ORIGINAL ARTICLE

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

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Hypothesis: When assessing the effect of operative approach on outcomes, it may be less relevant whether a transhiatal or an Ivor Lewis esophagectomy was performed and may be more important to focus on patient selection and the quality of the hospital performing the operation.

Design: Observational study.

Setting: Hospitals participating in the American College of Surgeons National Surgical Quality Improvement Program.

Patients: Individuals undergoing esophagectomy were identified from January 1, 2005, to December 31, 2010. The following 4 groups were created based on operative approach: transhiatal, Ivor Lewis, 3-field, and any approach with an intestinal conduit.

Main Outcome Measures: Risk-adjusted 30-day outcomes and hospital-level variation in performance.

Results: At 164 hospitals, 1738 patients underwent an esophageal resection: 710 (40.9%) were transhiatal, 497 (28.6%) were Ivor Lewis, 361 (20.8%) were 3-field, and 170 (9.8%) were intestinal conduits. Compared with the transhiatal approach, Ivor Lewis esophagectomy was not associated with increased risk for postoperative complications; however, 3-field esophagectomy was associated with increased likelihood of postoperative pneumonia (odds ratio [OR], 1.88; 95% CI, 1.28-2.77) and prolonged ventilation exceeding 48 hours (OR, 1.68; 95% CI, 1.16-2.42). Intestinal conduit use was associated with increased 30-day mortality (OR, 2.65; 95% CI, 1.08-6.47), prolonged ventilation exceeding 48 hours (OR, 1.61; 95% CI, 1.01-2.54), and return to the operating room for any indication (OR, 1.85; 95% CI, 1.16-2.96). Patient characteristics were the strongest predictive factors for 30-day mortality and serious morbidity. After case-mix adjustment, hospital performance varied by 161% for 30-day mortality and by 84% for serious morbidity.

Conclusions: Compared with transhiatal dissection, Ivor Lewis esophagectomy did not result in worse postoperative complications. After controlling for case-mix, hospital performance varied widely for all outcomes assessed, indicating that reductions in short-term outcomes will likely result from expanding other aspects of hospital quality beyond a focus on specific technical maneuvers.

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Morbidity and mortality following esophagectomy are considerable and have increasingly become a focus of surgical quality improvement efforts. For example, the National Quality Forum has 3 endorsed esophagectomy quality measures,[1] and the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) specifically targets esophagectomy outcome comparisons among participating hospitals.[2] Despite these and other initiatives, serious morbidity still occurs in up to 50% of patients undergoing esophageal resection.[3,4]

One controversy that continues to fuel debate is the influence of the operative approach on surgical complications.[5] For example, some research has shown that procedures involving a thoracotomy result in appreciably more complications,[3] particularly adverse pulmonary events, while other data do not support these findings.[5,6] Nevertheless, most investigations focus only on transhiatal vs Ivor Lewis esophagectomy, and little comparative research specifically addresses the influence of the 3-field approach or the use of an intestinal conduit. These more challenging techniques may be associated with inferior short-term outcomes.[7]

In addition, when assessing the effect of operative approach on outcomes, the influence of patient characteristics and the intrinsic quality of care delivered at the

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treating institution must be considered. For example, it may be less relevant whether a transhiatal or an Ivor Lewis esophagectomy was performed and may be more important to focus on patient selection and the quality of the hospital performing the operation. Therefore, the objectives of this study were (1) to evaluate the association of operative approach, conduit type, and patient-level factors on surgical outcomes after esophagectomy and (2) to assess the variation in risk-adjusted performance at 164 hospitals.

METHODS

DATA SOURCE AND PATIENT SELECTION

Data were obtained from the ACS NSQIP. Details about the ACS NSQIP's inclusion and exclusion criteria, case sampling, variables collected, and outcomes assessed have been described elsewhere.[8,9] In brief, the program collects standardized and reliable preoperative, intraoperative, and postoperative clinical data by trained and audited Surgical Clinical Reviewers.[10] Patients are followed up for 30 days after their index operation, and complications are captured irrespective of whether they occur during the initial hospital stay, after discharge, or during readmission to the same or an outside facility. The ACS NSQIP uses these data to provide risk-adjusted outcome comparisons to participating hospitals.

