Relationship Between Occurrence of Surgical Complications and Hospital Finances

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In the next 10 years, the rate of expected to outpace economic growth during the next 10 years. The rate of inpatient surgical complications is significant, with estimates ranging from 3% to 17.4%, depending on type of procedure, type of complications, length of follow-up, and data analyzed. In addition to patient harm, major complications add substantial costs, previously estimated at $11,500 per patient. Contributions associated with surgical complications are no longer reimbursed by payers. Previous estimates suggested that reducing surgical complications could harm hospital financial results but could change code 148 (major bowel procedure with complications) to 483 (tracheostomy with mechanical ventilation >96 hours), triggering a 5-fold increase in Medicare reimbursement. On the other hand, some complications—such as certain “never event” complications—are no longer reimbursed by many payers.

Importance The effect of surgical complications on hospital finances is unclear.

Objective To determine the relationship between major surgical complications and per-encounter hospital costs and revenues by payer type.

Design, Setting, and Participants Retrospective analysis of administrative data for all inpatient surgical discharges during 2010 from a nonprofit 12-hospital system in the southern United States. Discharges were categorized by principal procedure and occurrence of 1 or more postsurgical complications, using International Classification of Diseases, Ninth Revision, diagnosis and procedure codes. Nine common surgical procedures and 10 major complications across 4 payer types were analyzed. Hospital costs and revenue at discharge were obtained from hospital accounting systems and classified by payer type.

Main Outcomes and Measures Hospital costs, revenues, and contribution margin (defined as revenue minus variable expenses) were compared for patients with and without surgical complications according to payer type.

Results Of 34,256 surgical discharges, 1,820 patients (5.3%; 95% CI, 4.4%-6.4%) experienced 1 or more postsurgical complications. Compared with absence of complications, complications were associated with a $39,017 (95% CI, $20,069-$50,394; P < .001) higher contribution margin per patient with private insurance ($55,953 vs $16,936) and a $17,49 (95% CI, $976-$3287; P < .001) higher contribution margin per patient with Medicare ($3629 vs $1880). For this hospital system in which private insurers covered 40% of patients (13,544), Medicare covered 45% (15,406), Medicaid covered 4% (1354), and self-payment covered 6% (2,202), occurrence of complications was associated with an $8,084 (95% CI, $4903-$9,740; P < .001) higher contribution margin per patient ($15,726 vs $7,642) and with a $7,435 lower per-patient total margin (95% CI, $5103-$10,507; P < .001) ($10,13 vs $6,422).

Conclusions and Relevance In this hospital system, the occurrence of postsurgical complications was associated with a higher per-encounter hospital contribution margin for patients covered by Medicare and private insurance but a lower one for patients covered by Medicaid and who self-paid. Depending on payer mix, many hospitals have the potential for adverse near-term financial consequences for decreasing postsurgical complications.
Box. Definitions of Costs and Margins

**Variable costs:** Costs that vary with patient volume (ie, supplies and nurse staffing).

**Fixed costs:** Costs that do not vary with patient volume (ie, costs for the hospital building, utilities, and maintenance).

**Total margin:** Revenue minus variable costs and fixed costs.

**Contribution margin:** Revenue minus variable costs. These are revenues available to offset fixed costs.

The goal was to evaluate the financial implications associated with both higher- and lower-volume facilities located in urban and suburban/rural areas that included academic and nonacademic surgical departments. The goal was to evaluate the fixed and variable hospital costs and revenues associated with the occurrence of 1 or more major postsurgical complications for 4 primary payer types—private insurance, Medicare, Medicaid, and self-payment.

**METHODS**

**Study Population and Procedures**

Harvard School of Public Health and the nonprofit hospital system provided institutional research approval. The study population was generated from the administrative data of 12 hospitals in 1 southern hospital system for inpatient surgical patients who were discharged during the 2010 calendar year. Both elective and emergency procedures were included. Certified professional coders coded all data, following the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM).21

For each patient encounter, age, sex, admission status (emergency or elective/scheduled), length of stay, discharge status, insurance payer, and all ICD-9 procedure, diagnosis, and present-on-admission codes were collected. The first listed diagnosis and procedure code were identified as the principal diagnosis and principal procedure, respectively.

