**Hypothesis:** Operative mortality rates for esophageal resection vary across hospital volume groups in a nationally representative sample of hospitals.

**Design:** Cross-sectional study of all adult patients in the Nationwide Inpatient Sample who underwent esophageal resection from 1995 through 1999 (N=3023). Operative mortality was determined for hospital volume quartiles (low, <3 per year; medium, 3-5 per year; high, 6-16 per year; very high, >16 per year). Multiple logistic regression of in-hospital mortality was used for case-mix adjusted analyses.

**Setting:** Hospitals performing at least 1 esophageal resection from 1995 through 1999 in the Nationwide Inpatient Sample.

**Patients:** Patients having esophageal resection from 1995 through 1999 in the Nationwide Inpatient Sample.

**Results:** Overall mortality was 8.2% and varied 3-fold from 11.8% to 3.7% across hospital volume groups (P<.001). In the case-mix–adjusted multivariate analysis, having surgery at a low-volume hospital (odds ratio, 2.9; 95% confidence interval, 1.7-4.9; P<.001) or medium-volume hospital (odds ratio, 2.4; 95% confidence interval, 1.4-4.3; P=.002) was associated with an increased risk of mortality compared with the reference group of very high–volume hospitals. The effect of volume on mortality was significant for both malignant and benign disease. Given the absolute risk difference of 8.1% between very high– and low-volume hospitals, only 12 patients would need to be referred to prevent 1 death after esophageal resection.

**Conclusions:** The operative mortality rate for esophageal resection varies across hospitals in the United States. To improve the quality of care and reduce operative mortality rates for patients in need of esophageal surgery, patients should either be referred to higher-volume hospitals, or quality improvement should be directed at lower-volume hospitals.

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**METHODS**

**DATA SOURCE**

Patient data were derived from 5 years of the Nationwide Inpatient Sample (NIS). This database is maintained by the Agency for Health Care

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From the Department of Surgery, University of Michigan Medical Center, Ann Arbor.
Policy and Research as part of the Healthcare Cost and Utilization Project. The NIS is a 20% sample of all hospital discharges in the United States, stratified by geographic region, hospital size, urban vs rural location, and teaching vs nonteaching to be representative of the United States. Any adult patient discharged from an NIS hospital from 1995 to 1999 with an ICD-9-CM primary procedure code for esophageal resection was included in the study. Patient demographic information (age, race, and sex), nature of admission (elective, urgent, or emergent), hospital mortality, length of stay (LOS), and primary and secondary ICD-9-CM diagnostic codes were obtained from the NIS database. Indication for surgery and comorbid diseases were determined using the secondary ICD-9-CM codes. The Romano modification of the Charlson comorbidity score was used to determine comorbid diseases from the ICD-9-CM codes.

**OUTCOME VARIABLES**

The primary outcome variable was operative mortality (in-hospital mortality). A secondary outcome variable used to represent relative resource utilization was prolonged LOS. Prolonged LOS was defined as greater than the 75th percentile of 20 days and was encoded as a dichotomous variable. Prolonged LOS was used rather than comparing the median LOS, because using the latter method would minimize the effect of outliers. In the setting of high-risk surgery, patients with prolonged LOS are generally those who encounter complications. These outliers are therefore important, and their impact should not be minimized.

**HOSPITAL VOLUME**

Each hospital included in the NIS has a unique hospital identification number that was used to calculate the number of esophageal resections performed for each year of the study period (1995-1999). Hospital volume thresholds were determined by dividing the patients into 4 approximately equal sized groups based on quartiles of volume. The number of procedures for each quartile are the following: low, fewer than 3 per year; medium, 3 to 5 per year; high, 6 to 16 per year; and very high, more than 16 per year.

**RESULTS**

A total of 3023 adult patients underwent esophageal resection in hospitals included in the NIS from 1995 through 1999. Each year, approximately 200 hospitals performed esophageal resection, with relatively consistent hospital volume profiles (Table 1). For example, during 1999, most hospitals were low-volume (138 hospitals [72%]) or medium-volume (31 hospitals [16%]) with a smaller proportion of high-volume (17 hospitals [9%]) and very high–volume (6 hospitals [3%]).

