

Spending and Mortality in US Acute Care Hospitals

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Background: Despite evidence that greater US Medicare spending is not associated with better quality of care at a regional level, recent studies suggest that greater hospital spending is associated with lower risk-adjusted mortality. Studies have been limited to older data, specific US states and conditions, and the Medicare population.

Objectives: To analyze the association between hospital spending and risk-adjusted inpatient mortality for 6 major medical conditions in US acute care hospitals.

Study Design: Retrospective cohort study of risk-adjusted inpatient mortality, with hospital spending taken from the *Dartmouth Atlas of Health Care*. The study population included 2,635,510 patients admitted to 1201 US hospitals between 2003 and 2007.

Methods: Patient-level logistic regression models were used to estimate the effect of hospital spending on inpatient mortality, controlling for mortality risk, comorbidities, community characteristics (eg, median household income in a patient's zip code), hospital volume and ownership, and admission year.

Results: Patients treated at hospitals in the highest spending quintile (relative to the lowest) had lower risk-adjusted inpatient mortality for acute myocardial infarction (odds ratio [OR] 0.751, 95% confidence interval [CI] 0.656-0.859), congestive heart failure (OR 0.652, 95% CI 0.560-0.759), stroke (OR 0.852, 95% CI, 0.739-0.983), and hip fracture (OR 0.691, 95% CI 0.545-0.876). Greater spending was associated with lower mortality primarily in nonteaching hospitals, hospitals with fewer than the median number of beds, and nonprofit/public hospitals.

Conclusions: Greater hospital spending is associated with lower risk-adjusted inpatient mortality for major medical conditions in the United States.

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For author information and disclosures,
see end of text.

For more than 2 decades, research has documented significant geographic variation in the use of medical resources across the United States.^{1,2} Evidence indicates that higher Medicare spending is not associated with better quality measures or health outcomes at a regional level.^{2,3} The possibility that the United States can improve quality of care while simultaneously lowering medical care spending is central to healthcare reform.

Although greater total medical spending may not be associated with better health outcomes across regions, there may be specific instances in which greater medical spending is beneficial.⁴ For example, several recent studies suggest that greater hospital spending or resource use is associated with lower risk-adjusted mortality.⁵⁻¹⁰ A study of 6 California teaching hospitals demonstrated that patients with congestive heart failure (CHF) had lower mortality rates when treated at hospitals where lengths of stay and total costs were higher.⁵ Another study of Pennsylvania hospitals found lower postadmission mortality among patients in hospitals with more intensive end-of-life treatment (eg, mechanical ventilation, intensive care unit admission).⁶ An analysis of Medicare patients between 2001 and 2005 demonstrated an association between lower 30-day mortality and greater inpatient spending.⁷ An analysis of patients admitted with 1 of 6 acute medical conditions to California hospitals found lower risk-adjusted inpatient mortality in higher-spending hospitals.⁹ In Ontario, Canada, greater hospital spending was associated with lower readmission rates as well as mortality.¹⁰

Clearly, increasing the value of medical spending is central to improving US healthcare and while the importance of this goal is largely undisputed, how best to achieve it is not. Although recent work suggests that greater hospital spending is associated with lower risk-adjusted mortality, studies have been limited to the Medicare population, patients treated up to a decade or more ago,⁷⁻⁹ hospitals in specific states,^{5,6,9,10} small samples of hospitals,⁵ a single medical condition,⁵ or postsurgical patients.⁸

We used a national sample of hospital admissions from 2003 to 2007 to evaluate the association between hospital spending and inpatient mortality for adults with 6 major medical conditions. Our measure of hospital spending—the sum of inpatient physician visits, hospital room charges, laboratory testing, diagnostic imaging, medication, and procedures—was drawn from the *Dartmouth Atlas of Health Care*, which calculates hospital spend-

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ing among Medicare beneficiaries in the last 2 years of life.¹ In addition to patient comorbid conditions, sociodemographic characteristics, and hospital and regional factors, we used validated risk adjustment models developed by the Agency for Healthcare Research and Quality (AHRQ) to account for underlying differences in inpatient mortality risk across hospitals.^{9,11} We analyzed whether hospital teaching status, size, or for-profit ownership modified the association between hospital spending and inpatient mortality.

