

Relationship Between Occurrence of Surgical Complications and Hospital Finances

Sunil Eappen, MD

Bennett H. Lane, MS

Barry Rosenberg, MD, MBA

Stuart A. Lipsitz, ScD

David Sadoff, MBA

Dave Matheson, JD, MBA

William R. Berry, MD, MPP, MPH

Mark Lester, MD, MBA

Atul A. Gawande, MD, MPH

NATIONAL HEALTH EXPENDITURES for surgical procedures are estimated to cost \$400 billion annually and are expected to outpace economic growth during the next 10 years.^{1,2} 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.³⁻⁸ In addition to patient harm, major complications add substantial costs, previously estimated at \$11 500 per patient.⁹

Effective methods for reducing surgical complications have been identified.⁸⁻¹⁰ However, hospitals have been slow to implement them.¹¹ Resource constraints may be a factor. Quality improvement efforts often require expenditures for staff time and technologies, and financial benefits are uncertain.^{12,13} Improvements can reduce revenues under per diem reimbursement schemes and even diagnosis related group–based reimbursement because complications can result in severity adjustments or diagnosis related group changes that increase revenues. For ex-

For editorial comment see p 1634.

Author Video Interview available at www.jama.com.

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, 1820 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 \$1749 (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% (1336), and self-payment covered 6% (2202), occurrence of complications was associated with an \$8084 (95% CI, \$4903-\$9740; $P < .001$) higher contribution margin per patient (\$15 726 vs \$7642) and with a \$7435 lower per-patient total margin (95% CI, \$5103-\$10 507; $P < .001$) (\$1013 vs -\$6422).

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.

JAMA. 2013;309(15):1599-1606

www.jama.com

ample, a colectomy patient's diagnosis could change from code 148 (major bowel procedure with complications) to 483 (tracheostomy with mechanical ventilation >96 hours), triggering a 5-fold increase in Medicare reimbursement.¹⁴ On the other hand, some complications—such as certain “never event” complications—are no longer reimbursed by many payers.^{15,16} Previous estimates suggest that reducing surgical complications could harm hospital financial results but

Author Affiliations: Massachusetts Eye and Ear Infirmary, Harvard Medical School, Boston (Dr Eappen); Boston Consulting Group (Dr Rosenberg and Mssrs Lane, Sadoff, and Matheson); Center for Surgery and Public Health, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts (Dr Lipsitz); Harvard School of Public Health, Boston, Massachusetts (Dr Berry); Texas Health Resources, Arlington (Dr Lester); and Department of Health Policy and Management, Harvard School of Public Health, and Harvard Medical School, Boston (Dr Gawande).

Corresponding Author: Atul A. Gawande, MD, MPH, Department of Health Policy and Management, 677 Huntington Ave, Kresge Bldg, Room 400, Boston, MA 02115 (agawande@hsph.harvard.edu).

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.

have been limited by use of small data sets or simplified surrogates such as patient length of stay.¹⁷⁻²⁰

We therefore conducted a study to measure the financial implications associated with postsurgical complications, using internal claims-administration and cost-accounting data of a nonprofit southern US hospital system 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 (laminectomy, 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 con-

firmed 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 are 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 report both contribution margin and total margin but focus on the former (BOX). Hospital

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 resampling 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 noncomplications 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 (eTable 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 1820 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-\$43 801; $P < .001$). The occurrence of 1 or more surgical complications was associated with an \$8084 higher per-patient contribution margin (95% CI, \$4903-\$9740; $P < .001$) and with a \$7435 lower per-patient total margin (95% CI, \$5103-\$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 \$1749 (95% CI, \$976-\$3287; $P < .001$) 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 \$9218 per Medicare patient (95% CI, \$6882-\$10 681; $P < .001$).

For this particular hospital system, private insurers covered 40% of patients (13 544); Medicare, 45% (15 406); Medicaid, 4% (1336); and self-payment, 6% (2202). Other types of insurance (eg, worker's compensation) constituted 5% of coverage (1768).

