To be designated as a HVC, the hospital had to perform 10 or more cases per year during each sampled year. A hospital was designated a low-volume center (LCV) if it performed fewer than 10 cases per year. A hospital could be designated as HVC for 1 year but as LVC for another year because of fluctuation in its annual case volume. This annual threshold volume was selected on the basis of studies validating the effects of volume and outcomes in esophagectomy.[14,15]

We analyzed the temporal trends in the overall number of esophagectomy operations, the number of partial versus total esophagectomy operations, and the number of cases performed at LVC versus HVC over the 10-year study period. The temporal trends of in-hospital mortality rates for partial versus total esophagectomy and for LVC versus HVC were also determined. The average change per year, as indicated by the variation of trends per year, was calculated using a geometric mean. We compared patient characteristics, hospital characteristics (teaching vs nonteaching; urban vs rural), primary payer type, preoperative comorbidities between partial and total esophagectomy and between LVC and HVC. The Elixhauser method was used to calculate a comorbidity score for risk adjustment between groups and has been shown to more accurate than that of the Charlson method.[16] Multivariate analyses were used to analyze perioperative outcomes between partial and total esophagectomy and between LVC and HVC. Primary outcome measures were selected a priori and included the rate of serious morbidity, anastomotic leak, respiratory complications, and in-hospital mortality. Serious morbidity included anastomotic leak/mediastinitis, sepsis, pulmonary infections, acute respiratory failure, acute renal failure, cardiac complications, cerebrovascular accident, deep venous thrombosis, and wound complications. Respiratory complications included acute respiratory failure and pulmonary infections. A list of the ICD-9 diagnostic codes for in-hospital complication is listed in the Appendix (see Supplemental Digital Content, available at http://links.lww.com/SLA/A418). Pulmonary infectious complications included postoperative pneumonia, pulmonary empyema, and abscess. The ICD-9 code for anastomotic leak included complication of intestinal anastomosis (997.4) and was paired with suppurative peritonitis (567.22) and mediastinitis (519.2). Acute renal failure also included acute renal insufficiency. Secondary outcome measures included length of hospital stay, overall morbidity, specific postoperative complications, and total hospital charges.

Statistical Analysis

All statistical analyses were conducted on raw numbers that were weighted to reflect national averages. Weighted statistics were based on sampling probabilities for each stratum to ensure that the hospitals studied were representative of all US hospitals. Statistical analyses were conducted using SAS version 9.3 (Cary, NC) and the R statistical environment. For comparison of outcomes between partial and total esophagectomy and between LVC and HVC, inference was drawn using linear regression for continuous variables (length of stay and hospital charge) and logistic regression for binary endpoints (in-hospital mortality, serious morbidity, and specific complications). Independent variables used for risk adjustment included demographics (age, sex, race), hospital characteristics (teaching vs nonteaching; urban vs rural), primary payer type, and comorbidities (anemia, congestiveheart failure, chronic pulmonary disease, uncomplicated and complicated diabetes, liver disease, peripheral vascular disease, renal failure, obesity, weight loss/malnutrition, and smoking). For the partial and total esophagectomy comparison, hospital volume (LVC vs HVC) was used within the adjustment, and for the LVC and HVC comparison, procedural type (partial vs total) was used within the adjustment. Robust standard errors were used to guard against model misspecification. Holm method was used to account for multiple comparisons in the form of adjusted P values.[17,18] A comparison was declared statistically different than 0 (for mean difference) or 1 (for odds ratio [OR]) at the family-wise error level of 0.05 if an adjusted P value was less than 0.05. Patients with missing data points were excluded from the final analysis. Univariate and multivariate statistical analyses were conducted on unweighted numbers.

RESULTS

National Trends

Between the years 2001 and 2010, a total 15,190 esophagectomies were performed for cancer. Partial esophagectomy was consistently the preferred approach (76%) throughout the entire decade, and this was observed for both LVC and HVC (Fig. 1A). During the study period, the mean increase in the total number of esophagectomy cases was 4% per year. The number of total esophagectomy cases increased by 6% per year, and the number of partial esophagectomy cases increased by 3% per year (Fig. 1A). There was a trend for selective shift of esophagectomy cases to HVC over the study period. In 2001, 78% of esophagectomy cases were performed at LVC; by 2010, most (58%) esophagectomy cases were performed at HVC (Fig. 1B). There was an overall reduction in the in-hospital mortality rate (average of 5% per year) between 2001 and 2010, with the greatest reduction observed within the partial esophagectomy group (Fig. 2A) and at LVCs (Fig. 2B).