Patients undergoing esophagectomy were selected based on *Current Procedural Terminology* codes[11] (43107, 43108, 43112, 43113, 43116, 43117, 43118, 43123, and 43361). Patients were excluded from the analysis if the operation had been performed emergently (n=37) or if the patient was graded as American Society of Anesthesiologists (ASA) class V (n=5).

OPERATIVE APPROACH

Using *Current Procedural Terminology* codes, 4 groups were created based on the operative approach to evaluate potential differences in outcomes: (1) transhiatal, (2) Ivor Lewis, (3) 3-field, and (4) any approach with an intestinal conduit. The intestinal conduit group included the use of colon or small bowel interpositions.

PREOPERATIVE VARIABLES

The ACS NSQIP collects data about more than 130 preoperative, intraoperative, and postoperative variables. Patient demographic variables considered were age, sex, and race/ethnicity. Lifestyle factors considered were alcohol consumption and smoking status. General factors considered were preoperative dyspnea, American Society of Anesthesiologists class, body mass index, serum albumin level, preoperative functional status, and weight loss exceeding 10% within 6 months of surgery. Comorbidities included a history of ascites, hypertension, diabetes mellitus, disseminated cancer, congestive heart failure, peripheral vascular disease, previous cardiac event or intervention, and chronic obstructive pulmonary disease, as well as corticosteroid use and chemotherapy or radiotherapy use. Variable definitions have been described elsewhere.

OUTCOMES

Standard 30-day ACS NSQIP outcomes were assessed. To broadly evaluate postoperative complications, this study focused on the following 10 outcomes: pneumonia, renal failure, serious morbidity, all-cause mortality, sepsis or septic shock, overall surgical site infection, organ space surgical site infection, and return to the operating room for any indication, as well as prolonged mechanical ventilation exceeding 48 hours and reintubation. Serious morbidity was defined as the occurrence of at least 1 of the following complications: renal failure, reintubation, wound dehiscence, sepsis or septic shock, prolonged mechanical ventilation exceeding 48 hours, organ space surgical site infection, urinary tract infection, venous thromboembolism, deep surgical site infection, return to the operating room for any indication, or cardiac arrest or myocardial infarction. Patients were precluded from being categorized as experiencing postoperative pneumonia, prolonged mechanical ventilation exceeding 48 hours, reintubation, or surgical site infection if a related condition was present at the time of the index procedure.

STATISTICAL ANALYSIS

This study sought to evaluate predictors of postoperative complications, particularly the influence of operative approach, and to measure variation in hospital-level performance after esophagectomy. Predictors of postoperative complications were evaluated using generalized linear mixed models, with the hospital as the random effect. For each outcome assessed, in addition to operative approach, candidate predictor variables were selected for model inclusion if they had a univariate association with the outcome of interest at $P < .20$ or if considered clinically important. Model performance was evaluated using metrics of discrimination (C statistic), calibration (Hosmer-Lemeshow χ^2), and overall fit (Akaike information criterion) from standard logistic regression procedures.[12,13]

Next, hospital variation was measured by assessing unadjusted hospital-level (ie, hospital as the unit of analysis) complication rates and risk-adjusted hospital performance for all outcomes assessed in the study. Hospital performance was estimated using the hospital random effects method from the same generalized linear mixed models already described. This method optimally combines information from the specific hospital and the statistically estimated "average" hospital to get a best estimate of hospital performance in terms of an odds ratio (OR), the odds at the hospital vs the odds at the average hospital.[14-16] For each outcome, risk-adjusted variation was then measured by calculating the range in log-transformed hospital-specific OR point estimates, where the range is a measure of variation in hospital performance. For example, an OR range approaching 0.0 indicates minimal variation in performance, whereas an OR range of 1.0 indicates that hospital performance varied by 100%. Because of the small sample size, this study aimed only to assess variability among hospitals and not to specifically delineate hospital outlier status. The threshold for statistical significance was set at $P = .05$, and all P values were based on 2-sided tests. Statistical analysis was performed using commercially available software (SAS, version 9.3; SAS Institute Inc).