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 contri-

bution 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^a

	No. (%) [95% CI]										
	Spinal Surgery	Knee Arthroplasty	Hip Replacement	Intracranial Procedure	CABG	Cholecystectomy	Appendectomy	Colorectal Resection	Hysterectomy	All Other Procedures	Total
Total surgical discharges	3068	3205	2098	502	778	2193	1218	1231	2078	17 885	34 256
Surgical discharges with no complication	3002	3131	2013	416	692	2126	1203	1067	2049	16 737	32 436
Surgical discharges with ≥1 complication	66 (2.2) [1.6-3.0]	74 (2.3) [1.8-3.1]	85 (4.1) [3.2-5.2]	86 (17.1) [9.7-28.9]	86 (11.1) [8.7-14.2]	67 (3.1) [2.4-3.9]	15 (1.2) [0.8-2.2]	164 (13.3) [11.3-15.8]	29 (1.4) [0.9-2.3]	1148 (6.4) [5.5-7.5]	1820 (5.3) [4.4-6.4]
Surgical site infection	3 (0.1) [0-0.4]	5 (0.2) [0.1-0.5]	4 (0.2) [0.1-0.6]	4 (0.8) [0.4-2.3]	7 (0.9) [0.5-2.0]	4 (0.2) [0.1-0.5]	8 (0.7) [0.4-1.4]	47 (3.8) [3.0-5.1]	3 (0.1) [0.1-0.5]	152 (0.9) [0.7-1.0]	237 (0.7) [0.5-0.9]
Wound disruption	3 (0.1) [0.1-0.3]	2 (0.1) [0-0.3]	0 [0-0.3]	1 (0.2) [0.1-1.4]	6 (0.8) [0.4-1.8]	1 (0.1) [0-0.3]	0 [0-0.5]	8 (0.7) [0.4-1.4]	3 (0.1) [0.1-0.5]	64 (0.4) [0.3-0.5]	88 (0.3) [0.2-0.3]
Sepsis ^b	5 (0.2) [0.1-0.4]	3 (0.1) [0-0.3]	11 (0.5) [0.3-1.0]	7 (1.4) [0.8-3.1]	14 (1.8) [1.2-3.1]	9 (0.4) [0.2-0.9]	4 (0.3) [0.2-1.1]	51 (4.1) [3.2-5.5]	5 (0.2) [0.1-0.6]	278 (1.6) [1.3-1.9]	387 (1.1) [0.9-1.5]
PE or DVT	15 (0.5) [0.3-0.9]	31 (1.0) [0.5-2.0]	21 (1.0) [0.4-2.5]	11 (2.2) [1.4-4.1]	5 (0.6) [0.3-1.7]	8 (0.4) [0.2-0.7]	1 (0.1) [0-0.6]	12 (1.0) [0.6-1.8]	5 (0.2) [0.1-0.8]	120 (0.7) [0.5-1.0]	229 (0.7) [0.5-1.0]
Stroke	6 (0.2) [0.1-0.5]	4 (0.1) [0.1-0.4]	8 (0.4) [0.2-1.0]	16 (3.2) [2.1-5.3]	15 (1.9) [1.3-3.3]	3 (0.1) [0-0.6]	0 [0-0.5]	6 (0.5) [0.3-1.2]	0 [0-0.3]	74 (0.4) [0.3-0.6]	132 (0.4) [0.3-0.6]
Myocardial infarction	6 (0.2) [0.1-0.5]	6 (0.2) [0.1-0.4]	14 (0.7) [0.4-1.2]	3 (0.6) [0.3-2.0]	13 (1.7) [0.8-3.9]	9 (0.4) [0.2-0.8]	1 (0.1) [0-0.6]	10 (0.8) [0.5-1.6]	0 [0-0.3]	77 (0.4) [0.3-0.6]	139 (0.4) [0.3-0.5]
Cardiac arrest	4 (0.1) [0.1-0.4]	1 (0.03) [0-0.2]	3 (0.1) [0.1-0.5]	5 (1.0) [0.6-2.6]	13 (1.7) [0.9-3.7]	4 (0.2) [0.1-0.5]	1 (0.1) [0-0.6]	12 (1.0) [0.6-2.0]	1 (0.1) [0-0.3]	73 (0.4) [0.3-0.6]	117 (0.3) [0.2-0.6]
Pneumonia	22 (0.7) [0.5-1.2]	19 (0.6) [0.4-1.0]	20 (1.0) [0.6-1.5]	20 (4.0) [2.8-6.3]	22 (2.8) [2.0-4.4]	21 (1.0) [0.5-1.7]	4 (0.3) [0.2-1.0]	34 (2.8) [1.9-4.2]	11 (0.5) [0.3-1.3]	305 (1.7) [1.2-2.4]	478 (1.4) [1.0-1.9]
Ventilator >96 h ^c	10 (0.3) [0.2-0.8]	2 (0.1) [0-0.3]	4 (0.2) [0.1-0.7]	40 (8.0) [4.7-13.8]	26 (3.3) [2.0-5.8]	3 (0.1) [0-0.4]	2 (0.2) [0.1-0.7]	26 (2.1) [1.2-4.0]	1 (0.1) [0-0.3]	181 (1.0) [0.6-1.7]	295 (0.9) [0.5-1.5]
Infection (all other sites) ^d	14 (0.5) [0.3-0.8]	6 (0.2) [0.1-0.5]	18 (0.9) [0.5-1.4]	15 (3.0) [1.6-6.1]	15 (1.9) [1.3-3.3]	16 (0.7) [0.4-1.3]	2 (0.2) [0.1-0.7]	32 (2.6) [1.8-3.9]	7 (0.3) [0.2-0.8]	249 (1.4) [1.1-1.8]	374 (1.1) [0.8-1.4]
Median LOS, d											
No complications	3 (2.0-3.1)	3 (2.9-3.1)	4 (3.0-4.1)	6 (4.0-6.1)	7 (6.9-8.0)	3 (2.0-3.1)	2 (1.0-2.1)	6 (5.9-7.1)	2 (1.9-2.1)	4 (3.0-4.1)	3 (2.9-4.0)
≥1 Complication	10 (7.0-13.2)	6 (5.0-8.0)	8 (7.0-10.0)	14 (13.0-16.0)	17 (14.0-18.7)	10 (7.0-11.0)	9 (5.0-18.0)	15 (13.0-18.0)	8 (4.0-12.0)	15 (13.0-16.5)	14 (11.5-15.0)
Difference (95% CI) ^e	7 (4.0-10.2)	3 (2.0-5.0)	4 (3.0-6.0)	8 (7.0-12.0)	10 (7.0-11.7)	7 (4.0-8.5)	7 (4.0-16.0)	9 (6.0-12.0)	6 (2.0-10.0)	11 (10.0-13.0)	11 (8.5-12.0)

