RESEARCH LETTER

Does the Effect of Surgical Volume on Outcomes Diminish Over Time?

Many studies have found that high-volume hospitals have improved surgical outcomes.1,2 However, as surgical techniques become more commonly used, knowledge becomes disseminated over time. We hypothesize that with the diffusion of knowledge of surgical techniques, high-volume hospitals have a diminished comparative advantage compared with low-volume hospitals over time.

Methods | A retrospective review of the Nationwide Inpatient Sample from 1998 to 2010 was performed. The Nationwide Inpatient Sample is the largest all-payer inpatient database in the United States, containing data from an approximately 20% stratified sample of all US community hospitals.3

All patients with one of the following procedures identified by International Classification of Diseases, Ninth Revision procedure codes were included: aortic valve replacement (AVR), abdominal aortic aneurysm (AAA) repair, pancreatic resection, and esophagectomy. These surgical procedures were selected because of the presence of the Leapfrog Group quality standards.4 Patients younger than 18 years of age or patients with more than 1 procedure of interest during the same hospitalization were excluded.

Hospital volume per year was calculated by adding the number of patients who underwent each procedure. Hospitals were considered to be “high-volume” hospitals with regard to each procedure if they met the following case-loads: 120 or more AVR cases, 50 or more AAA repair cases, 11 or more pancreatic resection cases, and 13 or more esophagectomy cases.5 This was calculated for each year. Thus, hospitals may have been considered high-volume hospitals one year but low-volume hospitals another year, depending on the caseload.

Using logistic regression and adjusting for age, race, female sex, Charlson comorbidity index, and teaching hospital status, we found odds ratios of inpatient mortality by comparing patients at high-volume hospitals with those at low-volume hospitals, by procedure. Separate analyses were performed for each 2-year interval in the study period to observe changing odds ratios over time. The Charlson comorbidity index is a measure of comorbidities based on the presence or absence of a number of diagnoses for the patient and is combined in a weighted formula.6

Statistical analysis was performed using the Stata 64-bit special edition, version 11.2 (StataCorp). A P value of less than .05 was considered to be statistically significant.

Results | A total of 361 686 patients were included (Table). Most patients underwent an AAA repair (44.1%) or an AVR (44.0%), whereas a minority of patients underwent an esophagectomy (6.1%) or a pancreatic resection (5.9%). A majority of patients (62.6%) received care at a teaching hospital. Around half (47.3%) of all patients received care at a high-volume hospital (designated as high volume for that particular procedure). Patients who underwent a pancreatic resection were more likely to receive care at both a teaching hospital (80.4%) and a high-volume hospital (62.9%). The

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (N = 361 686)</th>
<th>AAA Repair (n = 159 333 [44.1%])</th>
<th>AVR (n = 159 122 [44.0%])</th>
<th>Esophagectomy (n = 22 057 [6.1%])</th>
<th>Pancreatic Resection (n = 21 174 [5.9%])</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>68.3 (12.2)</td>
<td>69.8 (10.4)</td>
<td>68.2 (13.3)</td>
<td>63.3 (12.2)</td>
<td>62.5 (13.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female sex, No. (%)</td>
<td>119 878 (33.1)</td>
<td>42 878 (26.9)</td>
<td>60 965 (38.3)</td>
<td>5882 (26.7)</td>
<td>10 153 (48.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Teaching hospital, a No. (%)</td>
<td>255 713 (62.6)</td>
<td>87 842 (55.3)</td>
<td>105 161 (66.3)</td>
<td>15 747 (71.8)</td>
<td>16 963 (80.4)</td>
<td>.001</td>
</tr>
<tr>
<td>Charlson comorbidity index, mean (SD)</td>
<td>1.9 (2.1)</td>
<td>1.8 (1.3)</td>
<td>1.2 (1.2)</td>
<td>4.3 (3.4)</td>
<td>5.9 (3.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Received care at high-volume hospital, No. (%)</td>
<td>171 074 (47.3)</td>
<td>83 970 (52.7)</td>
<td>63 599 (40.0)</td>
<td>10 181 (46.2)</td>
<td>13 324 (62.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Died, No. (%)</td>
<td>22 437 (6.2)</td>
<td>10 722 (6.7)</td>
<td>8697 (5.5)</td>
<td>1742 (7.9)</td>
<td>1276 (6.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Race, No. (%)</td>
<td>238 671 (85.5)</td>
<td>108 543 (88.2)</td>
<td>101 570 (84.6)</td>
<td>13 651 (80.1)</td>
<td>12 907 (77.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>White</td>
<td>15 163 (5.4)</td>
<td>6467 (5.3)</td>
<td>6095 (5.0)</td>
<td>1172 (6.9)</td>
<td>1429 (8.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Asian or Pacific Islander</td>
<td>4172 (1.5)</td>
<td>1452 (1.2)</td>
<td>1698 (1.4)</td>
<td>526 (3.1)</td>
<td>496 (3.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Native American or other</td>
<td>7542 (2.7)</td>
<td>2690 (2.2)</td>
<td>3880 (3.2)</td>
<td>450 (2.6)</td>
<td>522 (3.1)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: AAA, abdominal aortic aneurysm; AVR, aortic valve replacement.

* The denominators are smaller than the total denominators because not all patients had this information.
The inpatient mortality rate was 6.2%, with the highest mortality rate among patients who underwent an esophagectomy (7.9%).