RESULTS

From the ACS NSQIP, 1738 patients were identified who underwent an esophagectomy at 164 hospitals from January 1, 2005, to December 31, 2010. Most patients underwent transhiatal esophagectomy (40.9%), followed by Ivor Lewis (28.6%), 3-field (20.8%), and intestinal conduit use (9.8%). The mean (SD) operative time was greatest for the 3-field approach (430.4 [124.2] minutes) relative to intestinal conduit use (414 [193.5] minutes), Ivor Lewis (361.8 [120.1] minutes), and transhiatal (303.0

Table 1. Characteristics of 1738 Patients Undergoing Esophagectomy at 164 ACS NSQIP Hospitals From 2005 to 2010[a]

Characteristic	No. (%) (N = 1738)
Female sex	363 (20.9)
American Society of Anesthesiologists class	
I or II	405 (23.3)
III	1218 (70.1)
IV	115 (6.6)
Preoperative functional status	
Independent	1701 (97.9)
Dependent	37 (2.1)
Weight loss >10% within 6 mo of surgery	355 (20.4)
Serum albumin level <3.0 g/dL	77 (5.9)
Body mass index (n = 1722)	
Underweight	72 (4.2)
Normal	551 (32.0)
Overweight	613 (35.6)
Obese	303 (17.6)
Morbidly obese	183 (10.6)
Cardiovascular	
Previous cardiac event or intervention	251 (14.4)
Hypertension	889 (51.2)
Peripheral vascular disease	42 (2.4)
Pulmonary	
Preoperative dyspnea	197 (11.3)
Chronic obstructive pulmonary disease	115 (6.6)
Preoperative sepsis or septic shock	41 (2.4)
Diabetes mellitus	300 (17.3)
Wound class	
Clean or clean contaminated	1666 (95.9)
Contaminated or dirty infected	72 (4.1)
Operative indication	
Cancer	1534 (88.3)
Other or unknown	204 (11.7)
Neoadjuvant chemotherapy or radiotherapy	533 (30.7)
Disseminated cancer	52 (3.0)
Operative approach	
Transhiatal	710 (40.9)
Ivor Lewis	497 (28.6)
3-Field	361 (20.8)
Intestinal conduit	170 (9.8)

Abbreviation: ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program.
SI conversion factor: To convert albumin level to grams per liter, multiply by 10.
[a] The median (interquartile range) age of patients was 63 (56-71) years.

[106.5] minutes) operative techniques. These and other patient characteristics are summarized in **Table 1**.

ASSOCIATION OF SURGICAL APPROACH WITH POSTOPERATIVE COMPLICATIONS

The influence of surgical approach on postoperative complications was assessed in aggregate for all the patients during the study period (**Table 2** and **Table 3**). Compared with the transhiatal approach, Ivor Lewis esophagectomy was not associated with an increased risk for postoperative complications on univariate or multivariable analysis. In contrast, on univariate and multivariable analyses, patients undergoing 3-field esophagectomy had increased likelihood of pulmonary complications, namely, postoperative pneumonia (20.8%

Table 2. Postoperative Complication Rates by Operative Approach in 1738 Patients Undergoing Esophagectomy at 164 ACS NSQIP Hospitals From 2005 to 2010

Postoperative Complication	Operative Approach, %			
	Transhiatal	Ivor Lewis	3-Field	Intestinal Conduit
30-Day mortality	2.5	4.0	2.5	7.1
Serious morbidity	41.8	44.9	42.9	50.0
Pneumonia	14.5	18.3	20.8	20.0
Prolonged ventilation >48 h	15.4	17.1	20.5	25.3
Reintubation	15.8	17.1	18.6	15.9
Overall SSI	20.7	15.1	19.1	21.2
Organ space SSI	6.1	7.2	5.3	6.5
Sepsis or septic shock	19.6	23.3	21.9	26.5
Renal failure	1.7	2.0	1.4	5.3
Return to the operating room for any indication	12.0	15.1	12.5	23.5

Abbreviations: ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program; SSI, surgical site infection.

vs 14.5%; adjusted OR, 1.88; 95% CI, 1.28-2.77) and prolonged mechanical ventilation exceeding 48 hours (20.5% vs 15.4%; adjusted OR, 1.68; 95% CI, 1.16-2.42) compared with the transhiatal approach.