METHODS

Study Sample

We used the Nationwide Inpatient Sample (NIS) from the Healthcare Cost and Utilization Project to identify a nationally representative sample of patients admitted to US acute care hospitals between 2003 and 2007.¹² The institutional review board at the RAND Corporation exempted these de-identified data from human subjects review. The NIS approximates a 20% stratified random sample of US community hospitals and provides demographic and clinical data on each patient, including age, sex, race, month/year of hospital admission, length of stay, primary and secondary diagnoses, primary and secondary procedures, discharge outcome (eg, discharge to home, in-hospital mortality), and source of payment. Diagnoses and procedures are coded according to the *International Classification of Diseases, Ninth Revision (ICD-9)*. The number of hospitals in NIS grew from 994 in 2003 to 1044 in 2007.¹²

We studied 6 medical conditions: acute myocardial infarction (AMI), CHF, stroke, gastrointestinal (GI) hemorrhage, hip fracture, and pneumonia. These conditions were selected because the processes of care associated with them are considered important indicators of inpatient quality,¹¹ the acute conditions reflect chronic conditions evaluated in the *Dartmouth Atlas of Health Care*, and they comprise a substantial portion of all hospital admissions in the United States (6.6% from 2003 to 2007).

We created diagnosis-specific patient samples for each hospital from ICD-9 discharge codes, according to the criteria of the AHRQ Inpatient Quality Indicators, version 4.2.^{13,14} Patients admitted with AMI included transfers from other hospitals. We excluded all NIS observations where any of the analysis variables was missing (0.41%).

In addition to patient data present in NIS, we linked each discharge record to community-level data from the 2000 US Census, similar to prior research.³ Hospital zip code was used unless missing; then, county and state were used. Specific variables

Take-Away Points

Spending on inpatient care appears to be efficacious in reducing mortality.

- This finding contrasts with evidence that US regions with higher Medicare spending do not have better quality of care.
- Inpatient spending is associated with lower mortality primarily in nonteaching hospitals, small hospitals, and nonprofit/public hospitals.
- Greater intensity of nursing care does not explain the association between spending and risk-adjusted mortality.

included median annual household income, average annual Social Security income, and the percentage of the population who were living below poverty level, were employed, had less than a high school education, were Hispanic, were single, lived in an urban area, were elderly, were institutionalized elderly, and were noninstitutionalized elderly with various disabilities.

Hospital Spending and Other Characteristics

Hospital spending was drawn from the *Dartmouth Atlas of Health Care*, which was based on inpatient spending during the last 2 years of life among Medicare fee-for-service beneficiaries with 1 of 9 chronic diseases (including, eg, coronary artery disease and CHF), who died from January 1, 2003 to December 31, 2007.^{15,16} Patients were assigned to the hospital at which most inpatient care was received. This measure included reimbursements to both hospitals and physicians and was adjusted for age, sex, race and primary chronic diagnosis, but did not vary by condition.^{15,17} Because patients at the end of life may be similarly ill, this measure may be more closely related to a hospital's overall approach to spending and care rather than to patients' severity of illness.^{3,10,15} In addition, end-of-life spending is strongly correlated with forward-looking measures of costs^{5,18} and also is positively correlated with total charges from NIS for the conditions we studied.

Additional hospital characteristics included teaching status, quartile of discharge volume by condition, size, and for-profit ownership. Teaching status was defined by the presence of an American Medical Association–approved residency, membership in the Council of Teaching Hospitals, or a ratio of full-time equivalent house staff to beds of 0.25 or higher.¹⁴ Hospital size was a binary variable defined by whether a hospital had more than the median number of general medical and surgical beds in the sample (96 beds). For-profit ownership was also a binary variable. Teaching status and discharge volume were taken from NIS, while size and ownership were taken from American Hospital Association annual surveys.¹⁹

Hospitals included in the NIS samples from 2003 to 2007 were matched on Medicare provider number to hospitals in the *Dartmouth Atlas of Health Care* for which spending was reported. This resulted in a final sample of 1201 hospitals.