**HOSPITAL CHARACTERISTICS**

Patients were similar with respect to age and sex across hospital volume groups (Table 2). Patients having their operation at low-volume hospitals were more likely to be of nonwhite race (15% vs 11%) and have an urgent (17% vs 7%) or emergent (10% vs 6%) nature of admission compared with very high–volume hospitals (Table 2). With respect to comorbid diseases, patients at lower-volume hospitals had a higher incidence of chronic obstructive pulmonary disease (15% vs 6%) and diabetes mellitus (11% vs 7%). Patients were generally similar...
across volume groups with respect to other demographics and comorbid diseases (Table 2).

**OPERATIVE MORTALITY**

The overall operative mortality for esophageal resection in NIS hospitals from 1995 to 1999 was 8.2%. The operative mortality rate varied more than 3-fold across hospital volume groups (11.8% to 3.7%; \( P \leq .001 \)), with a stepwise decrease in mortality with increasing volume (Figure). The variation across hospital volume groups was apparent for both benign and malignant indications for esophageal resection (Table 3). Given the absolute risk difference of 8.1% between very high- and low-volume hospitals, only 12 patients would need to be referred to prevent 1 death after esophageal resection.

The urgency of admission was also a significant predictor of mortality, with an increase across elective (6.6%), urgent (13.8%), and emergent (17.3%) categories (\( P < .001 \)). When considering only elective admissions (\( n = 2093 \)), there remains a strong relationship between increasing volume and operative mortality (Table 3). Older age was associated with a higher operative mortality and varied 3-fold from 5.3% to 15.6% across patient age groups (\( P < .005 \)) (Table 3). Other factors associated with mortality in the univariate analysis included female sex (\( P = .004 \)), nonwhite race (\( P = .02 \)), extent of resection (\( P < .005 \)), history of chronic obstructive pulmonary disease (\( P = .08 \)), chronic liver disease (\( P < .001 \)), and chronic renal insufficiency (\( P = .002 \)).

In the multivariate analysis of operative mortality, having surgery at a low-volume hospital (odds ratio, [OR], 2.9; 95% confidence interval [95% CI], 1.7-4.9; \( P < .001 \)) or a medium-volume hospital (OR, 2.4; 95% CI, 1.4-4.3; \( P = .002 \)) was associated with an increased risk of mortality compared with a very high-volume hospital (Table 4). Other significant variables in the multivariate analysis included age of 71 to 80 years (OR, 2.5; 95% CI, 1.6-2.5; \( P = .001 \), age greater than 80 years (OR, 3.2; 95% CI, 1.6-6.1; \( P = .001 \)) urgent admission (OR, 1.9; 95% CI, 1.3-3.0; \( P = .003 \)), emergent admission (OR, 2.3; 95% CI, 1.4-3.7; \( P = .001 \)), and nonwhite race (OR, 1.9 95% CI, 1.2-3.0; \( P = .003 \)).

**LENGTH OF STAY**

The overall median LOS was 13 days (interquartile range, 10-20 days). Any patient who had an LOS greater than the 75th percentile of 20 days was considered to have a prolonged LOS. Patients having surgery at very high-volume hospitals were less likely to have prolonged LOS compared with low-volume hospitals (20% vs 28%; \( P < .001 \)). Nature of admission was a significant univariate predictor of prolonged LOS, with 21% for elective, 33% for urgent, and 50% for emergent admissions (\( P < .001 \)). Other factors associated with prolonged LOS include increasing age (\( P < .001 \)), nonwhite race (\( P < .001 \)), chronic obstructive pulmonary disease (\( P < .001 \)), malignant indication for surgery (\( P = .02 \)), and history of chronic renal insufficiency (\( P < .001 \)).

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**Table 3. Variation in Operative Mortality Rates Across Hospital Volume Quartiles for Patient Subgroups Undergoing Esophageal Resection**

<table>
<thead>
<tr>
<th>Annual Hospital Volume</th>
<th>Nature of admission</th>
<th>Risk of In-Hospital Mortality, OR (95% CI)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>(&lt;3)</td>
<td>(3-5)</td>
<td>(6-16)</td>
</tr>
<tr>
<td>Elective</td>
<td>6.7</td>
<td>7.3</td>
<td>9.7</td>
</tr>
<tr>
<td>Urgent or emergent</td>
<td>15.2</td>
<td>21</td>
<td>11.4</td>
</tr>
</tbody>
</table>

**Table 4. Independent Variables Associated With In-Hospital Mortality After Esophageal Resection in the United States From 1995 Through 1999**