On univariate analysis, the use of an intestinal conduit increased the likelihood of 30-day mortality, sepsis or septic shock, renal failure, prolonged mechanical ventilation exceeding 48 hours, and return to the operating room for any indication. After multivariable adjustment, 30-day mortality (7.1% vs 2.5%; adjusted OR, 2.65; 95% CI, 1.08-6.47), prolonged mechanical ventilation exceeding 48 hours (25.3% vs 15.4%; adjusted OR, 1.61; 95% CI, 1.01-2.54), and return to the operating room for any indication (23.5% vs 12.0%; adjusted OR, 1.85, 95% CI, 1.16-2.96) remained significant for the use of an intestinal conduit vs the transhiatal approach.

ASSOCIATION OF PATIENT FACTORS WITH POSTOPERATIVE COMPLICATIONS

Rates for complications varied widely across patient demographic and comorbidity categories (eTable; http://www.archsurg.com). For example, 30-day mortality ranged from a low of 0.6% among patients younger than 55 years to 10.8% among patients with dependent functional status. Serious morbidity ranged from a low of 33.8% among ASA class I or II patients to a high of 78.4% among patients with preoperative dependent functional status.

On multivariable analysis, patient characteristics independently associated with increased 30-day mortality were age between 55 and 69 years and 70 years or older (vs <55 years), ASA class III (vs class I or II), the presence of preoperative dyspnea, and dirty or infected wounds (vs clean or clean contaminated). Patient factors increasing the likelihood of serious morbidity were hypertension, diabetes mellitus, preoperative dyspnea, preoperative dependent functional status, and ASA class III or IV (vs class I or II) (**Table 4**).

Table 3. Unadjusted and Adjusted Postoperative Complication Rates by Operative Approach in 1738 Patients Undergoing Esophagectomy at 164 ACS NSQIP Hospitals From 2005 to 2010

	Operative Approach, OR (95% CI)			
Postoperative Complication	Transhiatal (n = 710)	Ivor Lewis (n = 497)	3-Field (n = 361)	Intestinal Conduit (n = 170)
30-Day mortality				
Unadjusted	1 [Reference]	1.61 (0.84-3.08)	0.98 (0.44-2.21)	2.92 (1.38-6.19)
Adjusted	1 [Reference]	1.35 (0.65-2.79)	1.17 (0.48-2.83)	2.65 (1.08-6.47)
Serious morbidity				
Unadjusted	1 [Reference]	1.13 (0.90-1.43)	1.05 (0.81-1.35)	1.39 (0.99-1.94)
Adjusted	1 [Reference]	1.03 (0.78-1.34)	1.17 (0.88-1.57)	1.21 (0.83-1.76)
Sepsis or septic shock				
Unadjusted	1 [Reference]	1.25 (0.95-1.65)	1.15 (0.84-1.57)	1.48 (1.00-2.18)
Adjusted	1 [Reference]	1.07 (0.76-1.50)	1.14 (0.80-1.64)	1.37 (0.87-2.16)
Overall SSI				
Unadjusted	1 [Reference]	0.68 (0.50-0.92)	0.91 (0.66-1.25)	1.03 (0.68-1.55)
Adjusted	1 [Reference]	0.60 (0.42-0.85)	0.92 (0.64-1.32)	1.05 (0.66-1.67)
Organ space SSI				
Unadjusted	1 [Reference]	1.21 (0.77-1.92)	0.86 (0.50-1.50)	1.07 (0.54-2.13)
Adjusted	1 [Reference]	0.96 (0.57-1.63)	0.90 (0.49-1.66)	1.00 (0.46-2.16)
Renal failure				
Unadjusted	1 [Reference]	1.19 (0.51-2.79)	0.82 (0.29-2.34)	3.25 (1.35-7.85)
Adjusted	1 [Reference]	0.92 (0.37-2.31)	0.88 (0.29-2.70)	2.59 (0.93-7.20)
Pneumonia				
Unadjusted	1 [Reference]	1.32 (0.97-1.79)	1.54 (1.11-2.15)	1.47 (0.96-2.27)
Adjusted	1 [Reference]	1.04 (0.72-1.50)	1.88 (1.28-2.77)	1.16 (0.70-1.90)
Prolonged ventilation >48 h				
Unadjusted	1 [Reference]	1.14 (0.83-1.55)	1.44 (1.03-1.97)	1.87 (1.25-2.80)
Adjusted	1 [Reference]	1.00 (0.71-1.42)	1.68 (1.16-2.42)	1.61 (1.01-2.54)
Reintubation				
Unadjusted	1 [Reference]	1.10 (0.81-1.50)	1.22 (0.87-1.70)	1.01 (0.64-1.59)
Adjusted	1 [Reference]	0.99 (0.70-1.40)	1.40 (0.97-2.03)	0.90 (0.55-1.49)
Return to the operating room for any indication				
Unadjusted	1 [Reference]	1.31 (0.94-1.83)	1.05 (0.71-1.54)	2.26 (1.48-3.45)
Adjusted	1 [Reference]	1.15 (0.80-1.66)	1.08 (0.72-1.64)	1.85 (1.16-2.96)