Statistical Analysis

Following prior work,⁹ for each diagnosis, we estimated logistic models in which patients were the unit of analysis:

$$\text{Death}_{i,h} = b_0 + b_1 \times \text{pred mortality}_i + b_2 \times \text{spending}_h + b_3 \times \text{patient factors}_i + b_4 \times \text{hospital factors}_h + b_5 \times \text{year indicators} + b_6 \times \text{hospital referral region indicators} + b_7 \times \text{pred mortality}_i \times \text{pred mortality hospital referral region},$$

where $\text{Death}_{i,h}$ is an indicator for death of patient i in hospital h , pred mortality_i is the AHRQ patient-level predicted mortality risk (discussed below), and spending_h is hospital spending in hospital h from 2003 to 2007. Hospital spending (spending_h) was divided into quintiles.³ Individual observations were weighted with discharge sample weights from NIS.

For patients admitted with each disease, we accounted for underlying comorbidities affecting inpatient mortality by applying risk adjustments from the AHRQ Inpatient Quality Indicators.¹³ AHRQ risk parameters are estimated from national discharge data and can be applied to patient comorbidities in other discharge data to predict diagnosis-specific inpatient mortality for a given patient. For each patient in the 6 admitting diagnoses we considered, we applied these risk parameters to obtain patient-level predicted mortality risk (pred mortality_i) based on a patient's age, sex (interacted with age), and relevant diagnoses and procedure codes. Our model also adjusted for other patient factors (patient factors_i) including the number of Charlson-Deyo comorbid conditions^{3,20} and sociodemographic factors drawn from the US Census. Hospital factors were described earlier; indicator variables were included for the years in which patients were treated.

Recent evidence indicates that hospitals in higher spending regions may bill insurers for a larger number of diagnoses for a given patient than hospitals in lower-spending regions.^{21,22} Because NIS is based on recorded diagnoses, patients admitted to higher-spending hospitals may appear at higher mortality risk than similar patients admitted to lower-spending hospitals. To account for differences in diagnostic intensity, we included indicators for hospital referral region in our models and interacted predicted patient mortality risk with average risk within each hospital referral region. This specification allowed the effect of measured patient-level risk on mortality to be smaller in magnitude in areas with high diagnosed risk.

In addition to the baseline analysis, we explored whether the association between spending and mortality was affected by incorporating nursing intensity, measured as the share of full-time-equivalent nursing employees who were registered

nurses and the number of nurses per 1000 adjusted patient days. These variables were constructed from the American Hospital Association surveys and included as independent variables in the mortality model.

Effect Modification

Following prior work,⁹ we analyzed whether teaching status and hospital size modified the association between hospital spending and inpatient mortality. For-profit ownership was also analyzed. To do so, we added interactions between the hospital characteristic and spending quintiles to the baseline analysis.

We reported odds ratios comparing risk-adjusted inpatient mortality in hospitals in the top-spending quintile compared with the lowest spending quintile by hospital teaching status, size, and ownership.

Sensitivity Analysis

The degree of confounding due to the observational nature of the data was evaluated by assuming an unmeasured, binary, hospital-specific confounder independent of the included variables with no interaction between the unmeasured confounder and hospital spending. A log-linear approximation to the logistic model was estimated.²³ In addition, we estimated linear and quadratic specifications of hospital spending. Likelihood ratio tests were used to test the quadratic specification against the linear,²⁴ while the Vuong method for nonnested model selection was used to test the quintile specification against linear/quadratic spending.²⁵

Stata version 11 (StataCorp, College Station, Texas) was used for statistical analyses, and 95% confidence intervals (CIs) accounted for clustering of patients within hospitals.

RESULTS

Our sample included 2,635,510 patients admitted to 1201 US hospitals between 2003 and 2007. Because NIS is an annual stratified sample of US hospitals, 569 (47%) hospitals were included in more than 1 of the 5 years of data. The number of patients hospitalized ranged from 178,918 for hip fracture to 723,823 for CHF (Table 1), representing 869,763 to 3,522,694 discharges in the United States, respectively, based on NIS sample weights. Inpatient mortality was highest for stroke (10.85%) and lowest for GI hemorrhage (2.74%). Mean age ranged from 68.6 years (AMI) to 82.9 years (hip fracture).