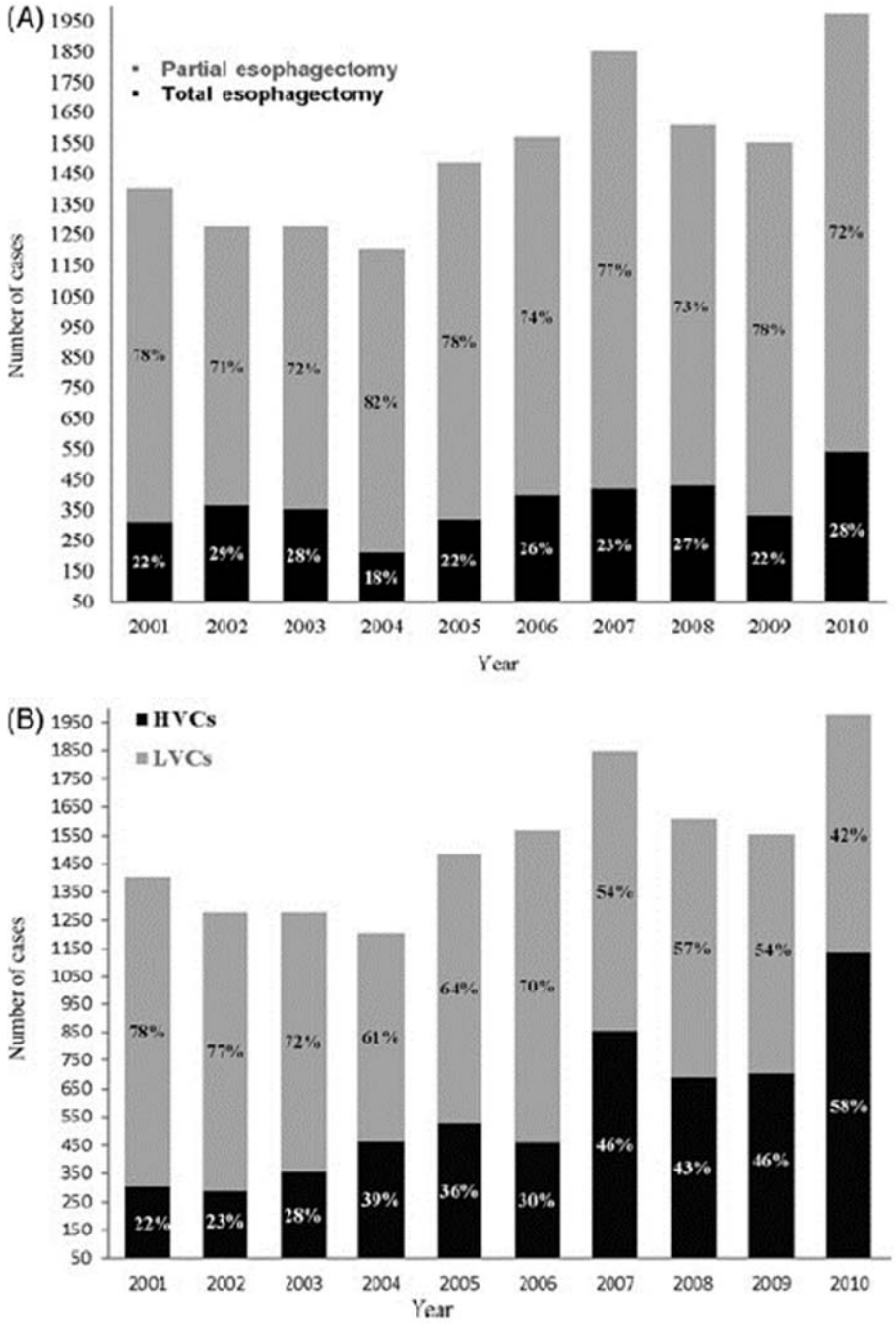

FIGURE 1. A, Distribution of the number of partial and total esophagectomy cases performed in the United States, 2001–2010. B, Distribution of esophagectomy cases performed at LVCs versus HVCs in the United States, 2001–2010.

