Hypothesis: Complex operations performed in teaching hospitals have similar outcomes as those performed in nonteaching hospitals.

Design: Observational cohort study with clinical patient data obtained from the Nationwide Inpatient Sample. The Nationwide Inpatient Sample data were linked to the American Hospital Association hospital survey data for 1997 to determine hospital characteristics. Hospitals were considered high volume if they performed more than the median (50th percentile) number of procedures per year.


Patients: Individuals undergoing esophageal resection (n=1247), hepatic resection (n=2073), or pancreatic resection (n=3337) in Nationwide Inpatient Sample hospitals during 1996 and 1997 were included.

Main Outcomes Measures: Unadjusted and adjusted in-hospital mortality and prolonged length of stay (>75th percentile).

Results: None of the procedures had higher operative mortality rates at teaching hospitals. In unadjusted analyses, pancreatic resection (4.0% vs 8.8%; P<.001), hepatic resection (5.3% vs 8.0%; P=.03), and esophageal resection (7.7% vs 10.2%; P=.10) had lower operative mortality rates at teaching compared with nonteaching hospitals. However, after adjusting for hospital volume in the multivariate analysis, hospital teaching status was no longer a predictor of operative mortality.

Conclusions: Teaching hospitals have lower operative mortality rates for complex surgical procedures. However, the lower mortality rates at teaching hospitals can be explained by higher procedural volume.

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Methods

DATA SOURCE

Patient data were derived from 2 years (1996 and 1997) of a nationally representative administrative database, the Nationwide Inpatient Sample (NIS). The NIS is maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project. The NIS is a 20% representative sample of all hospital discharges in the United States, stratified by geographic region, hospital size, urban vs rural location, and teaching vs nonteaching status.


From the Department of Surgery, University of Michigan Medical Center, Ann Arbor.
Table 1. Characteristics of Patients Undergoing Pancreatic, Hepatic, or Esophageal Resection in a Representative Sample of US Hospitals During 1996 and 1997*

<table>
<thead>
<tr>
<th>Type of Resection</th>
<th>Pancreatic (n = 3337)</th>
<th>Hepatic (n = 2068)</th>
<th>Esophageal (n = 1234)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic</strong></td>
<td><strong>Median</strong></td>
<td><strong>Median</strong></td>
<td><strong>Median</strong></td>
</tr>
<tr>
<td>Age, mean ± SD, y</td>
<td>61 ± 15</td>
<td>57 ± 16</td>
<td>63 ± 12</td>
</tr>
<tr>
<td>Female sex</td>
<td>1658 (49.7)</td>
<td>1080 (52.2)</td>
<td>273 (22.1)</td>
</tr>
<tr>
<td>Nonwhite race</td>
<td>450 (13.5)</td>
<td>354 (17.1)</td>
<td>127 (10.3)</td>
</tr>
<tr>
<td>Urgent admission</td>
<td>560 (16.8)</td>
<td>174 (8.4)</td>
<td>143 (11.6)</td>
</tr>
<tr>
<td>Emergency admission</td>
<td>442 (13.2)</td>
<td>226 (10.9)</td>
<td>100 (8.1)</td>
</tr>
<tr>
<td>No. of comorbid diseases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>829 (24.8)</td>
<td>458 (22.1)</td>
<td>182 (14.7)</td>
</tr>
<tr>
<td>1</td>
<td>883 (26.5)</td>
<td>848 (41.0)</td>
<td>448 (36.3)</td>
</tr>
<tr>
<td>2</td>
<td>868 (26.0)</td>
<td>537 (26.0)</td>
<td>410 (33.2)</td>
</tr>
<tr>
<td>≥3</td>
<td>757 (22.7)</td>
<td>225 (10.9)</td>
<td>194 (15.7)</td>
</tr>
<tr>
<td><strong>Median annual income, $</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-24 999</td>
<td>870 (27.6)</td>
<td>500 (25.8)</td>
<td>354 (30.7)</td>
</tr>
<tr>
<td>25 000-34 999</td>
<td>649 (20.6)</td>
<td>375 (19.3)</td>
<td>282 (24.5)</td>
</tr>
<tr>
<td>35 000-44 999</td>
<td>504 (16.0)</td>
<td>320 (16.5)</td>
<td>183 (15.9)</td>
</tr>
<tr>
<td>≥45 000</td>
<td>1125 (35.7)</td>
<td>743 (38.3)</td>
<td>333 (28.9)</td>
</tr>
<tr>
<td><strong>Type of insurance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicare</td>
<td>1564 (49.2)</td>
<td>762 (38.6)</td>
<td>575 (48.3)</td>
</tr>
<tr>
<td>Medicaid</td>
<td>186 (5.9)</td>
<td>108 (5.5)</td>
<td>106 (8.9)</td>
</tr>
<tr>
<td>Private insurance</td>
<td>1340 (42.2)</td>
<td>1038 (52.5)</td>
<td>494 (41.5)</td>
</tr>
<tr>
<td>No insurance</td>
<td>89 (2.8)</td>
<td>67 (3.4)</td>
<td>16 (1.3)</td>
</tr>
</tbody>
</table>