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Risk of In-Hospital Mortality, OR (95% CI)</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium volume*</td>
<td>2.4 (1.4-4.3)</td>
<td>.002</td>
</tr>
<tr>
<td>Low volume*</td>
<td>2.9 (1.7-4.9)</td>
<td>(&lt;.001)</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-69</td>
<td>1.6 (1.0-2.5)</td>
<td>.04</td>
</tr>
<tr>
<td>70-79</td>
<td>2.5 (1.8-2.9)</td>
<td>(&lt;.001)</td>
</tr>
<tr>
<td>80†</td>
<td>3.2 (1.6-6.1)</td>
<td>.001</td>
</tr>
<tr>
<td>Urgent admission‡</td>
<td>1.9 (1.3-3.0)</td>
<td>.003</td>
</tr>
<tr>
<td>Emergent admission‡</td>
<td>2.3 (1.4-3.7)</td>
<td>.001</td>
</tr>
<tr>
<td>Nonwhite</td>
<td>1.9 (1.2-3.0)</td>
<td>.003</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; OR, odds ratio.

*The increased risk at medium- and low-volume hospitals is relative to very high-volume hospitals.
†Each age category is relative to the lowest age group (\(<60\)).
‡Urgent and emergent admissions are relative to elective admission.
In the multivariate analysis of prolonged LOS, having surgery at a low-volume hospital (OR, 1.5; 95% CI, 1.1-2.0; P = .01) or a medium-volume hospital (OR, 1.4; 95% CI, 1.0-1.9; P = .03) was associated with an increased risk of prolonged LOS compared with a very high-volume hospital. Independent variables associated with prolonged LOS in the multivariate analysis include ages 61 to 70 years (OR 1.4; 95% CI, 1.1-1.8; P = .01), 71 to 80 years (OR, 1.5; 95% CI, 1.1-2.0; P = .004), older than 80 years (OR, 1.7; 95% CI, 1.0-2.7; P = .03), urgent admission (OR, 2.0; 95% CI, 1.5-2.7; P < .001), emergent admission (OR, 3.6; 95% CI, 2.6-5.0; P < .001), nonwhite race (OR, 1.8; 95% CI, 1.4-2.3; P < .001), and chronic obstructive pulmonary disease (OR, 1.5; 95% CI, 1.1-2.0; P = .007).

In recent years, health care consumers, providers, and policy-makers have become increasingly concerned with the quality of health care delivered in US hospitals. For many surgical procedures, outcomes are not uniform across hospitals. Variation in patient outcomes, particularly operative mortality rates, has been shown to relate to hospital volume. The current study documents a 3-fold variation in risk-adjusted operative mortality across a representative sample of US hospitals. Such discrepancy in outcomes across hospitals should not be ignored. Two strategies exist for reducing the variation in mortality after complex surgical procedures. The first is to study the structure and process variables at high-volume hospitals. The second is to study the structure and process variables at high-volume hospitals and use these to guide quality improvement at lower-volume hospitals.

The previous statewide investigations of the effect of volume on outcome for esophageal resection have all demonstrated significantly lower mortality rates at higher-volume hospitals, but the magnitude of the effect varies among reports. Dimick et al described the outcomes for esophageal resection for 1136 patients undergoing surgery in Maryland from 1984 through 1999. The mortality rates for the current study period were 0.6% at high-volume hospitals compared with 13.5% and 12.1% (P < .001) at medium- and low-volume hospitals, respectively. Overall, in the case-mix adjusted multivariate analysis, there was a 5-fold reduction in mortality at high-volume hospitals (OR, 0.21; 95% CI, 0.10-0.42; P < .001).

In a similar recent report, Kuo and colleagues used data from the Massachusetts Health Data Consortium from 1992 through 2000 to investigate the effect of hospital volume on outcomes for 1193 patients undergoing esophageal resection. They demonstrated a 3.7-fold increase in mortality at low-volume hospitals relative to high-volume hospitals, which persisted after case-mix adjustment (9.2% vs 2.5%; P < .001). Maryland and Massachusetts are not representative states, since they both have high-quality providers that perform a large proportion of the states’ high-risk surgical procedures. As such, relying on studies from these states would overestimate the effect of volume on outcome after esophageal resection. The present study demonstrates that, although volume is significantly associated with outcome, the magnitude of the volume-outcome effect for the entire United States is not as large as in states with these national referral centers.