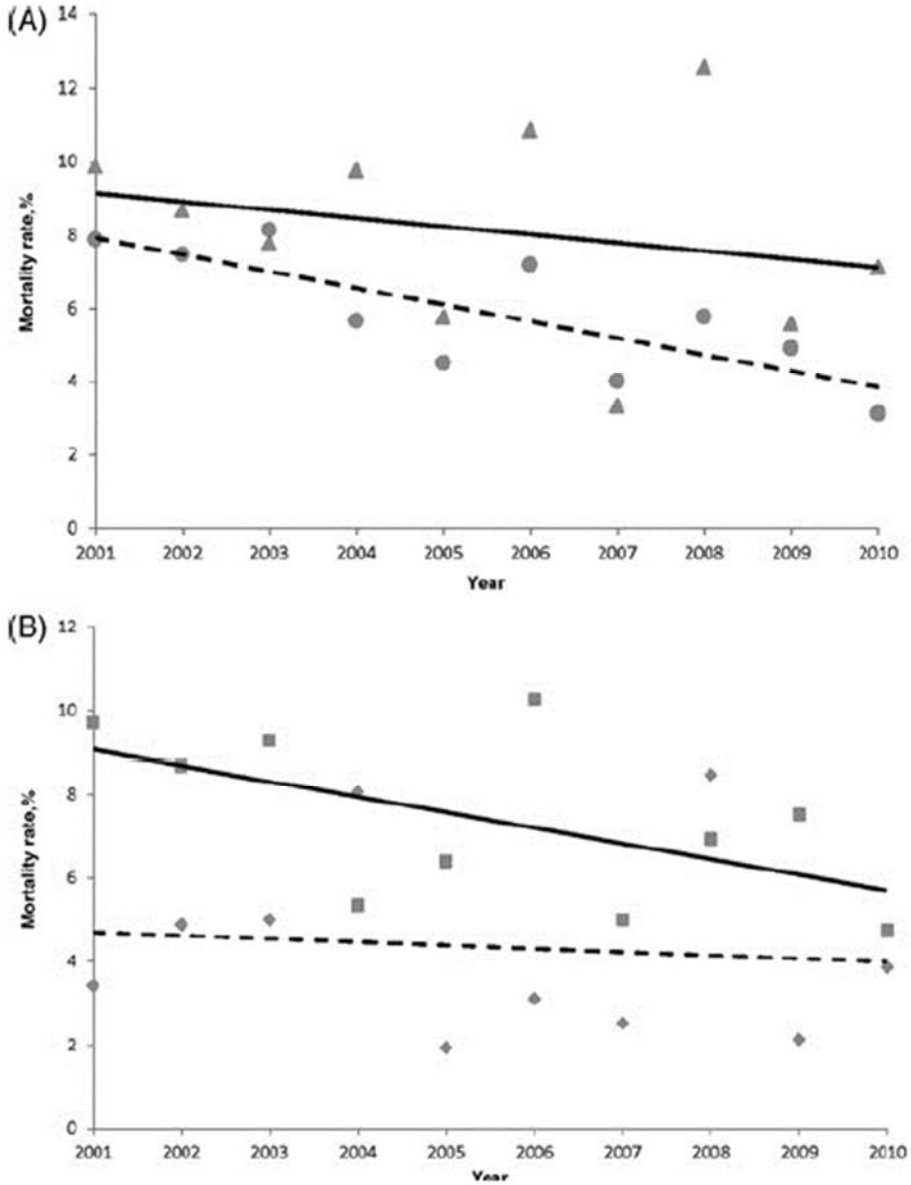

FIGURE 2. A, Mortality rate (%) for partial (circle) and total (triangle) esophagectomy cases in the United States, 2001–2010. Linear line denotes the change in mortality rate per year for partial (dash line) and total (solid line) esophagectomy. B, Mortality rate (%) for esophagectomy performed at LVCs (square) and HVCs (diamond) in the United States, 2001–2010. Linear line denotes the change in mortality rate per year for LVCs (solid line) and HVCs (dash line).

Demographics and Comorbidities

The overall average age of patients who underwent an esophagectomy was 63 ± 10 years, with the majority being white and men. As seen in Table 1, the predominant operation for treatment of esophageal cancer was partial esophagectomy (76%; n = 11,473). Most esophagectomy cases were performed at LVC (62%; n = 9386) at a mean

of 485 ± 58 centers per year, compared with 5804 operations performed at a mean of 35 ± 13 HVC per year (Table 2). High volume centers performed an average of 16 ± 5.7 esophagectomies per year, whereas LVCs performed an average of 2 ± 1.7 esophagectomies per year. High-volume centers were more likely to be large teaching hospitals compared with LVC ($P < 0.01$) (Table 2). Table 3 lists comorbidities for patients who underwent partial esophagectomy versus total esophagectomy. The prevalence of hypertensionwas higher in the partial esophagectomy group than in the total esophagectomy group (44.2% vs 38.9%, respectively; $P < 0.05$). Table 4 lists comorbidities for patients who underwent esophagectomies performed at LVC versus HVC. Although the overall Elixhauser19 comorbidity score was similar between LVC and HVC, the prevalence of chronic pulmonary disease and congestive heart failure was higher at LVC.

TABLE 1. Demographics for Patients Undergoing Partial Versus Total Esophagectomy

	Total Esophagectomy (n = 3717)	Partial Esophagectomy (n = 11,473)
Age, *M* ± SD, yr	63 ± 10	63 ± 10
Sex, %		
Men	82.5	81
Women	17.5	19
Race or ethnicity, %		
White	61.8	64.8
Black	4.7	3.8
Hispanic	3	2.4
Asian or Pacific Islander	0.5	0.5
Native American	0.4	0.3
Other/unknown	29.6	28.2
Primary payer, %		
Medicare	28.5	29.3
Medicaid	4.7	3.8
Private including HMO	29.2	29.9
Self-pay	1.2	0.9
Other/unknown	6.4	36.1
Hospital type, %		
Nonteaching	18.3	19.2
Teaching	81.6	80.6
Hospital location, %		
Urban	95.4	94.9
Rural	4.4	4.9

HMO indicates Health Maintenance Organization.