Abbreviations: ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program; OR, odds ratio; SSI, surgical site infection.

VARIATION IN HOSPITAL-LEVEL PERFORMANCE

Variation in hospital-level performance was assessed for all 10 outcomes (**Table 5**). The mean (SD) hospital-level rates were 4.9% (13.4%) for 30-day mortality and 43.8% (31.6%) for serious morbidity. Hospital-level ORs, which represent each hospital's performance compared with the average hospital, varied by 161% for 30-day mortality and by 84% for serious morbidity. Pulmonary complications also demonstrated marked variability among hospitals. For postoperative pneumonia, the mean (SD) hospital-level complication rate was 18.4% (22.8%), with hospital-level ORs varying by 237%. For prolonged mechanical ventilation exceeding 48 hours, the mean (SD) complication rate was 18.5% (25.1%), and hospital-level ORs varied by 107%. Finally, the mean (SD) reintubation rate was 17.0% (22.9%), and hospital-level odds ratios varied by 84%.

COMMENT

In the past decade, advances in surgical technique and a push toward regionalizing esophageal surgery to high-volume centers may have in part contributed to an apparent reduction in perioperative mortality[6]; however, the morbidity associated with this procedure remains substantial. The effect of operative approach on esophagectomy outcomes has been described,[5] but these relationships remain controversial and generally focus only on the transhiatal vs Ivor Lewis approach. Moreover, the relative importance of other factors (such as patient comorbidities and hospital quality) on outcomes is less clear. In the present study, after adjusting for confounding factors and accounting for the hierarchical nature of patient clustering within hospitals, only the 3-field operative approach and the use of an intestinal conduit were associated with significantly increased postoperative complications after esophagectomy. Notably, the Ivor Lewis approach did not seem to increase pulmonary complications. In addition, we demonstrate that patient selection remains paramount for morbidity and mortality and that risk-adjusted hospital performance varied widely.

ASSOCIATION OF OPERATIVE APPROACH WITH POSTOPERATIVE COMPLICATIONS

The debate about the optimal surgical technique in esophageal surgery has lingered for decades. For oncologic principles, transthoracic procedures permit a formal lymphadenectomy and may offer improved staging, as well as

Table 4. Predictors of 30-Day Mortality and Serious Morbidity in 1738 Patients Undergoing Esophagectomy at 164 ACS NSQIP Hospitals From 2005 to 2010