*Data are given as number (percentage) of each group unless otherwise indicated.

surgical procedures was included. The 3 procedures included esophageal resection (ICD-9-CM codes 4240-4242), pancreatic resection (ICD-9-CM codes 527, 5251-5253, 5259, and 5526), and hepatic resection (ICD-9-CM codes 503 and 5022). Patient demographic information (age, sex, and race), nature of the admission (elective, urgent, or emergency), in-hospital mortality, length of stay (LOS), and primary and secondary ICD-9-CM diagnostic codes were obtained from the NIS database.

HOSPITAL TEACHING STATUS

Data from the American Hospital Association’s annual survey of hospitals were linked to the clinical information from the NIS using the American Hospital Association hospital identification number. The American Hospital Association conducts an annual survey of hospitals to create a comprehensive data set of health care providers. The database contains hospital-specific data items for more than 6200 hospitals and health care systems, including more than 600 data fields covering organizational structure, personnel, hospital facilities and services, and financial performance. In the American Hospital Association data set, information regarding the presence of a residency training program, affiliation with a medical school, and membership in the Council of Teaching Hospitals is available. For the primary analysis, membership in the Council of Teaching Hospitals was used to differentiate teaching from nonteaching hospitals. To test the importance of the definition of teaching hospitals, sensitivity analyses were performed using alternate definitions based on either the presence of an American Council of Graduate Medical Education–approved residency program or affiliation with a medical school.

HOSPITAL VOLUME

In addition to teaching status, hospitals were also stratified by annual hospital procedural volume for each of the complex procedures. Each hospital included in the NIS has a unique hospital identification number that was used to calculate the number of complex surgical procedures performed for each year of the study period, 1996 and 1997. Hospitals were considered high volume if they performed more than the median (50th percentile) number of procedures per year for each type of operation. The volume thresholds for the 3 procedures were as follows: esophageal resection, greater than 6 per year; pancreatic resection, greater than 9 per year; and hepatic resection, greater than 10 per year.

OUTCOME VARIABLES

The primary outcome variable was operative mortality (in-hospital mortality). A secondary outcome variable used to represent relative resource use was prolonged LOS. Prolonged LOS was considered as any patient with an LOS greater than the 75th percentile, 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 a prolonged LOS are generally those who encounter complications; these outliers are, therefore, important and their impact should not be minimized.