TABLE 2. Demographics for Patients Undergoing Esophagectomy at LVCs Versus HVCs

	LVCs (n = 9386)	HVCs (n = 5804)
No. centers/yr, $M \pm$ SD	485 ± 58	35 ±13
No. cases/center/yr, $M \pm$ SD	2 ± 1.7	16 ± 5.7
Procedure type, %		
Total esophagectomy	24.9	23.9
Partial esophagectomy	75.1	76.1
Age, yr	63 ± 10	63 ± 10
Sex, %		
Men	80.3	83
Women	19.7	17
Race or ethnicity, %		
White	61.3*	68.6
Black	5.3*	2
Hispanic	2.6	2.5
Asian or Pacific Islander	0.5	0.5
Native American	0.3	0.4
Other/unknown	30.0	26.0
Primary payer, %		
Medicare	28.3	30.5
Medicaid	3.9	4.4
Private including HMO	25.3*	36.9
Self-pay	0.7	1.3
Other/unknown	41.8	26.9
Hospital type, %		
Nonteaching	29.4*	1.8
Teaching	70.3*	98.2
Hospital location, %		
Urban	94.9	95.3
Rural	4.8	4.7

*$P < 0.05$, compared with HVCs.
HMO indicates Health Maintenance Organization.

TABLE 3. Comorbidities in Patients Undergoing Partial Versus Total Esophagectomy

	Total Esophagectomy (n = 3717)	Partial Esophagectomy (n = 11,473)
Comorbidity score, $M \pm SD$	6 ± 3	6 ± 3
Hypertension, %	38.9*	44.2
Smoking, %	27.2	31.0
Chronic pulmonary disease, %	22.6	21.3
Diabetes, %	13.2	14.6
Anemia, %	13.7	13.5
Weight loss, %	14.8	11.8
Hypoalbuminemia, %	0.3	0.7
Congestive heart failure, %	6.2	4.4
Coagulopathy, %	4.3	4.7
Obesity, %	4.0	4.4
Peripheral vascular disorders, %	3.3	3.2
Renal failure, %	1.4	2.2
Liver disease, %	1.8	1.7

*$P < 0.05$, compared with partial esophagectomy.

TABLE 4. Comorbidities in Patients Undergoing Esophagectomy at LVCs Versus HVCs

	LVCs (n = 9386)	HVCs (n = 5804)
Comorbidity score	6	6
Hypertension, %	42.5	43.7
Smoking, %	28.7	31.8
Chronic pulmonary disease, %	24.9*	15.9
Diabetes, %	14.6	14.4
Anemia, %	14.1	12.4
Weight loss, %	13.5	11.4
Hypoalbuminemia, %	0.8	0.4
Congestive heart failure, %	6.0*	2.8
Coagulopathy, %	4.6	4.3
Obesity, %	4.0	4.9
Peripheral vascular disorders, %	3.2	3.1
Renal failure, %	2.4	1.5
Liver disease, %	1.7	1.6

*$P < 0.05$, compared with HVCs.

Outcomes

Partial Versus Total Esophagectomy

On univariate analyses, total esophagectomy group had higher overall morbidity rate (48.9% vs 43.8%, respectively; $P < 0.05$) and higher in-hospital mortality rate (8.3% vs 5.8%, respectively; $P < 0.01$) than partial esophagectomy group (Table 5). There was a lower rate of bowel obstruction for total esophagectomy group than for partial esophagectomy group ($P < 0.01$). The most common complications for both partial and total esophagectomy were respiratory failure and pulmonary infectious complications. Compared with total esophagectomy, partial esophagectomy operations had a shorter length of stay (mean difference, −3 days) and lower hospital charges (mean difference, −$19,130) (Table 5). Table 6 lists the comparison of multivariate analyses of partial and total esophagectomy. With partial esophagectomy as a reference, total esophagectomy was associated with a higher in-hospital mortality rate (OR = 1.67; $P = 0.03$), a higher rate of serious morbidity (OR = 1.39; $P < 0.01$), and a higher rate of respiratory complications (OR =1.37; P =0.03).

TABLE 5. Outcomes of Partial Versus Total Esophagectomy

	Total Esophagectomy (n = 3717)	Partial Esophagectomy (n = 11,473)	*P*
Anastomotic leak/mediastinitis, %	9.5	10.3	0.41
Sepsis, %	6.1	5.6	0.79
Wound complications, %	9.8	9.0	0.70
Pulmonary infections, %	13.0	11.6	0.48
Respiratory failure, %	20.6	16.8	0.06
Intestinal obstruction, %	3.9*	6.0	0.02
Acute renal failure/insufficiency, %	9.0	8.1	0.60
Cardiac complications, %	9.5	7.9	0.26
Urinary tract infection, %	5.4	4.0	0.18
Cerebral vascular accident, %	0.1	0.4	0.47
Deep venous thrombosis/embolism, %	1.3	1.1	0.55
Dysphagia	4.0*	2.1	0.03
Overall morbidity rate, %	48.9*	43.8	0.01
In-hospital mortality rate, %	8.3*	5.8	0.03
Mean length of stay, $M \pm$ SD, d	19 ± 9*	16 ± 6	0.0001
Mean total charge, $M \pm$ SD, $	138,496 ± 25,340*	119,339 ± 59,413	0.0001

*$P < 0.05$, compared with partial esophagectomy.