	30-Day Mortality, OR (95% CI)		Serious Morbidity, OR (95% CI)	
Characteristic	Unadjusted	Adjusted	Unadjusted	Adjusted
Age, y				
<55	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
55-69	7.15 (1.70-29.98)	6.89 (1.56-30.48)	1.23 (0.96-1.58)	1.06 (0.80-1.40)
≥70	9.10 (2.14-38.66)	9.56 (2.09-43.81)	1.25 (0.96-1.65)	1.03 (0.76-1.41)
Female sex	0.84 (0.46-1.55)	1.22 (0.59-2.50)	0.65 (0.51-0.81)	0.67 (0.52-0.87)
American Society of Anesthesiologists class				
I or II	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
III	4.02 (1.44-11.24)	3.18 (1.08-9.40)	1.63 (1.29-2.06)	1.36 (1.05-1.77)
IV	7.50 (2.22-25.36)	3.63 (0.91-14.58)	2.93 (1.92-4.49)	1.67 (1.02-2.73)
Preoperative functional status				
Independent	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Dependent	3.63 (1.24-10.60)	1.63 (0.39-6.79)	4.81 (2.19-10.58)	2.94 (1.21-7.11)
Weight loss >10% within 6 mo of surgery	1.75 (0.99-3.08)	1.64 (0.84-3.19)	1.17 (0.92-1.47)	1.08 (0.82-1.42)
Serum albumin level <3.0 g/dL	1.81 (0.63-5.22)	0.52 (0.13-2.11)	1.92 (1.20-3.08)	1.52 (0.90- 2.58)
Body mass index				
Underweight	2.29 (0.89-5.89)	2.18 (0.72-6.54)	1.70 (1.03-2.79)	1.42 (0.82- 2.41)
Normal	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Overweight	0.81 (0.43-1.52)	0.75 (0.37-1.52)	0.78 (0.61-0.98)	0.80 (0.62-1.03)
Obese	0.77 (0.35-1.71)	0.74 (0.30-1.81)	0.84 (0.63-1.12)	0.79 (0.58-1.09)
Morbidly obese	0.56 (0.19-1.67)	0.53 (0.16-1.79)	1.40 (1.00-1.96)	1.25 (0.86-1.80)
Cardiovascular				
Previous cardiac event or intervention	1.20 (0.60-2.41)	0.79 (0.36-1.74)	1.38 (1.06-1.81)	1.22 (0.90-1.65)
Hypertension	1.31 (0.77-2.21)	0.91 (0.49-1.69)	1.42 (1.17-1.72)	1.28 (1.02-1.60)
Peripheral vascular disease	2.25 (0.68-7.51)	1.66 (0.41-6.76)	1.74 (0.94-3.23)	1.28 (0.64-2.57)
Pulmonary				
Preoperative dyspnea	2.81 (1.53-5.15)	2.13 (1.07-4.27)	1.95 (1.44-2.63)	1.53 (1.09-2.15)
Chronic obstructive pulmonary disease	1.63 (0.69-3.88)	0.68 (0.24-1.93)	2.02 (1.38-2.98)	1.42 (0.91-2.20)
Preoperative sepsis or septic shock	3.29 (1.13-9.56)	1.44 (0.32-6.48)	2.84 (1.46-5.52)	1.81 (0.84-3.91)
Diabetes mellitus	1.99 (1.12-3.55)	1.87 (0.97-3.62)	1.55 (1.20-1.98)	1.36 (1.02-1.80)
Neoadjuvant chemotherapy or radiotherapy	0.70 (0.38-1.28)	0.67 (0.34-1.34)	0.74 (0.60-0.91)	0.73 (0.58-0.92)
Operative indication				
Cancer	1.84 (0.66-5.12)	4.39 (1.15-16.76)	0.61 (0.45-0.82)	0.69 (0.48-0.99)
Other or unknown	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Disseminated cancer	3.33 (1.27-8.72)	2.20 (0.67-7.21)	1.94 (1.10-3.40)	1.66 (0.88-3.12)
Wound class[a]	4.05 (1.84-8.90)	4.49 (1.70-11.86)	1.66 (1.02-2.68)	1.47 (0.85-2.53)
Operative approach				
Transhiatal	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Ivor Lewis	1.61 (0.84-3.07)	1.36 (0.66-2.80)	1.13 (0.90-1.43)	1.03 (0.78-1.34)
3-Field	0.98 (0.43-2.20)	1.17 (0.48-2.84)	1.05 (0.81-1.35)	1.17 (0.88-1.56)
Intestinal conduit	2.92 (1.38-6.19)	2.67 (1.10-6.50)	1.39 (0.99-1.94)	1.21 (0.83-1.76)

Abbreviations: ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program; OR, odds ratio.
SI conversion factor: To convert albumin level to grams per liter, multiply by 10.
[a]Contaminated or dirty infected vs clean or clean contaminated.

a potential therapeutic benefit. Nevertheless, these oncologic advantages are believed by some to be at the expense of worse short-term morbidity and mortality, and it remains controversial whether they influence long-term outcomes.[5,17] Furthermore, most investigations that focus on the comparative effectiveness of one operative approach over another are small, retrospective, based on administrative data, or are only of historical reference. Moreover, findings are often contradictory and generally focus only on the Ivor Lewis and transhiatal techniques.[5] Although these are the most common operations, the 3-field approach is routinely performed at certain centers in select patients.[18,19] In addition, patients in whom reconstruction cannot be performed with the preferred gastric conduit require an intestinal interposition, for which outcomes are even less well defined.