Two other recent reports using subsets of the Medicare database provide additional evidence of the volume-outcome effect for esophagectomy. In a comparison of national cancer centers with a sample of community hospitals, Swisher and colleagues reported a significant difference in mortality rate between high-volume hospitals (3.0%) and low-volume hospitals (12.2%) for 340 patients in the Health Care Utilization Project. In a subset of the national Medicare database linked to the Surveillance, Epidemiology, and End Results database, Begg and colleagues showed a mortality rate of 17.3% at low-volume hospitals compared with 3.4% at high-volume hospitals (P < .001). Studies including only patients older than 65 years are likely to overestimate the effect of volume on outcome for esophageal resection, given the strong relationship between mortality and age.

Hospital volume is a complex variable, likely representing many aspects of the health care system. The quality of health care can be studied according to the structure, process, or outcome of a hospital-patient encounter. Structure represents the organization of health care systems in which care is delivered; process is what the health care system does to and for the patient; and outcome is to what extent the process allows the patient to achieve a desired health status. With respect to the volume-outcome relationship, hospital volume is an example of structure. Other structural variables that may contribute to the volume-outcome relationship for esophagectomy include intensive care unit staffing of physicians and nurses. Patients having surgery at hospitals with daily rounds by an intensive care unit physician—and intensive care unit nurse—to patient ratios of no more than 1:2 have a lower incidence of postoperative complications and decreased resource use. Further, this effect was independent of hospital volume, which was the most important predictor of in-hospital mortality. Individual surgeon volume and surgical subspecialty are other structural variables that may be related to outcomes and contribute to the hospital volume-outcome effect. Very little information exists regarding health care processes that differ between high- and low-volume hospitals. Future studies on the structure and process of care at high- and low-volume hospitals are needed.

Hospital volume is only a surrogate for the quality of health care. An alternative to selective referral would be to prospectively measure risk-adjusted outcomes and use these as a tool to compare and improve the quality of care across medical centers. Several regional and national quality improvement initiatives have been successful in improving outcomes for cardiac surgery in New York State and Northern New England. Additionally, morbidity and mortality for noncardiac surgery have declined significantly in Veterans Affairs hospitals as a result of the National Surgical Quality Improvement Project. These initiatives have improved quality by identifying hospitals with low risk-adjusted mortality rates and studying the processes of care that lead to superior outcomes at these hospitals. These practices are then shared with other medical centers to improve quality in the region of study.

For example, the primary focus of the National Surgical Quality Improvement Project is to provide the sur-
geons at each Veterans Affairs hospital with reliable outcomes data that can be used for benchmarking and quality improvement. Such efforts are carried out using the following tools: (1) feedback to each participating hospital regarding the hospital’s ratio of observed to expected outcomes relative to other hospitals; (2) periodic assessment of the performance of high and low outlier institutions; (3) provision of self-assessment tools to help surgical leaders identify quality problems; (4) structured site visits to ensure accurate data collection; and (5) identification and dissemination of “best practices” (eg, processes of care that lead to superior outcomes). 31

The utility of such quality improvement efforts for esophageal resection depends on whether improvement in the overall delivery of surgical services will carry over to specific procedures. Few operations are performed frequently enough to obtain statistical precision in determining procedure-specific morbidity and mortality rates. This is particularly so for esophageal resection, with some hospitals only performing a few operations per year. In this setting, outcomes measures are of little use in quality improvement for a single procedure. Future studies should determine whether summary quality measures (eg, hospital-level quality determinations) also identify hospitals with superior outcomes for specific procedures.

Using the NIS will yield a generalizable estimate of the volume-outcome effect. However, this database comprises administrative datasets from several different states and is subject to certain limitations. Specifically, the ability to adjust for differing severity of illness and comorbidity disease is limited. In the present study, the case-mix adjustment included demographics (age, sex, and race), nature of admission (elective, urgent, or emergent), primary diagnosis, extent of resection, and several comorbidity diseases. There is no doubt that using a clinical database with more clinical and physiologic variables would provide for more robust risk adjustment. The profound effect of volume on outcome, however, is unlikely to be affected significantly by such adjustment. Further, there currently does not exist a nationally representative clinical database for general thoracic surgical procedures.

Our study demonstrates that the operative mortality rate for esophageal resection varies across hospitals in the United States. Some of the variation is related to the hospitals’ experience with the operation, with increasing volume associated with decreased mortality rates. To improve the quality of care for patients in need of esophageal surgery, patients should either be referred to higher-volume hospitals or quality improvement should be directed at lower-volume hospitals.

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