Hospital Spending

Hospital spending varied substantially across the 5 quintiles and was skewed right (Figure 1). Hospitals in the lowest quintile of spending averaged \$21,659 during the last 2 years

Spending and Mortality in US Hospitals

Table 1. Summary Statistics for Patients Admitted With 1 of 6 Major Medical Conditions, 2003 to 2007a

Variable	AMI	CHF	Stroke	GI Hemorrhage	Hip Fracture	Pneumonia
Unweighted number of patients	393,814	723,823	338,859	343,877	178,918	656,219
Weighted population	1,922,030	3,522,604	1,646,957	1,671,486	869,763	3,194,296
Observed inpatient mortality, %	7.84 (26.88)	3.94 (19.46)	10.85 (31.10)	2.74 (16.33)	3.15 (17.47)	5.06 (21.93)
Age, y	68.6 (14.7)	73.4 (14.1)	71.3 (14.7)	70.3 (16.3)	82.9 (7.5)	69.7 (17.2)
Female, %	40.7 (49.1)	52.3 (49.9)	53.7 (49.9)	51.0 (50.0)	74.2 (43.8)	53.1 (49.9)
Number of Charlson-Deyo index comorbidities	2.5 (1.6)	2.9 (1.6)	2.6 (1.7)	1.8 (1.8)	1.3 (1.4)	1.9 (1.8)
Treated at teaching hospital, %	51.4 (50.0)	40.1 (49.0)	44.8 (49.7)	38.6 (48.7)	35.4 (47.8)	35.7 (47.9)
Treated in large hospital, %	85.3 (12.5)	77.3 (17.6)	79.9 (16.1)	75.6 (18.4)	73.5 (19.5)	71.2 (20.5)
Treated in for-profit hospital, %	11.5 (31.9)	12.9 (33.5)	11.3 (31.7)	12.3 (32.9)	11.7 (32.2)	12.0 (32.5)
Nurse FTEs with RN, %	93.0 (5.8)	91.8 (6.8)	92.4 (6.3)	92.0 (6.6)	91.8 (6.6)	91.2 (7.3)
Nurse FTEs per 1000 adjusted patient days	4.43 (15.57)	4.27 (21.20)	4.45 (22.27)	4.29 (21.83)	4.30 (22.06)	4.44 (27.73)
Zip code demographics						
Median household income, \$	42,113 (17960)	42,020 (17145)	42,417 (17162)	43,074 (17208)	43,562 (17086)	42,311 (16605)
Below poverty line, %	15.2 (10.8)	14.8 (10.3)	14.7 (10.4)	14.1 (9.7)	13.2 (9.1)	14.1 (9.5)
Social Security income, mean, \$	11,183 (1695)	11,142 (1615)	11,173 (1629)	11,244 (1580)	11,397 (1526)	11,197 (1531)
Urban, %	93.7 (13.9)	91.6 (16.7)	92.3 (15.7)	91.4 (16.8)	90.9 (16.6)	89.3 (18.6)
Hispanic, %	12.0 (15.8)	12.5 (16.6)	12.4 (16.3)	12.3 (16.3)	10.9 (14.7)	11.7 (15.8)
Single, %	49.8 (10.8)	48.3 (10.1)	48.8 (10.4)	47.7 (9.9)	47.0 (9.6)	47.3 (9.7)
Less than high school, %	19.4 (11.3)	20.7 (11.5)	19.9 (11.3)	19.7 (11.0)	18.4 (10.1)	20.0 (10.9)
Employed, %	57.8 (9.1)	57.0 (8.9)	57.6 (8.8)	57.7 (8.7)	58.2 (8.5)	57.7 (8.5)
Zip code health characteristics among population age ≥65 y						
Institutionalized, %	6.8 (6.0)	6.8 (6.0)	6.8 (6.0)	6.8 (5.9)	6.9 (5.7)	7.0 (5.8)
Physical disability, %	29.3 (7.0)	29.6 (6.9)	29.4 (7.0)	29.1 (6.8)	28.5 (6.4)	29.4 (6.8)
Mental disability, %	11.1 (4.5)	11.4 (4.7)	11.2 (4.6)	11.1 (4.4)	10.6 (4.0)	11.2 (4.6)
Sensory disability, %	14.1 (3.6)	14.2 (3.6)	14.2 (3.6)	14.2 (3.6)	14.1 (3.6)	14.4 (3.7)
Self-care disability, %	10.1 (3.7)	10.3 (3.8)	10.1 (3.7)	10.0 (3.6)	9.6 (3.3)	10.0 (3.6)
Home-bound disability, %	21.1 (6.0)	21.6 (6.2)	21.2 (6.1)	21.0 (5.9)	20.2 (5.4)	21.1 (5.9)

AMI indicates acute myocardial infarction; CHF, congestive heart failure; FTE, full-time equivalent; GI, gastrointestinal; RN, registered nurse.

aStandard deviations are in parentheses. Based on weighted data from the Nationwide Inpatient Sample¹² and American Hospital Association annual surveys.¹⁹

of life, compared with \$34,532 and \$52,188, respectively, at hospitals in the fourth and fifth quintiles. Patient statistics by hospital spending quintile are reported in [Appendix A](#).