Abbreviations: CABG, coronary artery bypass graft; DVT, deep vein thrombosis; LOS, length of stay; PE, pulmonary embolism.
^aComplication 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).
^bSepsis: Includes all ICD-9 diagnosis codes covering sepsis, septic shock, and severe inflammatory response syndrome.
^cVentilator >96 hours: ICD-9 code for "continuous invasive mechanical ventilation for 96 consecutive hours or more."
^dInfections (all other sites): ICD-9 code for an infections not specified at surgical site as defined in the Methods.
^e $P < .001$ 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

Variable	Unadjusted (95% CI)		
	Without Complications (n = 32 436)	With ≥1 Complication (n = 1820)	Difference ^a
Age, mean, y ^b	57.4 (55.7 to 58.3)	64.8 (63.8 to 67.0)	7.4 (5.8 to 10.7)
Length of stay, median, d	3.0 (2.9 to 4.0)	14.0 (11.5 to 15.0)	11.0 (9 to 12)
Mean, \$, in thousands			
Net revenue per patient	18.9 (15.8 to 20.5)	49.4 (40.7 to 54.0)	30.5 (23.9 to 34.5)
Variable costs per patient	11.3 (9.4 to 12.1)	33.7 (27.7 to 36.8)	22.4 (18.1 to 25.7)
Contribution margin per patient	7.6 (6.1 to 8.9)	15.7 (11.0 to 18.4)	8.1 (4.9 to 9.7)
Fixed costs per patient	6.6 (5.7 to 7.0)	22.1 (18.7 to 24.7)	15.5 (12.8 to 18.2)
Total costs per patient	17.9 (15.1 to 19.1)	55.8 (46.7 to 61.1)	37.9 (31.1 to 43.8)
Total margin per patient	1.0 (0.01 to 2.2)	-6.4 (-10.3 to -4.4)	-7.4 (-10.5 to -5.1)

^aP < .001 for all differences (95% CIs were calculated with a bootstrap method). Comparison of variables between groups with and without complications was made with a Wilcoxon rank sum 2-sample test, adjusting for clustering within facility.

^bAll ages 90 years or higher reported as equal to 90 years.