In the present study, which included 1738 patients at 164 ACS NSQIP hospitals, we evaluated 9 specific complications and a composite serious morbidity outcome. After adjusting for confounding variables, only intestinal conduit use was associated with increased 30-day mortality (OR, 2.65; 95% CI, 1.08-6.47). Rates for serious morbidity by operative approach ranged from 41.8% after the transhiatal approach to 50.0% after the use of an intestinal conduit, although differences were not statistically significant among any of the procedures. For pulmonary complications, only the 3-field approach and intestinal conduit use resulted in worse outcomes, specifically prolonged mechanical ventilation exceeding 48 hours (3-field approach and intestinal conduit use) and postoperative pneumonia (3-field approach only) compared with transhiatal esophagectomy. It is unclear from these

Table 5. Variation in Postoperative Complication Rates and Risk-Adjusted Performance in 1738 Patients Undergoing Esophagectomy at 164 ACS NSQIP Hospitals From 2005 to 2010

Postoperative Complication	Unadjusted Variation, Mean (SD)	Adjusted Variation, OR Range[a]
30-Day mortality	4.9 (13.4)	1.61
Serious morbidity	43.8 (31.6)	0.84
Pneumonia	18.4 (22.8)	2.37
Prolonged ventilation >48 h	18.5 (25.1)	1.07
Reintubation	17.0 (22.9)	0.84
Overall SSI	16.8 (21.3)	1.84
Organ space SSI	6.8 (15.2)	2.07
Sepsis or septic shock	21.2 (25.7)	2.51
Renal failure	1.8 (4.9)	0.92
Return to the operating room for any indication	16.0 (21.1)	1.02

Abbreviations: ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program; OR, odds ratio; SSI, surgical site infection.
[a]Based on log-transformed hospital OR.

data why the 3-field approach was associated with increased risk for pulmonary complications; however, this may be related to longer operative times and to an overall increased operative insult.

A 2011 meta-analysis by Boshier et al[5] of 52 studies comparing patients undergoing transhiatal vs transthoracic procedures highlights the inconsistencies among short-term outcomes in the current literature. Overall, they found that patients undergoing transthoracic esophagectomy had increased rates for mortality and pulmonary complications; however, on sensitivity analysis that included only randomized trials or studies since 2000, no major differences in these complication rates were noted. In a separate retrospective study specifically focused on surgical technique and complications, Bakhos et al[6] also found no statistically significant increased rates for mortality, pneumonia, or other major respiratory complications following Ivor Lewis esophagectomy. These evolving findings suggest that improvements in patient selection, operative technique, anesthesia, and postoperative care may mitigate some of the historically observed differences.

Comparative data about the 3-field approach or intestinal conduits are lacking because most investigations are small case series from specialized centers spanning many years. With respect to the 3-field approach, Lerut et al[18] described 192 patients and found a hospital mortality of 1.2%, an overall complication rate of 58.0%, and a pulmonary complication rate of 32.8%. In a separate study from a single center in Japan, Tachibana et al[20] reported a 30-day mortality rate of 2.1%, an overall complication rate of 80%, and a pulmonary complication rate of 30.5% associated with the 3-field approach. In our study, which included 361 esophagectomies performed using the 3-field approach, we found similar complication rates (30-day mortality of 2.5% and serious morbidity of 42.9%).

Few contemporary investigations are available that focus on the use of intestinal conduits. In one of the largest series on jejunal conduits,[7] which included 51 patients during a 10-year period from The University of Texas MD Anderson Cancer Center in Houston, a mortality rate of 0%, an overall morbidity rate of 65%, a respiratory failure rate of 21%, and a pneumonia rate of 16% were observed. In our multicenter study, the use of intestinal conduit interpositions was associated with a similar serious morbidity rate of 50.0% but with a substantially greater 30-day mortality rate of 7.1%. The 7.1% mortality is likely more representative of real-world outcomes following an intestinal interposition.