Patients were entered into the study if they had inpatient status, a charge for the minimum unit of 60 minutes of operating room time, validated charges of more than $0.10, at least 1 coded diagnosis and 1 coded procedure, a date of discharge in calendar year 2010, and no principal procedure code for cesarean delivery (ICD-9-CM procedure codes 74.00, 74.10, 74.40, and 74.99).

Nine common procedure groups were identified with Clinical Classifications Software–defined grouping of procedure codes22-24: craniotomy, colorectal resection, total or partial hip replacement, knee arthroplasty, coronary artery bypass graft, spinal surgery (laminctomy, excision of intervertebral disk, or spinal fusion), hysterectomy (abdominal or vaginal), appendectomy, and cholecystectomy and common bile duct exploration. The specific clinical classification software–defined groups are listed in eTable 1, available at http://www.jama.com. Patient encounters were included in a procedure group according to their principal procedure code.

**Complications and Comorbidities**

A subset of 10 potentially preventable, severe surgical complications was identified in our data set. This subset is referred to as “complications” in this article, does not capture all possible complications, and includes surgical site infection, wound disruption, sepsis/severe inflammatory response syndrome/septic shock, pulmonary embolism or deep vein thrombosis, stroke, myocardial infarction, cardiac arrest, pneumonia, ventilator use of 96 hours or longer, and infections (other than surgical site).8,18,25-27 Each complication was identified by a predefined set of ICD-9-CM codes (eTable 2) and confirmed to be absent on admission according to ICD-9 codes for present on admission. In addition, for the postsurgical complication of mechanical ventilation for 96 hours or longer, additional exclusion ICD-9 diagnosis codes (listed in eTable 2) were also applied. In-hospital mortality for patients who had inpatient surgery was captured separately from postsurgical complications, using discharge status.

Patient comorbidities were assessed with modified Charlson comorbidity scores,28-30 which were incorporated into propensity score models.

**Financial Information**

For each inpatient surgical discharge, financial information (net revenue, total cost, fixed cost, and variable cost) was extracted from the hospital system’s EPSI cost accounting system (Allscripts Inc). EPSI uses actual payroll and general ledger expenses and categorizes them as either fixed or variable costs. Fixed costs are defined as those that do not vary with patient volume, whereas variable costs are those that do. Examples of fixed costs include the cost of constructing parking or purchasing a computed tomography scanner. In this hospital system’s implementation of EPSI, fixed costs were allocated to each revenue department that treats patients. A patient discharge is allocated a portion of the fixed costs from revenue departments whose services were accessed by that patient, according to the specific charges incurred. Variable costs are those incurred during treatment of patients; examples include knee implant hardware and nursing labor. For each discharge, total hospital costs were calculated according to expenses accrued from both fixed and variable costs. Net revenue was based on actual reimbursement from the payer. (Gross revenue is sometimes defined as hospital charges; we do not use this terminology and revenue is always used to correspond to net revenue.) Physician professional fee or salary data were not collected.

We calculated and reported both contribution margin and total margin but focus on the former (Box). Hospital

For each patient encounter, age, sex, admission status (emergency or elective/scheduled), length of stay, discharge status, insurance payer, and all ICD-9 procedure, diagnosis, and present-on-admission codes were collected. The first listed diagnosis and procedure code were identified as the principal diagnosis and principal procedure, respectively.

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Surgical Complications and Hospital Finances

managers seeking to improve financial performance work to maximize contribution margin. As long as it is positive and hospital and operating room capacity exists, a hospital is financially motivated to provide care, even if total margin is negative.31

However, hospitals with negative total margins will ultimately go bankrupt. To calculate total margin, hospital managers must allocate a portion of fixed costs to each patient. As activities in a hospital increase, the total fixed costs remain the same but the proportion of fixed costs attributed to each activity decreases. We report total margin because eventually it reflects the comprehensive financial outlook of a hospital. We focus on contribution margin analysis because it drives hospital decision making in the near term.