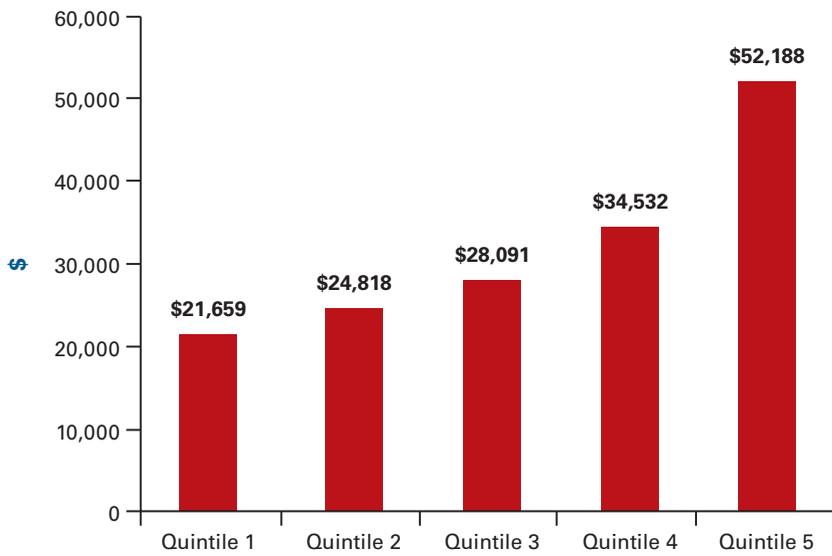
Association of Hospital Spending and Risk-Adjusted Inpatient Mortality

Patients admitted to hospitals in the highest spending quintile had lower risk-adjusted inpatient mortality for all 6 conditions compared with those admitted to hospitals in the lowest spending quintile ([Figure 2](#)). With the exception of GI hemorrhage and pneumonia, all associations were statistically significant at the 5% level. Comparing patients admitted to hospitals in the highest quintile with those ad-

mitted to hospitals in the lowest quintile, the odds ratios of risk-adjusted inpatient mortality ranged from 0.652 (95% CI 0.560-0.759) for CHF to 0.852 (95% CI 0.739-0.983) for stroke. Increases in spending from 1 quintile to the next tended to be associated with incremental reductions in inpatient mortality—except for GI hemorrhage—with the monotonic relationship most pronounced for AMI and CHF. Incorporating the share of full-time-equivalent nursing employees who were registered nurses and the number of nurses per 1000 adjusted patient days into the model did not affect the association between hospital spending and inpatient mortality.