TABLE 6. Risk-Adjusted Outcomes of Esophagectomy Performed at LVCs Versus HVCs (HVCs as a Reference) and Partial Versus Total Esophagectomy (Partial Esophagectomy as a Reference)*

	Adjusted OR (95% CI)	Naive *P* Value	Adjusted *P* Value
LVCs vs HVCs			
In-hospital mortality	1.49 (0.94–2.38)	0.0879	0.2638
Serious complications	1.20 (0.99–1.49)	0.0634	0.2536
Respiratory complications	1.29 (1.02–1.63)	0.0324	0.1619
Anastomotic leak	0.99 (0.71–1.37)	0.942	0.942
Partial vs total esophagectomy			
In-hospital mortality	1.67 (1.09–2.50)	0.0163	0.0327
Serious complications	1.39 (1.12–1.72)	0.002	0.0079
Respiratory complications	1.37 (1.07–1.72)	0.019	0.0327
Anastomotic leak	1.16 (0.81–1.64)	0.402	0.4021

*Adjusted *P* value signifies adjustment for multiple comparisons.
CI indicates confidence interval.

Low-Volume Versus High-Volume Centers

On univariate analyses, LVC had higher overall morbidity rate (47.4% vs 40.9%, respectively; $P < 0.05$) and higher in-hospital mortality rate (7.6% vs 4.3%, respectively; $P < 0.01$) than HVC. The incidence of sepsis and of respiratory failure was higher at LVC than at HVC ($P < 0.01$). The most common complications for both LVC and HVC were pulmonary complications, including respiratory failure and pulmonary infectious complications. High-volume centers had a shorter length of stay (mean difference, −3 days) than LVC (Table 7). On multivariate analyses, no significant differences were detected for in-hospital mortality, serious morbidity, respiratory complications, or anastomotic leak between LVC and HVC (Table 6).

TABLE 7 . Outcomes of Esophagectomy Performed at LVCs Versus HVCs

	LVCs (n = 9386)	HVCs (n = 5804)	*P*
Anastomotic leak/ mediastinitis, %	9.8	10.3	0.74
Sepsis, %	6.5*	4.8	0.04
Wound complications, %	9.8	8.5	0.23
Pulmonary infections, %	12.6	10.4	0.07
Respiratory failure, %	19.6*	14.2	0.0001
Bowel obstruction, %	5.4	5.4	1.0
Acute renal failure/ insufficiency, %	8.8	7.9	0.39
Cardiac complications, %	8.3	7.9	0.79
Urinary tract infection, %	4.7	3.7	0.18
Cerebral vascular accident, %	0.3	0.4	0.52
Deep venous thrombosis, %	1.0	1.3	0.38
Overall morbidity rate, %	47.4*	40.9	0.004
In-hospital mortality rate, %	7.6*	4.3	0.0002
Mean length of stay, $M \pm$ SD, d	18 ± 8*	15 ± 6	0.0001
Mean total charge, $M \pm$ SD, $	123,332 ± 62,506	126,859 ± 63,172	0.12

*$P < 0.05$, compared to HVCs.

DISCUSSION

The historical debate regarding the best surgical approach and the best setting for surgical management of esophageal cancer continues to the present. This stems mainly from a lack of consensus in the literature and the high degree of variability in outcomes among hospitals.20 Using the NIS to examine trends of esophagectomy over the past decade, we found an increase in the number of esophageal resections (by 4% per year) with an overall reduction in the in-hospital mortality rate (by 5%per year). The largest reduction in mortality was observed within the partial esophagectomy group. Partial esophagectomy with an intrathoracic anastomosis continues to be the preferred

surgical approach and was associated with lower risk-adjusted inhospital mortality and serious morbidity rates than total esophagectomy. There were no significant differences in risk-adjusted outcomes between LVC and HVC.