Statistical Analysis
We calculated results with means, totals, medians, and proportions, with 95% CIs for each. Because the continuous outcome variables (eg, revenue, costs, margin) were right skewed, 95% CIs for unadjusted and adjusted totals, means, medians, and differences were calculated with a nonparametric bootstrap percentile method, which does not assume normality,32 with re-sampling to account for clustering at the facility level. For testing whether a continuous outcome variable had the same underlying probability distribution for patients with and without complications, the nonparametric Wilcoxon rank sum test adjusting for clustering at the facility level33 was used. For dichotomous outcomes (eg, mortality, complications), 95% CIs were calculated with a modified Wilson CI for clustered binary data.34

Our main analysis concerns differences in costs by complication occurrence and payer. Propensity-score weighting was used to adjust for case-mix differences between patients with and without complications within payer group. By estimating the propensity for being in the groups of interest, propensity score methods provide better control for observed confounding factors than regression models alone. Propensity methods improve the ability to compare groups in observational studies. The propensity for being in the 2 complication groups was calculated with logistic regression models, with all demographic covariates available as predictors: patient age (age and age squared), sex, Charlson score (0, 1-2, ≥3), and risk of death according to clinical classification software–defined procedure group (scored as low, medium, or high).35 We ran logistic regression models for each of the 4 payers, with uncomplications as the reference group and main effects for the covariates. The clinical classification software–defined covariate was obtained with group-level mortality rate data from the Nationwide Inpatient Sample and divided into tertiles. In the propensity-weighted approach, each patient’s information was weighted by the inverse propensity of being in the given payer complication group, with the goal of balancing characteristics across the complication groups. The Hosmer-Lemeshow goodness-of-fit statistic was used to assess the fit of the logistic regression propensity score models.36,37

To determine the sensitivity of the results, we performed sensitivity analyses, including linear mixed-model regression adjustment, as well as other propensity-score model adjustments (Table 3).

All tests and 95% CIs were 2-sided. P < .05 was considered statistically significant. All analysis was completed with SAS/STAT version 9.2.

RESULTS
There were 35,394 unique surgical inpatients discharged during calendar year 2010. We analyzed the 34,256 surgical inpatients who did not have cesarean delivery (eFigure). A total of 1,820 procedures (5.3%; 95% CI, 4.4%-6.4%) were identified as having at least 1 complication (Table 1). We identified 428 postsurgical inpatient deaths, for a 1.25% inpatient mortality rate (95% CI, 0.90%-1.75%). The inpatient mortality rate was 0.6% (95% CI, 0.49%-0.82%) for patients without an identified complication and 12.3% (95% CI, 9.31%-15.96%) for patients with a defined complication. The median length of stay (Table 2) was more than 4 times higher for surgical patients who developed 1 or more complications (3 vs 14 days; 95% CI for the difference, 8.5-12.0; P < .001). Table 2 displays the total hospital revenue, variable costs, total costs, and resulting contribution margin and total margin for patients with and without 1 or more complications. The occurrence of 1 or more complications was associated with a $22,398 higher per-patient variable cost (95% CI for the difference, $18,097-$25,682; P < .001) and with a $37,917 higher per-patient total cost (95% CI, $31,017-$53,801; P < .001). The occurrence of 1 or more surgical complications was associated with an $8084 higher per-patient contribution margin (95% CI, $4,903-$9,740; P < .001) and with a $7435 lower per-patient total margin (95% CI, $31,031-$10,507; P < .001).

Table 3 displays the detailed hospital cost and revenue results by procedure. Occurrence of 1 or more complications was associated with higher hospital costs in all payer types (Table 4). The relative difference in hospital revenue varied by payer type. Patients experiencing 1 or more complications were associated with a higher contribution margin of $39,017 (95% CI, $20,069-$50,394; P < .001) per patient with private insurance and $17,490 (95% CI, $9,767-$32,827; P < .001) per Medicare patient compared with that of patients without complications. Occurrence of surgical complications was also associated with a higher total margin of $25,622 per patient with private insurance (95% CI, $10,590-$35,057; P < .001) but a lower total margin of $9,218 per Medicare patient (95% CI, $6,882-$10,681; P < .001).

For this particular hospital system, private insurers covered 40% of patients (13,544); Medicare, 45% (15,406); Medicaid, 4% (1,336); and self-payment, 6% (2,202). Other types of insurance (eg, worker’s compensation) constituted 5% of coverage (1,768).
The results in Table 4 are propensity-adjusted; the Hosmer-Lemeshow goodness-of-fit statistic indicated that the logistic regression models for the propensity of being in the 2 complication groups were excellent fits to the data ($P > .36$ for observed being different than expected for all of the 4 payers). Thus, the observed confounding factors are important to control for when comparing cost and revenue across patients with and without complications. Finally, the sensitivity analyses for Table 4 (regression adjustments and other propensity-score model adjustments) yielded similar results in terms of estimated revenue to contribution margin and total margin and their 95% CIs (eTable 3) and thus affirm that the results presented in this article are robust and not sensitive to the approach that we used.