Table 3. Revenue, Contribution Margin, and Total Margin, by Procedure^a

Procedure Type	No. of Patients	Without Complications (95% CI)					With ≥1 Complication (95% CI)					Change, \$, in Thousands (95% CI)		
		Contribution Margin		Total Margin			Contribution Margin		Total Margin			Δ in Contribution Margin per Patient	Δ in Total Margin per Patient	
		Net Revenue, \$, in Millions	\$, in Millions	Per Patient, \$, in Thousands	\$, in Millions	Per Patient, \$, in Thousands	No. of Patients	Net Revenue, \$, in Millions	\$, in Millions	Per Patient, \$, in Thousands	\$, in Millions			Per Patient, \$, in Thousands
Spinal surgery	3002	103.2 (33.5 to 192.7)	42.2 (14.0 to 76.2)	14.0 (11.4 to 18.4)	16.3 (5.6 to 30.5)	5.4 (2.9 to 9.6)	66	4.9 (1.0 to 10.4)	1.8 (0.3 to 3.6)	26.6 (17.4 to 32.8)	0.3 (-0.2 to 0.9)	3.9 (-3.3 to 13.7)	12.6 (5.2 to 16.0) ^b	-1.5 (-6.5 to 5.0)
Knee arthroplasty	3131	77.5 (30.6 to 141.4)	30.4 (10.1 to 57.9)	9.7 (6.2 to 11.6)	9.0 (-1.7 to 22.7)	2.9 (-0.9 to 4.7)	74	2.6 (0.6 to 5.6)	0.8 (0.1 to 1.8)	10.3 (3.3 to 16.1)	-0.2 (-0.5 to 0.1)	-2.4 (-7.0 to 1.0)	0.6 (-5.8 to 7.1)	-5.2 (-9.9 to -0.4) ^b
Hip replacement	2013	46.9 (16.4 to 86.3)	16.8 (4.3 to 33.9)	8.3 (4.6 to 10.3)	2.2 (-3.8 to 9.4)	1.1 (-2.6 to 3.2)	85	2.4 (0.9 to 4.5)	0.5 (0.0 to 1.2)	5.6 (0.3 to 10.5)	-0.7 (-1.2 to -0.2)	-7.8 (-12.3 to -3.7)	-2.7 (-5.3 to 0.5)	-8.9 (-10.4 to -6.4) ^c
Intracranial procedure	416	14.3 (2.1 to 34.1)	7.3 (1.2 to 17.1)	17.5 (15.6 to 20.0)	2.4 (0.6 to 5.3)	5.8 (4.9 to 10.5)	86	5.8 (0.6 to 15.2)	2.5 (0.2 to 6.7)	29.2 (19.1 to 31.1)	0.3 (-0.1 to 1.1)	3.9 (-5.5 to 5.6)	11.7 (1.4 to 13.7) ^b	-1.9 (-12.1 to -0.2) ^b
Coronary artery bypass and graft	692	26.5 (8.7 to 52.0)	12.2 (3.3 to 25.0)	17.7 (15.4 to 19.3)	2.3 (-1.5 to 7.5)	3.4 (-4.1 to 6.6)	86	6.8 (2.4 to 12.1)	2.5 (0.7 to 4.7)	29.6 (17.8 to 41.6)	-0.3 (-1.1 to 0.4)	-3.4 (-15.5 to 5.5)	11.9 (23.6) ^c	-6.7 (-16.1 to 3.3)
Cholecystectomy	2126	19.8 (11.2 to 28.4)	8.1 (4.5 to 11.6)	3.8 (3.2 to 4.5)	-1.2 (-3.5 to 0.5)	-0.6 (-1.4 to 0.3)	67	1.7 (0.9 to 2.5)	0.4 (0.2 to 0.7)	6.6 (2.3 to 13.1)	-0.4 (-1.1 to 0.1)	-6.2 (-12.0 to 1.5)	2.9 (-0.6 to 9.4)	-5.6 (-10.5 to 1.8)
Appendectomy	1203	8.6 (5.7 to 11.9)	4.1 (2.5 to 5.8)	3.4 (2.8 to 3.9)	0.5 (-0.1 to 1.2)	0.4 (-0.1 to 0.9)	15	0.3 (0.1 to 0.6)	0.0 (-0.1 to 0.1)	1.1 (-8.3 to 9.4)	-0.2 (-0.4 to 0.0)	-13.1 (-30.6 to -2.0)	-2.3 (-11.221 to 5.8)	-13.5 (-28.7 to -2.7) ^b
Colorectal resection	1067	21.4 (10.6 to 34.3)	10.0 (4.7 to 16.6)	9.3 (8.0 to 10.8)	2.0 (0.4 to 4.5)	1.9 (0.5 to 3.3)	164	7.6 (3.5 to 12.8)	2.7 (1.0 to 5.0)	16.6 (8.0 to 27.0)	-0.7 (-2.0 to 0.3)	-4.6 (-10.5 to 2.0)	7.2 (0.7 to 18.5) ^b	-6.5 (-11.2 to -1.5) ^b
Hysterectomy	2049	18.9 (10.4 to 28.8)	9.9 (5.5 to 15.1)	4.8 (4.3 to 5.5)	2.9 (1.1 to 5.2)	1.4 (0.6 to 2.3)	29	0.6 (0.2 to 1.1)	0.2 (0.1 to 0.4)	8.1 (2.9 to 13.5)	0.0 (-0.2 to 0.1)	-1.6 (-8.1 to 4.2)	3.3 (8.2)	-3.1 (-9.5 to 2.4)
All other procedures	16 737	276.6 (104.8 to 507.5)	107.1 (41.5 to 193.4)	6.4 (5.1 to 7.4)	-3.7 (-15.7 to 6.8)	-0.2 (-0.9 to 0.5)	1148	57.2 (19.6 to 109.9)	17.1 (5.2 to 33.6)	14.9 (10.3 to 18.3)	-9.7 (-17.0 to -3.8)	-8.5 (-13.3 to -5.6)	8.5 (5.2 to 10.8) ^c	-8.3 (-12.0 to -5.1) ^c
Total	32 436	613.9 (258.8 to 1101.2)	247.9 (101.2 to 439.6)	7.6 (6.1 to 8.9)	32.8 (-3.9 to 80.8)	1.0 (-0.2 to 2.2)	1820	89.9 (31.8 to 171.2)	28.6 (9.4 to 55.4)	15.7 (11.0 to 18.4)	-11.7 (-20.3 to -4.6)	-6.4 (-10.3 to -4.4)	8.1 (4.9 to 9.7) ^c	-7.4 (-10.4 to -5.1) ^c