We found that the number of esophagectomy operations has steadily increased over the past decade accompanied by an overall reduction in the mortality rate and a trend toward higher proportion of esophagectomies being performed at HVC. We observed a 41% increase in the number of esophagectomies performed between 2001 and 2010. Dimick et al8 reviewed data from the NIS between 1988 and 2000 and similarly found a trend toward an increase in the total number of esophagectomies performed in the United States. Our study found an overall reduction in the mortality rate by an average of 5% per year, particularly in patients who underwent partial esophagectomy. Using the national Medicare data, Finks and colleagues[9] reported a reduction of 11% in the risk-adjusted mortality rate for esophagectomies performed between 1999 and 2008. We also found a steady increase in the number of esophagectomies performed at HVC (15% per year), with a reduction in the number of cases performed at LVC (3% per year) after the year 2006. Dimick et al[8] similarly found that the proportion of esophageal resections performed at HVC increased from 40% in 1988–1991 to 57% during 1997–2000. This finding may be attributed to initiatives such as the Leapfrog Group, which advocates referral of patients requiring esophageal resection to centers that perform more than 13 cases per year as a component of a value-based purchasing program.[21] With regard to the procedures for esophagectomy, our data clearly show that partial esophagectomy with an intrathoracic anastomosis is the preferred operation for the treatment of esophageal cancer and is associated with improved risk-adjusted outcomes compared with total esophagectomy. A recentmeta-analysis of THE (total esophagectomy) versus TTE (partial esophagectomy) found that mortality and respiratory complications were higher in the TTE group, but there were decreased rates of anastomotic leak and strictures.[5] In contrast, Rentz et al,22 in a study of Veteran Administration hospitals, found no difference between the THE and TTE with regard to mortality rate (10% in each group). Similarly, a study of 17,395 patients using the NIS between 1999 and 2003 found equivalent in-hospital mortality rate after THE (8.91%) compared with TTE (8.47%).[15] However, a Swedish randomized trial of 83 patients who underwent partial versus total esophagectomy did not find any significant difference between the groups with regard to morbidity, mortality, and 5-year survival.23 One of the largest contemporary series of esophagectomy to date was published by the University of Pittsburgh group. Luketich and colleagues24 reviewed their experience of 1033 consecutive minimally invasive esophagectomy and reported a trend toward switching from a total esophagectomy with a cervical anastomosis to a partial esophagectomy with an intrathoracic anastomosis in the latter part of their large series. In addition, they found clinical advantages with partial esophagectomy, including a lower rate of vocal cord paralysis, lower pulmonary complication, and a trend toward lower mortality rate (2.5% vs 0.9%, respectively; $P = 0.08$).24 The improved outcomes associated with partial esophagectomy are multifactorial and may be attributed to the recent increase in the use of the minimally invasive technique (ie, thoracoscopic esophagectomy), improved management of anastomotic leaks with the use of endoscopic stenting, and improvement in critical care management of these complex patients. Anastomotic leak after an intrathoracic anastomosis can be associated with significant

morbidity and a high risk for mortality. Over the past several years, clinical use of endoscopic esophageal stenting has been shown to be an effective modality for the treatment of anastomotic leak while reducing the need for gastrointestinal diversion.[25]

There is no consensus with regard to the relationship between volume and mortality in esophagectomy. Although we found significantly higher in-hospital mortality rate at LVC than at HVC (7.6% vs 4.3%, respectively) on univariate analysis, this difference was not significant on multivariate analysis. Many large studies have found improved outcomes associated with HVC.[8,26–28] Meguid et al[29] analyzed the NIS and found a relationship between volume and outcome and concluded that the best model was with an annual hospital volume of 15 or more cases per year. Instead, other studies have shown no direct relationship between yearly volume and mortality.[15,30,31] Rodgers and colleagues30 analyzed the NIS and found inpatient mortality is strongly associated with patient variables (ie, comorbidities) rather than hospital variables (ie, volume). The opposing findings on the relationship between volume and mortality may be related to the fact that cutoffs used to define HVC are variable (ranging from 6 to 20 cases per year) among studies. However, Kozower and colleagues[31] examined the relationship between volume and mortality risk using 3 different statistical models—continuous linear function, a nonlinear function using restricted cubic splines, and using quintiles of volume. The most accurate being the spline regression model that characterizes the nonlinearity of the relationship. No significant association was found between hospital procedure volume and in-hospital mortality in any of the 3 models. Instead, they found important predictors of mortality to include higher age, hypertension, weight loss history, and peripheral vascular disease.31 Also, in a recent large analysis of the NIS, LaPar and colleagues[32] found that hospital procedure volume was not a statistically significant predictor of in-hospital mortality for esophagectomy by using hierarchical general linear modeling with restricted cubic splines adjusted for patient demographics, comorbid disease, and elective procedure status. Instead of volume, LaPar et al[33] found that Medicaid and uninsured payer status confers worse risk-adjusted outcomes compared with that of private insurance. In addition, Funk and colleagues[34] found that low-volume hospitals with certain systems characteristics achieved better outcomes, which may indicate that volume alone is not an important indicator of outcome in esophagectomy.