**COMMENT**

We found that under private insurance and Medicare, which cover the majority of US patients, the occurrence of surgical complications was associated with higher hospital contribution margins. Depending on payer mix, efforts to reduce surgical complications may result in worsened near-term financial performance.

The financial effects of surgical complications varied considerably by payer type. Complications were associated with more than $30,000 greater contribution margin per privately insured patient ($16,936 vs $55,953) compared with less than $2000 per Medicare patient ($1880 vs $3629). In contrast, for Medicaid and self-pay procedures, those with complications were associated with

**Table 1. Complication Rate by Surgical Procedure and Median Length of Stay by Complication Occurrence and Procedure**

<table>
<thead>
<tr>
<th>No. (%) [95% CI]</th>
<th>Spinal Surgery</th>
<th>Knee Arthroplasty</th>
<th>Hip Replacement</th>
<th>Intracranial Procedure</th>
<th>CABG</th>
<th>Cholecystectomy</th>
<th>Appendectomy</th>
<th>Colorectal Resection</th>
<th>Hysterectomy</th>
<th>All Other Procedures</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total surgical discharges</td>
<td>3088</td>
<td>3205</td>
<td>2098</td>
<td>502</td>
<td>778</td>
<td>2193</td>
<td>1218</td>
<td>1231</td>
<td>2078</td>
<td>17885</td>
<td>34256</td>
</tr>
<tr>
<td>Surgical discharges with ≥1 complication</td>
<td>502</td>
<td>778</td>
<td>2193</td>
<td>1218</td>
<td>1231</td>
<td>2078</td>
<td>17885</td>
<td>34256</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>5 (0.2)</td>
<td>7 (0.9)</td>
<td>8 (1.0)</td>
<td>9 (1.0)</td>
<td>4 (0.3)</td>
<td>7 (1.4)</td>
<td>5 (1.0)</td>
<td>2 (0.5)</td>
<td>7 (1.4)</td>
<td>5 (1.0)</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td>Wound disruption</td>
<td>3 (0.1)</td>
<td>2 (0.1)</td>
<td>0 (0.0)</td>
<td>1 (0.2)</td>
<td>6 (0.8)</td>
<td>1 (0.1)</td>
<td>0 (0.0)</td>
<td>8 (0.7)</td>
<td>3 (0.1)</td>
<td>64 (0.4)</td>
<td>88 (0.3)</td>
</tr>
<tr>
<td>Sepsis</td>
<td>5 (0.2)</td>
<td>3 (0.1)</td>
<td>11 (0.5)</td>
<td>7 (1.4)</td>
<td>14 (1.8)</td>
<td>9 (0.4)</td>
<td>4 (0.3)</td>
<td>51 (4.1)</td>
<td>5 (0.2)</td>
<td>278 (18.1)</td>
<td>387 (1.1)</td>
</tr>
<tr>
<td>PE or DVT</td>
<td>15 (0.5)</td>
<td>15 (0.5)</td>
<td>1 (0.0)</td>
<td>1 (0.0)</td>
<td>1 (0.0)</td>
<td>1 (0.0)</td>
<td>1 (0.0)</td>
<td>1 (0.0)</td>
<td>1 (0.0)</td>
<td>132 (4.2)</td>
<td>132 (4.2)</td>
</tr>
<tr>
<td>Stroke</td>
<td>6 (0.2)</td>
<td>4 (0.1)</td>
<td>9 (0.4)</td>
<td>16 (3.2)</td>
<td>15 (1.9)</td>
<td>3 (0.1)</td>
<td>0 (0.0)</td>
<td>6 (0.5)</td>
<td>0 (0.0)</td>
<td>74 (0.4)</td>
<td>132 (4.2)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>6 (0.2)</td>
<td>6 (0.2)</td>
<td>14 (0.7)</td>
<td>3 (0.6)</td>
<td>13 (1.7)</td>
<td>9 (0.4)</td>
<td>1 (0.0)</td>
<td>10 (0.8)</td>
<td>0 (0.3)</td>
<td>60 (2.0)</td>
<td>132 (4.2)</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>4 (0.1)</td>
<td>1 (0.0)</td>
<td>3 (0.6)</td>
<td>5 (1.0)</td>
<td>13 (1.7)</td>
<td>4 (0.2)</td>
<td>1 (0.0)</td>
<td>12 (1.0)</td>
<td>0 (0.0)</td>
<td>77 (4.0)</td>
<td>132 (4.2)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>22 (0.7)</td>
<td>19 (0.6)</td>
<td>20 (1.0)</td>
<td>20 (4.0)</td>
<td>22 (2.8)</td>
<td>21 (1.0)</td>
<td>4 (0.3)</td>
<td>34 (2.4)</td>
<td>12 (1.1)</td>
<td>306 (17.1)</td>
<td>478 (14.4)</td>
</tr>
<tr>
<td>Ventilator &gt;96 h</td>
<td>10 (0.3)</td>
<td>2 (0.1)</td>
<td>4 (0.2)</td>
<td>40 (8.0)</td>
<td>28 (5.8)</td>
<td>3 (0.1)</td>
<td>2 (0.2)</td>
<td>26 (2.1)</td>
<td>10 (0.0)</td>
<td>296 (9.9)</td>
<td>296 (9.9)</td>
</tr>
<tr>
<td>Infection (all other sites)</td>
<td>14 (0.5)</td>
<td>6 (0.2)</td>
<td>18 (0.9)</td>
<td>15 (3.0)</td>
<td>15 (1.9)</td>
<td>16 (0.7)</td>
<td>2 (0.2)</td>
<td>32 (2.6)</td>
<td>7 (0.3)</td>
<td>249 (14.9)</td>
<td>374 (1.4)</td>
</tr>
<tr>
<td>Median LOS, d</td>
<td>3 (1.3-3.1)</td>
<td>3 (1.3-3.1)</td>
<td>3 (1.3-3.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
<td>6 (3.0-4.1)</td>
</tr>
</tbody>
</table>