STATISTICAL ANALYSIS

Univariate analyses were performed using the χ² test, the t test, and the Wilcoxon rank sum test where appropriate. Multiple logistic regression was used for the risk-adjusted multivariate analysis for operative mortality and prolonged LOS. Independent variables used for risk adjustment included demographic data (age, sex, and race), indication for surgery, extent of resection, admission type (elective, urgent, or emergency), and comorbid diseases. The Romano modification of the Charlson comorbidity score was used to determine comorbid diseases from the ICD-9-CM codes. Independent variables with P<.10 in the univariate analysis were included in the multivariate analysis. For each surgical procedure, 2 separate multiple logistic regression models of mortality were created. In the first multivariate model, the impact of hospital teaching status was adjusted for all significant patient characteristics. In the second multivariate model, adjustment was made for patient characteristics and annual hospital volume. All statistical analyses were performed using Stata 7.0 (Stata Corp, College Station, Tex). P<.05 was considered significant in all final analyses.

RESULTS

PATIENT CHARACTERISTICS

During the 2-year study period, there were 6685 adult patients undergoing 1 of the 3 complex surgical procedures. Nearly half underwent a pancreatic resection (n=3337), and the remaining underwent either a hepatic resection (n=2068) or an esophageal resection (n=1234) (Table 1). Patients undergoing different procedures were generally similar with respect to age, proportion of nonwhite race, number of chronic diseases, and type of insurance (Table 1). Patients undergoing esophageal resection were less likely to be female compared with those undergoing pancreatic and hepatic resections. In general, patients were more likely to undergo an urgent or emergency pancreatic resection when compared with other surgical procedures (Table 1).
The overall mortality was 6.4% for pancreatic resection, 6.0% for hepatic resection, and 8.7% for esophageal resection (Table 4). In unadjusted analyses, pancreatic resection (4.0% vs 8.8%; P < .001) and hepatic resection (5.3% vs 8.0%; P = .03) had statistically significant lower mortality rates at teaching compared with nonteaching hospitals. Esophageal resection (7.7% vs 10.2%; P = .10) had a trend toward a lower operative mortality at teaching hospitals in the unadjusted analysis.

In the first multivariate analysis adjusting for significant patient characteristics, undergoing surgery at a nonteaching hospital predicted increased mortality for pancreatic and esophageal resections (Table 4). Hepatic resection at nonteaching hospitals was no longer predictive of increased mortality after accounting for patient characteristics. In the second multivariate analysis adjusting for hospital volume, teaching status was no longer a predictor of operative mortality for any of the 3 complex surgical procedures (Table 4).

**PROLONGED LOS**

The median (interquartile range) LOS was 13 (6-20) days for pancreatic resection, 7 (5-10) days for hepatic resection, and 13 (10-20) days for esophageal resection. The overall rates for prolonged LOS were 23.8% for pancreatic resection, 23.7% for hepatic resection, and 24.7% for esophageal resection. The unadjusted rates in nonteaching hospitals were 28.5%, 26.7%, and 23.1%, respectively; and in teaching hospitals, 22.7%, 21.5%, and 26.5%, respectively. In unadjusted analyses, patients who underwent an operation at nonteaching hospitals were 30%
more likely to have a prolonged LOS for pancreatic and hepatic resections (Table 4). After adjusting for patient characteristics, there were no differences in prolonged LOS between teaching and nonteaching hospitals. However, after adjusting for hospital volume, undergoing an esophageal resection at nonteaching hospitals was associated with a reduction in the risk of a prolonged LOS (Table 4).

**COMMENT**

Outcomes of complex surgery are not uniform across medical centers. The present study demonstrates that operative mortality and prolonged LOS vary according to certain hospital characteristics. For the 3 complex general surgical procedures included in the sample, teaching hospitals have superior outcomes when compared with nonteaching hospitals. Furthermore, the differences in outcomes can be attributed to the higher volumes of complex surgery performed at teaching hospitals. More important, there is not an increased risk of adverse outcomes at teaching hospitals, demonstrating that undergoing surgery at teaching hospitals is safe and perhaps, because of the increased volume at these centers, more safe than at nonteaching hospitals.