^aContribution 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 < .05.

^cP < .001.

Table 4. Propensity-Adjusted Revenue, Contribution Margin, and Total Margin, by Payer^a

Procedure Type	Without Complications (95% CI)						With ≥1 Complication (95% CI)						Change (95% CI), \$, in Thousands ^b			
	No. of Patients (% of Category)	Net Revenue, \$, in Millions		Contribution Margin		Total Margin		No. of Patients (% of Category)	Net Revenue, \$, in Millions		Contribution Margin		Total Margin		Δ in Contribution Margin per Patient	Δ in Total Margin per Patient
		\$, in Millions	Per Patient, \$, in Thousands	\$, in Millions	Per Patient, \$, in Thousands	\$, in Millions	Per Patient, \$, in Thousands		\$, in Millions	Per Patient, \$, in Thousands	\$, in Millions	Per Patient, \$, in Thousands				
Private payers	13 146 (41)	355.5 (162.9 to 581.5)	222.6 (104.2 to 363.3)	16.9 (14.3 to 18.5)	144.1 (66.9 to 236.3)	11.0 (9.1 to 12.1)	398 (22)	34.6 (11.7 to 63.1)	22.3 (7.1 to 42.2)	56.0 (35.0 to 68.9)	14.6 (4.1 to 29.1)	36.6 (19.6 to 47.2)	39.0 (20.1 to 50.4)	25.6 (10.6 to 35.1)		
Medicare	14 221 (44)	210.2 (85.8 to 358.6)	26.7 (9.6 to 50.3)	1.9 (1.1 to 2.6)	-78.2 (-128.2 to -35.6)	-5.5 (-6.2 to -4.7)	1185 (65)	38.4 (16.4 to 63.0)	4.3 (1.9 to 7.1)	3.6 (2.2 to 5.4)	-17.4 (-28.9 to -7.5)	-14.7 (-16.5 to -12.0)	1.7 (1.0 to 3.3)	-9.2 (-10.7 to -6.9)		
Medicaid	1236 (4)	14.1 (4.3 to 26.8)	-3.1 (-5.5 to -1.2)	-2.5 (-3.9 to -1.5)	-14.7 (-27.2 to -5.1)	-11.9 (-17.6 to -7.5)	100 (5)	3.2 (0.5 to 6.9)	-2.7 (-5.9 to -0.3)	-26.5 (-36.1 to -11.4)	-6.6 (-14.5 to -1.0)	-66.2 (-91.6 to -34.2)	-24.0 (-33.0 to -9.1)	-54.3 (-74.3 to -25.8)		
Self-pay	2124 (7)	1.6 (0.8 to 2.4)	-14.9 (-26.7 to -6.8)	-7.0 (-8.0 to -5.7)	-26.7 (-46.7 to -12.4)	-12.6 (-14.0 to -10.6)	78 (4)	0.1 (0 to 0.3)	-2.6 (-4.9 to -0.9)	-33.8 (-40.2 to -24.0)	-4.5 (-8.3 to -1.6)	-57.3 (-68.0 to -41.6)	-26.8 (-33.9 to -18.1)	-44.8 (-56.4 to -30.6)		
Others	1709 (5)	37.6 (15.9 to 66.1)	19.7 (8.1 to 34.4)	11.5 (9.0 to 14.3)	9.3 (3.2 to 16.3)	5.4 (3.4 to 7.9)	59 (3)	2.6 (1.0 to 4.8)	1.2 (0.4 to 2.2)	19.6 (10.2 to 29.7)	0.2 (-0.3 to 0.8)	3.8 (-5.7 to 16.0)	8.1 (0.1 to 17.1)	-1.7 (-10.3 to 10.3)		