Abbreviations: CABG, coronary artery bypass graft; DVT, deep vein thrombosis; LOS, length of stay; PE, pulmonary embolism.

**a**Complication incidence is listed by procedure for the 9 most common surgical procedures, as well as all other procedures. All surgical procedures listed were defined by ICD-9 codes defined by the clinical classification software-defined group(s) (see Methods).

**b**Sepsis includes all ICD-9 diagnosis codes covering sepsis, sepsis shock, and severe inflammatory response syndrome.

**c**Ventilator >96 hours: ICD-9 code for “continuous invasive mechanical ventilation for 96 consecutive hours or more.”

**d**Infections (all other sites): ICD-9 code for an infections not specified at surgical site as defined in the Methods.

**P < .001** for difference in median LOS for all procedure types.
significantly lower contribution margins than those without complications. As a result, the payer mix will determine the overall economics of surgical complications for a given hospital. The studied hospital system’s inpatient surgical payer mix (Medicare, 45%; private, 40%; Medicaid, 4%; and self-pay, 6%) was comparable to that of an average US hospital in 2010 (Medicare, 40%; private, 41%; Medicaid, 9%; and self-pay, 5%) (Marc Capuano, BS/BA, The Advisory Board Company, Washington, DC, October 2012).38

Most US hospitals treat patient populations primarily covered by Medicare or private payers,39 and programs to reduce complications may worsen their near-term financial performance. Some US hospitals, often referred to as safety net hospitals, treat populations primarily covered by Medicaid or self-payment, and complication reduction efforts might improve their financial performance.

### Table 2. Patient Age, Average Length of Stay, Revenue, and Variable Costs, With and Without Complications

<table>
<thead>
<tr>
<th>Variable</th>
<th>Without Complications</th>
<th>With ≥1 Complication</th>
<th>Difference*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean, y</td>
<td>57.4 (55.7 to 58.3)</td>
<td>64.8 (63.8 to 67.0)</td>
<td>7.4 (5.8 to 10.7)</td>
</tr>
<tr>
<td>Length of stay, median, d</td>
<td>3.0 (2.9 to 4.0)</td>
<td>14.0 (11.5 to 15.0)</td>
<td>11.0 (9.0 to 12)</td>
</tr>
</tbody>
</table>