Effect Modification

■ **Figure 1.** Average Hospital Spending, 2003 to 2007, by Quintile^a



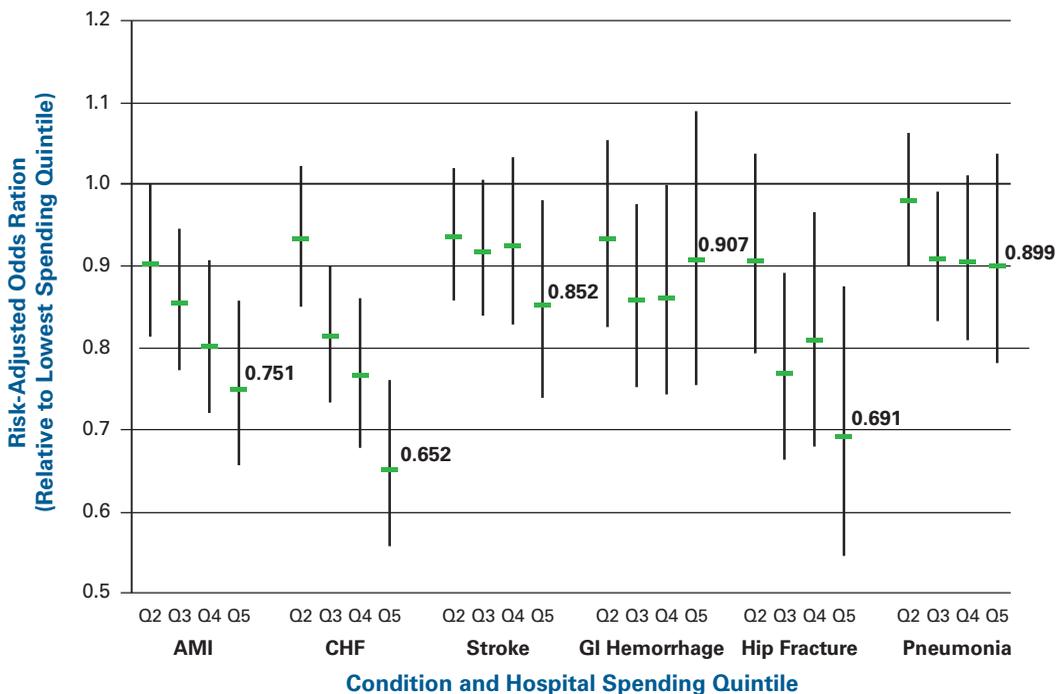
^aHospital spending was obtained from the *Dartmouth Atlas of Health Care*.¹

Admission to a hospital in the highest spending quintile (compared with the lowest spending quintile) was associated with lower inpatient mortality only among nonteaching hos-

profit/public hospitals, there was no statistically significant difference between nonprofit/public hospitals and private hospitals.

pitals, hospitals with fewer than the median number of beds in the sample, and nonprofit/public hospitals (Table 2). The odds ratio of risk-adjusted inpatient mortality for patients admitted with AMI to hospitals in the top-spending quintile relative to the lowest spending quintile was 0.747 (95% CI 0.641-0.870) for nonteaching hospitals ($P = .008$) versus 1.109 (95% CI 0.924-1.330) for teaching hospitals. Similarly, the odds ratio of risk-adjusted inpatient mortality for patients admitted with CHF to hospitals in the top-spending quintile relative to the lowest spending quintile was 1.082 (95% CI 0.900-1.300) for large hospitals versus 0.715 (95% CI 0.597-0.857) for small hospitals ($P = .015$). Although the odds ratio of risk-adjusted inpatient mortality between hospitals in the top-spending and bottom-spending quintiles was significantly less than 1 only in non-

■ **Figure 2.** Odds Ratio of Risk-Adjusted Inpatient Mortality by Hospital Spending Quintile for 6 Major Medical Conditions, 2003 to 2007^a



AMI indicates acute myocardial infarction; CHF, congestive heart failure; GI, gastrointestinal.

^aVertical bars represent 95% confidence intervals around the odds ratios (green dashes).

Table 2. Impact of Teaching Status, Hospital Size, and Ownership on the Association Between Hospital Spending and Inpatient Mortality^a

Variable	Odds Ratio of Risk-Adjusted Inpatient Mortality Between Highest and Lowest Quintile of Hospital Spending (95% CI)					
	AMI	CHF	Stroke	GI Hemorrhage	Hip Fracture	Pneumonia
Teaching status						
Teaching	1.109 (0.924-1.330)	1.047 (0.848-1.292)	1.365 (1.108-1.682)	1.097 (0.859-1.401)	1.071 (0.760-1.510)	1.023 (0.853-1.227)
Nonteaching	0.747 (0.641-0.870)	0.664 (0.567-0.778)	0.794 (0.687-0.918)	0.926 (0.763-1.125)	0.676 (0.525-0.872)	0.903 (0.776-1.050)
<i>P</i>	.008	.003	<.001	.362	.067	.367
Hospital size						
Larger than median hospital	1.082 (0.900-1.300)	0.891 (0.743-1.068)	1.252 (1.043-1.503)	0.797 (0.618-1.028)	1.062 (0.772-1.459)	0.943 (0.797-1.116)
Smaller than median hospital	0.715 (0.597-0.857)	0.739 (0.619-0.883)	0.724 (0.604-0.867)	1.076 (0.844-1.372)	0.649 (0.477-0.882)	0.940 (0.791-1.117)
<i>P</i>	.015	.240	<.001	.194	.088	.985
Ownership						
For profit	0.886 (0.707-1.111)	0.921 (0.654-1.299)	1.108 (0.844-1.455)	0.853 (0.596-1.222)	1.045 (0.712-1.534)	0.887 (0.690-1.139)
Nonprofit/public	0.761 (0.663-0.873)	0.660 (0.569-0.765)	0.841 (0.725-0.975)	0.924 (0.769-1.109)	0.688 (0.539-0.878)	0.912 (0.790-1.054)
<i>P</i>	.309	.093	.112	.720	.104	.856