Previous investigations on the quality of care at teaching vs nonteaching hospitals, in general, have shown that teaching hospitals have higher-quality care compared with nonteaching hospitals. Aymanian and Weisberg reviewed 20 observational studies conducted to determine differences in the quality of care related to hospital teaching status. These researchers concluded that, in studies using detailed clinical risk adjustment and process and outcome measures of quality, teaching hospitals had superior outcomes vs nonteaching hospitals for several common medical conditions. Most of these previous studies, however, have focused on common medical conditions, such as acute myocardial infarction, congestive heart failure, and pneumonia. For example, one study on the quality of care after acute myocardial infarction demonstrated that patients treated at teaching hospitals had a lower risk of mortality, which was, in part, because of the more frequent administration of aspirin and β-blockers at teaching compared with nonteaching hospitals. This study was particularly useful because certain processes of care (appropriate use of medications of known benefit) that account for some of the variation in outcomes between teaching and nonteaching hospitals were identified.

For the procedures in the present study, the improved outcomes at teaching hospitals were largely because of the high hospital volume performed at those centers. The relationship between hospital volume and mortality is well documented. The effect of hospital volume on outcomes is different depending on the procedure, with larger reductions in mortality at high-volume centers for complex gastrointestinal procedures. The 3 procedures in our study have had large volume-outcome effects compared with other procedures. Little is known about the processes of care that differ between high- and low-volume centers that contribute to the large differences in clinically important outcomes.

It is likely that individual physician variables (surgeon volume and advanced training) and system-level variables (intensive care unit staffing, availability of diagnostic technology, and other resources) account for differences in outcomes related to hospital volume. Another potential structural marker for the quality of care is being an ACS cancer center. In the present study, 82% to 86% of the hospitals were ACS-certified cancer centers, but only 50% were high volume. The ACS cancer center accreditation is based on professional leadership, treatment resources (eg, on-site radiation therapy and nurse managers), community outreach, data registry and research, and quality improvement activities. The ACS accreditation does not include volume standards, which explains the apparent disconnect between the number of high-volume centers and the proportion of hospitals that are ACS cancer centers. Further study is needed to determine the relative importance of other structure and process variables in contributing to and accounting for the volume-outcome effect for surgical procedures.

One finding from the present study that warrants discussion is the lower frequency of prolonged LOS at nonteaching hospitals for esophageal resection. This finding is counterintuitive given the presumed higher (or at least equivalent) quality of care at teaching hospitals. In addition, this finding is in contrast to those for the other 2 procedures (pancreatic and hepatic resection), which showed no association after adjusting for volume. The reason for this finding is not clear, and it is impossible to determine if the difference is because of a true difference in the quality of care or if it is a spurious finding. Direct determination of the reason why nonteaching hospitals have a lower LOS would require medical record review with either explicit or implicit quality review.

Most previous studies investigating the effect of hospital teaching status on outcomes rely on either medical record review or, similar to the present study, large administrative databases. Abstracting data from the medical record provides more accurate clinical data and the opportunity to relate certain processes of care to outcomes through either explicit or implicit quality review. However, these types of data are expensive to obtain compared with using an administrative database. Furthermore, large administrative data sets, such as the NIS used for the present study, can be taken from a nationally representative sample of hospitals, and the results can be extrapolated to the entire United States. Other limitations of using administrative databases include the limited information on physiologic and clinical variables. There may be additional patient differences (residual confounding) between teaching and nonteaching hospitals that could affect the relationship between outcomes, teaching status, and hospital volume.

The present study demonstrates that important clinical outcomes of complex surgery vary among hospitals with different organizational structures. Specifically, teaching hospitals have lower operative mortality rates for pancreatic, hepatic, and esophageal resections compared with nonteaching hospitals, but these differences can be attributed to higher volume at teaching hospitals. Further
studies should concentrate on the structure and process variables, other than volume, that contribute to variation in outcomes between hospitals.

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Corresponding author: Justin B. Dimick, MD, Department of Surgery, University of Michigan Medical Center, 1500 E Medical Center Dr, Taubman Center 2210, Ann Arbor, MI 48109-0329 (e-mail: jdimick@umich.edu).

REFERENCES