Limitations

This study has several limitations. The main limitation of this study is the lack of follow-up data within the NIS database to provide 30-day mortality, disposition, postdischarge complications, and 30-day readmission. In addition, functional status after surgery, long-term outcomes, cancer recurrence, and survival rates are unknown. Other limitations of the database include inability to adjust for certain important risk factors, such as tumor type and stage, pulmonary function, performance status, and the use of neoadjuvant therapy. The partial esophagectomy group includes a homogeneous group of patients who underwent TTE (Ivor Lewis), whereas the total esophagectomy group includes groups of patients who underwent both THE and the 3-hole McKeown esophagectomy. On the basis of the current ICD-9 procedural codes, we were unable to differentiate between these 2 procedures and therefore were not able to examine specific

outcome between TTE and THE. Because this study is not a randomized study, there can be selection bias between groups. Also, there can be a potential coding error for certain comorbidities and postoperative complications within the NIS database. There is also no information on the surgeons' specialty or case volume. Rodgers and colleagues30 reported that surgeons' case volume is more important than hospital volume. Currently, there is no specific ICD-9 procedural code for minimally invasive esophagectomy. The reduction in mortality over the past decademay be in part due to the increase in the use of the minimally invasive surgical technique. Finally, the volume threshold of 10 cases per year was derived from several publications within the literature.[14,15] We do not have information whether our volume analysis is comparable to other volume thresholds. However, Kozower and colleagues[31] did not find a relationship between volume and in-hospital mortality despite examining 3 different statistical models. Despite these limitations, this study provides a large sample size to compare contemporary outcomes of partial and total esophagectomy and examining the impact of hospital volume on outcomes in esophagectomy for the management of esophageal cancer.

CONCLUSIONS

Using a national inpatient database, we examined the trends and outcomes of patients with esophageal cancer who underwent partial versus total esophagectomy and found a steady increase in the number of esophagectomies being performed in the United States with a concurrent reduction in the in-hospital mortality, particularly observed in patientswho underwent partial esophagectomy. There is a trend toward increasing case volume at HVCs. Partial esophagectomy with an intrathoracic anastomosis continues to be the predominate operation. Compared with partial esophagectomy, total esophagectomy was associated with higher risk-adjusted morbidity and mortality. At a threshold of 10 cases per year, there were no significant differences in risk-adjusted outcomes between LVC and HVCs.

REFERENCES

1. Enzinger PC, Mayer RJ. Esophageal cancer. N Engl J Med. 2003;349:2241–2252.
2. Greenlee RT, Murray T, Bolden S, et al. Cancer statistics. CA Cancer J Clin. 2000;50:7–33.
3. Pennathur A, Farkas A, Krasinskas AM, et al. Esophagectomy for T1 esophageal cancer: outcomes in 100 patients and implications for endoscopic therapy. Ann Thorac Surg. 2009;87:1048–1054; discussion 1054–1055.
4. OrringerMB. Transthoracic versus transhiatal esophagectomy:what difference does it make? Ann Thorac Surg. 1987;44:116–118.
5. 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.
6. 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.

7. Rindani R, Martin CJ, Cox MR. Transhiatal versus Ivor-Lewis oesophagectomy: is there a difference? Aust N Z J Surg. 1999;69:187–194.
8. Dimick JB, Wainess RM, Upchurch GR Jr, et al. National trends in outcomes for esophageal resection. Ann Thorac Surg. 2005;79:212–216; discussion 217–218.
9. Finks JF, Osborne NH, Birkmeyer JD. Trends in hospital volume and operative mortality for high-risk surgery. N Engl J Med. 2011;364:2128–2137.
10. 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.
11. Dudley RA, Johansen KL, Brand R, et al. Selective referral to high volume hospitals: estimating potentially avoidable deaths. JAMA. 2000;283:1159–1166.
12. Learn PA, Bach PB. A decade of mortality reductions in major oncologic surgery: the impact of centralization and quality improvement. Med Care. 2010;48:1041–1049.
13. Milstein A, Galvin RS, Delbanco SF, et al. Improving the safety of health care: the Leapfrog initiative. Eff Clin Pract. 2000;3:313–316.
14. 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.
15. Rouvelas I, Lindblad M, Zeng W, et al. Impact of hospital volume on longterm survival after esophageal cancer surgery. Arch Surg. 2007;142:113–117; discussion 118.
16. Southern DA, Quan H, Ghali WA. Comparison of the Elixhauser and Charlson/Deyo methods of comorbidity measurement in administrative data. Med Care. 2004;42:355–360.
17. Holm S. Proceedings of the fifth Berkeley symposium on mathematical statistics and probability. Scand J Stat. 1979;6:65–70.
18. Wright SP. Adjusted P-values for simultaneous inference. Biometrics. 1992;48:1005–1013.
19. vanWalraven C, Austin PC, Jennings A, et al. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. Med Care. 2009;47:626–633.
20. 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.
21. Birkmeyer JD, Dimick JB. Potential benefits of the new Leapfrog standards: effect of process and outcomes measures. Surgery. 2004;135:569–575.
22. 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.
23. Walther B, Johansson J, Johnsson F, et al. Cervical or thoracic anastomosis after esophageal resection and gastric tube reconstruction: a prospective randomized trial comparing sutured neck anastomosis with stapled intrathoracic anastomosis. Ann Surg. 2003;238:803–812; discussion 812–814.
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.
25. Nguyen NT, Rudersdorf PD, Smith BR, et al. Management of gastrointestinal leaks after minimally invasive esophagectomy: conventional treatments vs. endoscopic stenting. J Gastrointest Surg. 2011;15:1952–1960.