Using adjusted logistic regressions, we found that, over time, patients had decreased odds ratios of inpatient mortality when they received care at a high-volume hospital compared to patients who received care at a low-volume hospital (Figure). There were several years in which there was no difference in mortality, including 2002-2003 for esophagectomy and pancreatic resection and 2010 for AAA repair, AVR, and pancreatic resection. Trends were similar for unadjusted analysis (data not shown).

Discussion | Our study finds that the effect of volume on surgical outcomes does not diminish over time. Instead, patients who receive care at high-volume hospitals, even when taking into account age, comorbidities, and teaching hospital status, generally have decreased odds of inpatient mortality compared with patients who receive care at low-volume hospitals. There were several years in which there was no difference in mortality, but these were the exception, and there was no clear trend. In conclusion, high-volume hospitals have maintained lower mortality rates compared with low-volume hospitals for patients who underwent an AAA repair, an AVR, an esophagectomy, or a pancreatic resection during the period from 1998 to 2010.

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Author Contributions: Ms Anderson and Dr Chang had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: All authors.

Acquisition of data: Chang.

Analysis and interpretation of data: All authors.

Drafting of the manuscript: Anderson.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: All authors.

Administrative, technical, and material support: All authors.

Study supervision: Chang.

Conflict of Interest Disclosures: None reported.

No Association Between Hospital-Reported Perioperative Venous Thromboembolism Prophylaxis and Outcome Rates in Publicly Reported Data

Venous thromboembolism (VTE), consisting of deep vein thrombosis (DVT) and pulmonary embolism, is an important cause of postoperative mortality and long-term morbidity. Because many events are preventable, VTE prophylaxis performance and postoperative VTE are used as measures of hospital quality of care and patient safety. Two such metrics are reported on the Centers for Medicare & Medicaid Services Hospital Compare website (http://www.medicare.gov/hospitalcompare/search.html) with the stated goal of helping consumers make decisions about where to receive their health care.

The Surgical Care Improvement Project (SCIP) VTE-2, a process measure, captures the percentage of a hospital's surgical patients who received any VTE prophylaxis within 24 hours of surgery. Previous studies have shown that performance on the SCIP VTE-2 measure is not associated with VTE among Medicare patients in 6 high-risk surgical procedures,1 nor with outcomes in a Veterans Affairs cohort.2 In October 2011, Hospital Compare made additional VTE outcomes data available to consumers. We hypothesized that there is no association between the process measure (SCIP VTE-2) and the outcome (Agency for Healthcare Research and Quality Patient Safety Indicator [PSI]-12, a risk-adjusted postoperative VTE rate based on administrative data).

Methods | The SCIP VTE-2 and PSI-12 data were downloaded from the Centers for Medicare & Medicaid Services website. Average annual prophylaxis performance was linked to the 2-year VTE rate for each hospital from July 1, 2009, to June 30, 2011. The PSI-12 is adjusted for age, sex, age × sex interactions, diagnosis-related group, and modified comorbidity index prior to public reporting. Simple linear regression was used to test for an association between VTE prophylaxis and VTE rate. Sensitivity analyses were performed that excluded outliers and that used a log-transformed VTE rate because the data were not normally distributed. Hospitals were categorized by quintile of prophylaxis performance, and VTE rates were compared using a nonparametric Kruskal-Wallis rank test and Bonferroni-corrected rank sum tests for multiple pairwise comparisons. Hospitals with 100% prophylaxis performance were compared to the lowest quintile using a rank sum test. Statistical analyses were conducted using Stata version 11.2 (StataCorp).

Results | There were 3040 hospitals with complete prophylaxis and VTE data. Average annual prophylaxis performance was negatively skewed (median rate, 94.5%). The median risk-adjusted VTE rate was 4.13 per 1000 surgical discharges. Prophylaxis performance was not associated with VTE rate (P = .13) on linear regression (Figure 1). Regression results were unchanged in sensitivity analyses that excluded outliers (P = .51) and that used a log-transformed VTE rate (P = .90). Among quintiles, the VTE rates appeared to be similar (Figure 2). Although the global Kruskal-Wallis test was significant (P = .04), no pairwise comparison by quintile was statistically significant. Hospitals reporting 100% VTE prophylaxis performance (n = 141) and hospitals in the bottom quintile of prophylaxis performance (n = 618) had nearly identical median VTE outcome rates (4.18 vs 4.17; P = .98, determined by rank sum test).

Discussion | Our findings show that there is no association between reported VTE prophylaxis and outcome rates for surgical patients, when compared across the range of process measure performance. There was no difference in quintiles, or between extremes at 100% performance and the lowest quintile. This may reflect the current low, minimum standard for VTE prophylaxis because the SCIP VTE-2 gives credit for even the most basic, suboptimal prophylaxis. Perhaps a more rigorously applied benchmark to report adherence to optimal, risk-appropriate prophylaxis would have a

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Figure 1. Risk-Adjusted AHRQ PSI-12 Postoperative VTE Rate vs Percentage of Patients Who Received SCIP VTE-2 Prophylaxis

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Linear regression (3040 hospitals) of VTE rate on percentage of surgical patients receiving timely VTE prophylaxis did not show a significant association (95% CI, −1.65% to 13.35%; P = .13). The horizontal red line represents the simple linear regression line. AHRQ indicates Agency for Healthcare Research and Quality; PSI, Patient Safety Indicator; SCIP, Surgical Care Improvement Project; and VTE, venous thromboembolism.