### Table 3. Revenue, Contribution Margin, and Total Margin, by Procedure

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>No. of Patients</th>
<th>Net Revenue, $ in Millions</th>
<th>Per Patient, $ in Thousands</th>
<th>Total Margin, $ in Millions</th>
<th>Per Patient, $ in Thousands</th>
<th>Without Complications</th>
<th>With ≥1 Complication</th>
<th>Change, $ in Total Margin per Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal surgery</td>
<td>3002</td>
<td>103.2 (33.3 to 212.7)</td>
<td>43.1 (14.0 to 88.9)</td>
<td>16.3 (5.6 to 30.5)</td>
<td>5.4</td>
<td>66</td>
<td>4.9 (1.0 to 17.4)</td>
<td>1.8 (0.3 to 32.8)</td>
</tr>
<tr>
<td>Knee arthroplasty</td>
<td>3131</td>
<td>77.5 (30.6 to 141.4)</td>
<td>30.4 (10.1 to 57.9)</td>
<td>9.7 (4.6 to 22.4)</td>
<td>5.0</td>
<td>74</td>
<td>2.6 (0.6 to 9.1)</td>
<td>1.8 (0.1 to 41.6)</td>
</tr>
<tr>
<td>Hip replacement</td>
<td>2013</td>
<td>46.9 (16.4 to 86.3)</td>
<td>16.8 (4.3 to 33.9)</td>
<td>8.3 (4.0 to 9.4)</td>
<td>5.5</td>
<td>85</td>
<td>2.4 (0.9 to 4.5)</td>
<td>1.7 (0.2 to 1.5)</td>
</tr>
<tr>
<td>Intracranial procedure</td>
<td>416</td>
<td>14.3 (2.1 to 34.1)</td>
<td>7.3 (1.2 to 17.1)</td>
<td>17.5 (15.6 to 20.0)</td>
<td>5.3 (15.2)</td>
<td>86</td>
<td>5.8 (0.6 to 2.5)</td>
<td>2.5 (0.2 to 6.7)</td>
</tr>
<tr>
<td>Coronary artery bypass and graft</td>
<td>692</td>
<td>26.5 (6.7 to 52.9)</td>
<td>12.7 (3.3 to 25.0)</td>
<td>17.7 (15.4 to 19.3)</td>
<td>7.5</td>
<td>86</td>
<td>8.8 (2.4 to 12.1)</td>
<td>2.5 (0.7 to 4.7)</td>
</tr>
<tr>
<td>Cholecystectomy</td>
<td>2126</td>
<td>19.8 (11.2 to 28.4)</td>
<td>8.1 (4.5 to 11.6)</td>
<td>3.8 (3.2 to 4.5)</td>
<td>0.5</td>
<td>67</td>
<td>1.7 (0.9 to 2.5)</td>
<td>0.2 (0.7)</td>
</tr>
<tr>
<td>Appendectomy</td>
<td>1203</td>
<td>8.6 (5.7 to 11.9)</td>
<td>4.1 (2.5 to 5.8)</td>
<td>3.4 (2.8 to 3.9)</td>
<td>0.5</td>
<td>15</td>
<td>0.3 (0.1 to 0.5)</td>
<td>0.0 (0.1)</td>
</tr>
<tr>
<td>Colorectal resection</td>
<td>1057</td>
<td>21.4 (10.6 to 34.3)</td>
<td>10.0 (4.7 to 16.8)</td>
<td>9.3 (8.0 to 10.8)</td>
<td>1.0</td>
<td>164</td>
<td>1.7 (3.5 to 12.8)</td>
<td>0.4 (2.0)</td>
</tr>
<tr>
<td>Hysterectomy</td>
<td>2049</td>
<td>18.9 (10.4 to 28.8)</td>
<td>9.9 (5.2 to 15.1)</td>
<td>4.8 (4.2 to 5.5)</td>
<td>2.3</td>
<td>29</td>
<td>0.6 (0.1 to 1.1)</td>
<td>0.2 (0.4)</td>
</tr>
<tr>
<td>All other procedures</td>
<td>16737</td>
<td>276.6 (104.8 to 507.5)</td>
<td>107.1 (41.5 to 193.4)</td>
<td>6.4 (5.1 to 7.4)</td>
<td>1148</td>
<td>57.2 (19.8 to 109)</td>
<td>17.1 (5.2 to 33.6)</td>
<td>14.9 (-10.0 to 18.3)</td>
</tr>
<tr>
<td>Total</td>
<td>32436</td>
<td>613.9 (258.8 to 1012)</td>
<td>247.9 (81.2 to 399)</td>
<td>6.4 (3.9 to 2.2)</td>
<td>1487</td>
<td>89.9 (31.8 to 110)</td>
<td>15.7 (3.1 to 15.0)</td>
<td>11.7 (-6.4 to 8.1)</td>
</tr>
</tbody>
</table>