26. Dimick JB, Cowan JA Jr, Ailawadi G, et al. National variation in operative mortality rates for esophageal resection and the need for quality improvement. Arch Surg. 2003;138:1305–1309.
27. Ghaferi AA, Birkmeyer JD, Dimick JB. Hospital volume and failure to rescue with high-risk surgery. Med Care. 2011;49:1076–1081.
28. Kuo EY, Chang Y, Wright CD. Impact of hospital volume on clinical and economic outcomes for esophagectomy. Ann Thorac Surg. 2001;72:1118–1124.
29. Meguid RA, Weiss ES, Chang DC, et al. The effect of volume on esophageal cancer resections: what constitutes acceptable resection volumes for centers of excellence? J Thorac Cardiovasc Surg. 2009;137:23–29.
30. Rodgers M, Jobe BA, O'Rourke RW, et al. Case volume as a predictor of inpatient mortality after esophagectomy. Arch Surg. 2007;142:829–837.
31. Kozower BD, Stukenborg GJ. Hospital esophageal cancer resection volume does not predict patient mortality risk. Ann Thorac Surg. 2012;93:1690–1698.
32. LaPar DJ, Kron IL, Jones DR, et al. Hospital procedure volume should not be used as a measure of surgical quality. Ann Surg. 2012;256:606–615.
33. LaPar DJ, Bhamidipati CM, Mery CM, et al. Primary payer status affects mortality for major surgical operations. Ann Surg. 2010;252:544–551.
34. Funk LM, Gawande AA, Semel ME, et al. Esophagectomy outcomes at lowv olume hospitals: the association between systems characteristics and mortality.
Ann Surg. 2011;253:912–917.

DISCUSSANTS

J.D. Luketich (Pittsburgh, PA):

The title of your article states that you are comparing transthoracic and transhiatal, but the transhiatal group included an unknown percentage of 3-hole McKeown procedure that also includes a transthoracic component but are similar to some degree to the transhiatal in that they include a neck incision and cervical anastomosis. You report of a better outcome for the intrathoracic anastomotic group, including lower morbidity rate, shorter hospital stay, lower mortality rate, and a lower cost to some degree. Recently, we have observed a similar phenomenon in Pittsburgh, comparing our minimally invasive McKeown procedure, which is a neck anastomosis, to our minimally invasive Ivor-Lewis, which has the intrathoracic anastomosis, and we also observed a lower rate of mortality and morbidity.

Do you think that your analysis is actually a comparison of cervical versus intrathoracic anastomosis rather than the inclusion of a thoracic component? If so, this finding is to some degree in contrast with previous meta-analysis of transthoracic versus transhiatal operations. Towhat do you attribute the better outcomes of the intrathoracic anastomotic group?

Second, how did you determine the volume number for your cutoff of high volume versus low volume? Also, how can you explain that a center performing 10 or fewer total esophagectomies per year can possibly compare to an individual esophageal specialist who might be doing 50 or more? Along these lines, do you know from this database analysis what the actual number of esophagectomies was per surgeon? In your

LVC, for example, one surgeon might be performing 10 procedures, versus 10 doing a single esophagectomy each. Do you think these questions can only be answered in future multicenter trials assessing the outcomes per surgeon more carefully?

Could you briefly comment on the morbidity results in more detail? I am unclear on the accuracy of some of the morbidities listed. For example, an incidence of 8% renal failure seems high. Can you tell me the definition of renal failure? Was it a transient bump in blood urea nitrogen and creatinine or full-blown hemodialysis? Some of the other complications listed were leaks. Did they include radiographic simple leaks that maybe required no intervention versus major leaks requiring reoperation? Likewise, with this type of database, can you comment on 30-day mortality disposition at discharge, home versus extended care facility, and how this might impact on ultimately the outcomes of these operations?

Response From N.T. Nguyen:

With regard to your first question, does the title of our article accurately reflect outcome of cervical versus an intrathoracic anastomosis, I agree with your point. Because of the limitation of the available ICD-9 procedural codes, the 3-hole McKeown procedure was included within the transhiatal group, as both operations are a form of total esophagectomy with a cervical anastomosis. Therefore, we were not able to differentiate between these 2 procedures.

In answer to your next question, what are the reasons for better outcome associated with the transthoracic group, until now, all of the meta-analyses have shown that the THE produces a lower morbidity and mortality than TTE. I think our study and your recent publication of more than 1000 esophagectomies showed the contrary. One reason, I believe, is that these represent contemporary data.

From the ∗Department of Surgery, University of California, Irvine Medical Center, Orange; and †Department of Statistics, University of California Irvine, Irvine.

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

Disclosure: This manuscript has been seen and approved by all authors. The authors declare no conflicts of interest.

Reprints: Ninh T. Nguyen, MD, Department of Surgery, University of California, Irvine Medical Center, 333 City Blvd, W Ste 850, Orange, CA 92868. E-mail: ninhn@uci.edu.