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

^b*P* < .001 for all Δ except for procedure type=others, where *P* = .047 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.

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.⁴³⁻⁴⁵

Third, reducing surgical complications is likely to reduce readmission rates, which may help hospitals subject to reimbursement penalties, but our current study was not structured to study the consequences of this effect.

In contrast to previous financial studies that focused on smaller surgical patient pools or fewer procedures, the data set used here comprises a large number of surgical inpatient encounters with a typical mix of surgical procedures.^{33,46} Our identification of post-surgical complications in administrative data built on previously existing methods, added new codes, and used

present-on-admission codes to improve the clinical relevance of the administrative data, as recommended elsewhere.⁴⁷ Our study also avoided the use of surrogates for cost data.

Our study has several potential limitations. A number of studies suggest that administrative data may underestimate surgical complication rates.^{47,48} Furthermore, we did not seek to capture all complications (and in fact recorded postoperative deaths in which there was no complication captured). However, the overall rate of surgical complications we report of 5.3% was within the range of that of other studies.³⁻⁸ Rates of specific complications that we included in our overall complication index were also within the range of that of other studies.⁴⁹ 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 re-

sults to individual hospitals.⁵⁰ Private payer rates and contracting structures vary widely across the country and even in the same region or city.⁵¹ For example, private payer reimbursement rates range from 100% to 250% of Medicare rates, depending on local market factors.⁵² 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.⁵³

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 com-

pleted 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.

Funding/Support: This research was supported by funding from the Boston Consulting Group and Texas Health Resources.