*Change margin = net revenue–variable cost. CIs for totals, means, and differences were calculated with a nonparametric bootstrap method, resampling facilities (to account for clustering within facility).

bP < 0.05.
cP < 0.01.
Contribution margin, defined as revenue minus variable costs, describes the financial resources generated by hospital activities that are available to pay for a hospital’s fixed costs. Hospital managers seeking to improve financial performance typically prioritize contribution margin when evaluating hospital activities.31 For hospitals with substantial unused capacity, which comprises the majority of US hospitals,40-42 any activity with a positive contribution margin is financially beneficial, regardless of total margin.

We also examined the relationship between occurrence of surgical complications and hospital financial performance on a total margin basis, which provides an understanding of the long-term sustainability of hospital operations. For inpatient procedures covered by private payers, the occurrence of complications was associated with a more than $25,000 greater total margin. In contrast, Medicare, Medicaid, or self-pay encounters all had negative total margins whether a complication occurred or not, and the total margin was worse with a complication. As a result, some hospitals could financially benefit in the long run by reducing complications if they could accept substantial near-term losses.

We did not estimate the effect of 3 potential factors that could affect the hospital economics of surgical complications. First, the shorter lengths of stay of procedures without complications could benefit the small percentage of hospitals operating at full capacity because they might be able to admit additional patients with favorable insurance who were “crowded out.”

Second, reduced complications could improve hospital reputation, thereby increasing market share. This effect is unclear, given the absence of public reporting of surgical complication rates.89-92 Rates of specific complications that we included in our overall complication index were also within the range of that of other studies.89 The consequence of underestimating the number of surgical complications is that we would also have underestimated the financial influence of complications.

Although we report hospital revenues from Medicare, Medicaid, and private payers, we were not able to account for regional or local variation in reimbursement rates. Variations in Medicare rates (eg, because of adjustments for local wage index) would need to be corrected for in applying our results.

Table 4. Propensity-Adjusted Revenue, Contribution Margin, and Total Margin, by Payera

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>No. of Patients (% of Category)</th>
<th>Net Revenue, S, in Millions</th>
<th>Per Patient, S, in Thousands</th>
<th>Per Patient, S, in Thousands</th>
<th>No. of Patients (% of Category)</th>
<th>Net Revenue, S, in Millions</th>
<th>Per Patient, S, in Thousands</th>
<th>Per Patient, S, in Thousands</th>
<th>Δ Contribution Margin Percentage per Patient</th>
<th>Δ Total Margin per Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private payers</td>
<td>13,146 (41)</td>
<td>355.5 (162.9 to 581.5)</td>
<td>16.9 (13.0 to 20.9)</td>
<td>11.0 (9.1 to 12.1)</td>
<td>398.23 (11.7 to 63.1)</td>
<td>34.6 (15.7 to 36.0)</td>
<td>22.3 (8.1 to 29.1)</td>
<td>14.6 (5.1 to 23.9)</td>
<td>19.7 (2.2 to 14.3)</td>
<td>14.7 (1.0 to 10.7)</td>
</tr>
<tr>
<td>Medicare</td>
<td>14,221 (44)</td>
<td>210.2 (85.8 to 356.6)</td>
<td>1.9 (1.1 to 2.6)</td>
<td>-5.5 (-3.5 to -7.5)</td>
<td>1185.83 (16.4 to 63.0)</td>
<td>38.4 (19.0 to 71.1)</td>
<td>4.3 (2.2 to 5.4)</td>
<td>14.7 (7.5 to 21.2)</td>
<td>14.7 (7.5 to 21.2)</td>
<td>14.7 (7.5 to 21.2)</td>
</tr>
<tr>
<td>Medicaid</td>
<td>1236 (4)</td>
<td>14.1 (-5.5 to -2.5)</td>
<td>-2.7 (-5.9 to -7.5)</td>
<td>11.9 (-17.8 to -5.1)</td>
<td>100.53 (0.5 to 6.9)</td>
<td>3.2 (0.5 to 6.9)</td>
<td>-2.7 (-5.8 to -6.6)</td>
<td>-66.2 (-24.0 to -54.3)</td>
<td>-66.2 (-24.0 to -54.3)</td>
<td>-66.2 (-24.0 to -54.3)</td>
</tr>
<tr>
<td>Self-pay</td>
<td>2124 (7)</td>
<td>1.6 (-26.7 to -7.0)</td>
<td>-26.7 (-6.8 to -12.6)</td>
<td>78.4 (-14.0 to -10.6)</td>
<td>78.4 (0.1 to -6.9)</td>
<td>0.1 (-4.9 to -24.0)</td>
<td>-2.6 (-11.4 to -1.0)</td>
<td>-34.4 (-25.8 to -18.1)</td>
<td>-34.4 (-25.8 to -18.1)</td>
<td>-34.4 (-25.8 to -18.1)</td>
</tr>
<tr>
<td>Others</td>
<td>1709 (5)</td>
<td>37.6 (15.9 to 56.1)</td>
<td>19.7 (8.1 to 34.4)</td>
<td>11.5 (9.0 to 14.3)</td>
<td>50 (3)</td>
<td>2.6 (1.0 to 4.0)</td>
<td>1.2 (0.4 to 2.2)</td>
<td>19.6 (10.2 to 29.7)</td>
<td>0.2 (-0.3 to -0.5)</td>
<td>-1.7 (-10.5 to -16.5)</td>
</tr>
</tbody>
</table>