ASSOCIATION OF PATIENT FACTORS WITH POSTOPERATIVE COMPLICATIONS

Although the operative approach is an important consideration, patient characteristics may impart a greater influence on postoperative complications. To investigate the association of patient factors with outcomes, we focused on 30-day mortality and serious morbidity complications and found that patient characteristics were the strongest predictors of adverse events. For 30-day mortality, age 70 years or older increased risk 9.6 times, and ASA class III increased risk 3.2 times, whereas the only operative approach that significantly increased risk was intestinal conduit use. Similarly, for serious morbidity we demonstrated that preoperative dependent functional status increased risk 1.6 times and that ASA class IV increased risk 3.6 times, but operative approach did not significantly increase risk.

Few studies have focused on the relative importance of the operative approach and patient selection on short-term outcomes. Lagarde et al[4] developed a nomogram predicting complication severity in 663 patients undergoing transhiatal or Ivor Lewis esophagectomy during a 12-year period. They categorized complications into 3 groups (none, minor, or severe) and developed an ordinal logistic regression model to identify predictors of increasing complication severity. The results showed that significant predictors of adverse events were advanced age, electrocardiographic changes, Ivor Lewis esophagectomy, preoperative respiratory status, and history of stroke, transient ischemic attack, or myocardial infarction. The strongest predictors were history of stroke or transient ischemic attack (OR, 3.06; 95% CI, 1.33-7.05) and transthoracic approach (OR, 2.64; 95% CI, 1.91-3.66). Notably, the raw severe complication rates differed minimally between the Ivor Lewis (53%) and transhiatal (47%) approaches. Furthermore, this study did not delineate the specific operative approach used but indicated only whether a thoracic or an abdominal incision was performed.

VARIATION IN HOSPITAL-LEVEL PERFORMANCE

Finally, we sought to determine variation in hospital-level performance at 164 ACS NSQIP centers. We assessed variation by examining the range in hospital-specific ORs for all 10 outcomes. For all the outcomes assessed, hospital performance varied widely, from a low of 84% for serious morbidity to a high of 251% for sepsis or septic shock.

The implications of these findings are 2-fold. First, hospital variation in performance indicates a need for surgical quality improvement focused specifically on esophageal surgery. As such, the ACS NSQIP is able to provide hospitals with their risk-adjusted performance for this procedure. Second, given the wide variation in performance, the results of our study suggest that efforts should focus on improving hospital outcome assessment and internal quality improvement efforts. This process begins with obtaining high-quality, standardized, and reliable clinical data.[21] Although policy initiatives tend to emphasize surgical volume thresholds and regionalization, an important parallel process is to encourage hospital participation in clinically based, risk-adjusted outcome assessment programs that allow centers to benchmark their outcomes compared with other hospitals.

LIMITATIONS

This study should be considered in the context of certain limitations. First, as with all secondary data set analysis, the study was limited by the variables collected. For example, the operative approach was based on *Current Procedural Terminology* codes, and no code exists for a minimally invasive esophagectomy. In addition, we did not account for case complexity, such as whether the case was a reoperation. Nevertheless, in the new ACS NSQIP procedure-targeted platform, many esophagectomy-specific variables will be collected, including whether a minimally invasive operative approach was used. Second, as with most observational comparative studies, selection bias was undoubtedly present. It is unknown why patients were selected for certain procedures, but it is likely multifactorial, involving disease variables (eg, operative indication and location of tumor), patient factors (eg, comorbidities), and physician characteristics (eg, surgeon training and experience). Third, our study may not be powered to detect differences in outcomes by operative approach. Nevertheless, the sample size was appropriate to detect clinical meaningful differences. Fourth, this study represents outcomes at hospitals participating in the ACS NSQIP, and the results may not be generalizable to all the hospitals performing esophageal surgery. Specifically, the seemingly similar outcomes by operative approach may be more reflective of an overall high level of performance among the participating hospitals, which may mitigate potential differences. Nevertheless, the hospitals that participate in the ACS NSQIP perform most esophageal procedures in the United States.

In conclusion, in this study of 1738 patients undergoing esophageal resection, no significant differences were observed in short-term outcomes between the transhiatal vs Ivor Lewis surgical approaches. Thirty-day risk-adjusted outcomes varied widely at the hospital level, emphasizing that reductions in postoperative complication rates will likely result from expanding other aspects of hospital quality beyond a focus on specific technical maneuvers such as operative approach.

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