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

- Sisko AM, Truffer CJ, Keehan SP, Poisal JA, Clemens MK, Madison AJ. National health spending projections: the estimated impact of reform through 2019. *Health Aff (Millwood)*. 2010;29(10):1933-1941.
- Centers for Medicare & Medicaid Services. National health care expenditures data, January 2010. http://www.cms.gov/nationalhealthexpenddata/01_overview.asp. Accessed May 17, 2011.
- Davenport DL, Henderson WG, Khuri SF, Mentzer RM Jr. Preoperative risk factors and surgical complexity are more predictive of costs than postoperative complications: a case study using the National Surgical Quality Improvement Program (NSQIP) database. *Ann Surg*. 2005;242(4):463-468, discussion 468-471.
- Khuri SF, Daley J, Henderson W, et al; National VA Surgical Quality Improvement Program. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. *Ann Surg*. 1998;228(4):491-507.
- Englesbe MJ, Pelletier SJ, Magee JC, et al. Seasonal variation in surgical outcomes as measured by the American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP). *Ann Surg*. 2007;246(3):456-462, discussion 463-465.
- Gawande AA, Thomas EJ, Zinner MJ, Brennan TA. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery*. 1999;126(1):66-75.
- Kable AK, Gibberd RW, Spigelman AD. Adverse events in surgical patients in Australia. *Int J Qual Health Care*. 2002;14(4):269-276.
- Haynes AB, Weiser TG, Berry WR, et al; Safe Surgery Saves Lives Study Group. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med*. 2009;360(5):491-499.
- Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA Jr. Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. *J Am Coll Surg*. 2004;199(4):531-537.
- Neily J, Mills PD, Young-Xu Y, et al. Association between implementation of a medical team training program and surgical mortality. *JAMA*. 2010;304(15):1693-1700.
- Conley DM, Singer SJ, Edmondson L, Berry WR, Gawande AA. Effective surgical safety checklist implementation. *J Am Coll Surg*. 2011;212(5):873-879.
- Cabana MD, Rand CS, Powe NR, et al. Why don't physicians follow clinical practice guidelines? A framework for improvement. *JAMA*. 1999;282(15):1458-1465.
- Wachter RM, Pronovost PJ. Balancing "no blame" with accountability in patient safety. *N Engl J Med*. 2009;361(14):1401-1406.
- DRG Handbook, 2006 Edition. Evanston, IL: Solucient LLC; 2006.
- Centers for Medicare & Medicaid Services (CMS), HHS. Medicare program: changes to the hospital inpatient prospective payment systems and fiscal year 2008 rates. *Fed Regist*. 2007;72:47379-47428.
- Rosenthal MB. Nonpayment for performance? Medicare's new reimbursement rule. *N Engl J Med*. 2007;357(16):1573-1575.
- Penel N, Lefebvre J-L, Cazin JL, et al. Additional direct medical costs associated with nosocomial infections after head and neck cancer surgery: a hospital-perspective analysis. *Int J Oral Maxillofac Surg*. 2008;37(2):135-139.
- Dimick JB, Pronovost PJ, Cowan JA, Lipsett PA. Complications and costs after high-risk surgery: where should we focus quality improvement initiatives? *J Am Coll Surg*. 2003;196(5):671-678.
- Librero J, Marín M, Peiró S, Munujos AV. Exploring the impact of complications on length of stay in major surgery diagnosis-related groups. *Int J Qual Health Care*. 2004;16(1):51-57.
- Krupka DC, Sandberg WS, Weeks WB. The impact on hospitals of reducing surgical complications suggests many will need shared savings programs with payers. *Health Aff (Millwood)*. 2012;31(11):2571-2578.
- ICD-9 provider and diagnostic codes. https://www.cms.gov/ICD9ProviderDiagnosticCodes/06_codes.asp. Accessed March 21, 2011.
- Healthcare Cost and Utilization Project-HCUP. <http://www.hcup-us.ahrq.gov/toolsoftware/ccs/ccs.jsp>. Accessed August 31, 2011.
- Healthcare Cost and Utilization Project-HCUP. <http://www.hcup-us.ahrq.gov/toolsoftware/ccs/CCSUsersGuide.pdf>. Accessed August 31, 2011.
- Healthcare Cost and Utilization Project-HCUP. <http://www.hcup-us.ahrq.gov/toolsoftware/ccs/AppendixBSinglePR.txt>.
- Khan NA, Quan H, Bugar JM, Lemaire JB, Brant R, Ghali WA. Association of postoperative complications with hospital costs and length of stay in a tertiary care center. *J Gen Intern Med*. 2006;21(2):177-180.
- de Vries EN, Prins HA, Crolla RM, et al; SURPASS Collaborative Group. Effect of a comprehensive surgical safety system on patient outcomes. *N Engl J Med*. 2010;363(20):1928-1937.
- Rajakaruna C, Rogers CA, Angelini GD, Ascione R. Risk factors for and economic implications of prolonged ventilation after cardiac surgery. *J Thorac Cardiovasc Surg*. 2005;130(5):1270-1277.
- Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-383.
- Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *Am J Epidemiol*. 2011;173(6):676-682.
- Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005;43(11):1130-1139.
- Rosenberg BL, Comstock MC, Butz DA, Taheri PA, Williams DM, Upchurch GR Jr. Endovascular abdominal aortic aneurysm repair is more profitable than open repair based on contribution margin per day. *Surgery*. 2005;137(3):285-292.
- DiCiccio TJ, Efron B. Bootstrap confidence intervals (with discussion). *Stat Sci*. 1996;11:189-228.
- Natarajan S, Lipsitz SR, Fitzmaurice GM, et al. An extension of the Wilcoxon rank sum test for complex sample survey data. *J R Stat Soc Ser C Appl Stat*. 2012;61:653-664.