a Estimates calculated with propensity score weights and adjusting for clustering within facility. CIs calculated with a nonparametric bootstrap to resampling facility (to account for clustering within facility).

b P &lt; .001 for all &Delta; except for procedure type = others, where P = .474 for contribution margin per patient and P = .85 for total margin per patient. "Others" is composed of those patients who did not fit into any of the other categories and included worker’s compensation. Contribution margin change = margin contribution with complications – margin contribution without complications.
sults to individual hospitals. Private payer rates and contracting structures vary widely across the country and even in the same region or city. For example, private payer reimbursement rates range from 100% to 250% of Medicare rates, depending on local market factors. Our results thus must be interpreted in light of these factors. It is possible that with certain combinations of insurances and procedures, findings will differ from our conclusions. However, we believe the hospital system studied reflects a fairly typical set of procedures and payer contracting rules. All payers benefit financially when surgical complications are avoided because they are associated with higher average payments to hospitals.

The present study suggests that strategies such as payers bundling the average costs of complications into the base diagnosis related group payment for a surgical procedure or limiting the hospital’s ability to recode retrospectively into a higher-paying diagnosis related group may give hospitals a stronger financial incentive to avoid complications.

CONCLUSIONS

In this hospital system, the occurrence of postsurgical complications was associated with higher per-encounter hospital contribution margin for patients covered by Medicare and private insurance but lower contribution margin for patients covered by Medicaid and self-payment. Depending on payer mix, some hospitals have the potential for adverse near-term financial consequences for decreasing postsurgical complications.

Author Contributions: Drs Gawande and Eappen had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Eappen, Lane, Rosenberg, Sadoff, Matheson, Berry, Lester, Gawande. Acquisition of data: Lane, Lester. Analysis and interpretation of data: Eappen, Lane, Rosenberg, Lipsitz, Sadoff, Berry, Lester, Gawande. Drafting of the manuscript: Eappen, Lane, Rosenberg, Lipsitz, Sadoff, Lester, Gawande. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: Lipsitz. Administrative, technical, or material support: Eappen, Lester. Study supervision: Matheson, Berry, Lester, Gawande. Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Gawande reported receiving honoraria for lectures and teaching about improvement of quality and safety in health care from clinical organizations and associations that are financially affected by the design of the health system and receiving royalties from multiple publishers for books, writing, and a documentary on health care systems and performance. No other authors reported disclosures.

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Role of the Sponsors: Coauthors from the supporting organizations were involved in the design and conduct of the study; collection, management, and interpretation of the data; and review of the manuscript.

Online-Only Material: Etables 1-3, the efigure, and the Author Audio Interview are available at http://www.jama.com.

REFERENCES