34. Korn EL, Graubard BI. *Analysis of Health Surveys*. New York, NY: John Wiley & Sons; 1999.
35. Quick national or state statistics—2009. <http://hcupnet.ahrq.gov/>. Accessed July 23, 2011.
36. Hosmer DW Jr, Lemeshow S. *Applied Logistic Regression*. 2nd ed. New York, NY: John Wiley & Sons, Inc; 2000.
37. Horton NJ, Bebchuk JD, Jones CL, et al. Goodness-of-fit for GEE: an example with mental health service utilization. *Stat Med*. 1999;18:213-222.
38. Wier LM, Andrews RM. *The National Hospital Bill: The Most Expensive Conditions by Payer, 2008*. Rockville, MD: Agency for Healthcare Research and Quality; 2011. HCUP Statistical Brief #107. <http://hcupnet.ahrq.gov/HCUPnet.jsp?Id=397B64456B70904F&Form=DispTab&GoTo=MAINSEL&JS=Y>. Accessed September 30, 2012.
39. Agency for Healthcare Research and Quality. *Healthcare Cost and Utilization Project, Nationwide Inpatient Sample, 2008*. <http://www.hcup-us.ahrq.gov/reports/statbriefs/sb107.jsp>. Accessed June 5, 2012.
40. Goodman DC, Fisher ES, Bronner KK. Hospital and physician capacity update: a brief report from the Dartmouth Atlas of Healthcare; (March) 2009;1-20. http://www.dartmouthatlas.org/downloads/reports/Capacity_Report_2009.pdf. Accessed March 26, 2013.
41. DeLia D, Wood E. The dwindling supply of empty beds: implications for hospital surge capacity. *Health Aff (Millwood)*. 2008;27(6):1688-1694.
42. Bazzoli GJ, Brewster LR, Liu G, Kuo S. Does U.S. hospital capacity need to be expanded? *Health Aff (Millwood)*. 2003;22(6):40-54.
43. Farley DO, Elliott MN, Short PF, Damiano P, Kanouse DE, Hays RD. Effect of CAHPS performance information on health plan choices by Iowa Medicaid beneficiaries. *Med Care Res Rev*. 2002;59(3):319-336.
44. Marshall MN, Shekelle PG, Leatherman S, Brook RH. The public release of performance data: what do we expect to gain? A review of the evidence. *JAMA*. 2000;283(14):1866-1874.
45. Schaffler HH, Mordavsky JK. Consumer reports in health care: do they make a difference? *Annu Rev Public Health*. 2001;22:69-89.
46. Thompson DA, Makary MA, Dorman T, Pronovost PJ. Clinical and economic outcomes of hospital acquired pneumonia in intra-abdominal surgery patients. *Ann Surg*. 2006;243(4):547-552.
47. Wright SB, Huskins WC, Dokholyan RS, Goldmann DA, Platt R. Administrative databases provide inaccurate data for surveillance of long-term central venous catheter-associated infections. *Infect Control Hosp Epidemiol*. 2003;24(12):946-949.
48. Gordon HS, Johnson ML, Wray NP, et al. Mortality after noncardiac surgery: prediction from administrative versus clinical data. *Med Care*. 2005;43(2):159-167.
49. de Lissovoy G, Fraeman K, Hutchins V, Murphy D, Song D, Vaughn BB. Surgical site infection: incidence and impact on hospital utilization and treatment costs. *Am J Infect Control*. 2009;37(5):387-397.
50. Centers for Medicare & Medicaid Services (CMS); HHS Medicare Program. Changes to the hospital inpatient prospective payment systems and fiscal year 2008 rates [pages 33-35]. <https://www.cms.gov/AcuteinpatientPPS/downloads/CMS-1533-FC.pdf>. Accessed September 16, 2011.
51. Centers for Medicare & Medicaid Services (CMS); HHS Medicare Program. Changes to the hospital inpatient prospective payment systems, 2008. <https://www.cms.gov/AcuteinpatientPPS/downloads/CMS-1533-FC.pdf>. Accessed September 16, 2011.
52. Ginsburg P. Wide variation in hospital and physician payment rates: evidence of provider market power. *HSC Research Brief #16*. November 2010.
53. Dimick JB, Weeks WB, Karia RJ, Das S, Campbell DA Jr. Who pays for poor surgical quality? Building a business case for quality improvement. *J Am Coll Surg*. 2006;202(6):933-937.