AMI indicates acute myocardial infarction; CHF, congestive heart failure; GI, gastrointestinal.

^aWe examined whether teaching status, hospital size, or ownership modified the association between hospital spending and inpatient mortality. Odds ratios compare inpatient mortality spending between the highest and lowest quintile of hospital spending (eg, an odds ratio less than 1 implies that adjusted inpatient mortality was lower in hospitals in the top-spending quintile compared with the lowest).

Sensitivity Analysis

Tests for selection between nonnested models favored the quintile specification of hospital spending over linear and quadratic specifications for 4 of the 6 conditions, and the quintile specification could not be rejected in the case of stroke (Appendix B). In terms of confounding, the true odds ratio of inpatient mortality in the top-spending quintile would be statistically indistinguishable from 1 for stroke patients if there were an unmeasured binary variable with an odds ratio of inpatient mortality of 0.85 that had a 20% probability of occurring at a hospital in the top-spending quintile and a 10% probability of occurring at a hospital in the lowest spending quintile. For CHF patients, the true odds ratio would be significantly less than 1, even with a 100% probability of the binary variable occurring at top-spending hospitals.

DISCUSSION

Using a national sample of patients admitted to US acute care hospitals between 2003 and 2007, we found that greater hospital spending was associated with lower risk-adjusted inpatient mortality for patients admitted with AMI, CHF, hip

fracture, and stroke. The association was most pronounced among nonteaching hospitals and hospitals with fewer than the median number of beds in the sample. Our results are comparable to those of a previous analysis of California hospitals⁹ as well as to results of other recent studies of the association of hospital care intensity and mortality.^{5-8,10} Our results add to a growing body of literature that suggests that medical spending may be efficacious in specific contexts.²⁶

Hospital spending, as measured in our study and others, comprises several distinct factors that contribute to inpatient care: physician and other healthcare provider services, hospital facilities, laboratory testing, diagnostic imaging, medication, and procedures. While our analysis suggests that hospitals that spend more on inpatient care may have lower associated inpatient mortality—at least for 4 of the 6 conditions we considered—than hospitals that spend less, the mechanism by which this spending may improve health outcomes is unknown. Higher-spending hospitals may differ in a number of ways from lower-spending hospitals. They may hire more specialists whose expertise is critical to the management of acutely ill patients (eg, interventional cardiologists for patients requiring coronary revascularization after AMI). Even among specialists, those employed at higher-

spending hospitals may be more experienced in the care of patients with acute conditions such as stroke. For example, among patients with acute ischemic stroke, admission to designated stroke centers is associated with lower mortality.²⁷ Prior work also suggests that patients at moderate to high risk have lower mortality when treated at hospitals where patients are more likely to be admitted to the intensive care unit, undergo invasive mechanical ventilation, or receive hemodialysis.⁶ A recent study found that higher-spending hospitals had more specialist visits and other kinds of specialized care, as well as higher nursing staff ratios.¹⁰ Incorporating nurse staffing ratios into our analysis did not affect the results. In the context of AMI, hospitals offering interventional cardiac catheterization had higher average spending (\$33,564 vs \$28,334; $P < .001$). A richer understanding of the mechanisms by which greater spending may lead to improved health is needed.

Our finding that greater hospital spending is associated with lower inpatient mortality primarily in nonteaching hospitals and smaller hospitals also merits further study. Because total resources available at nonteaching and smaller hospitals may be less than those available at their teaching and larger counterparts, the impact of additional spending on patients may be greatest in those settings. For example, if access to specialist physicians and advanced diagnostic and therapeutic modalities is on average lower in nonteaching and smaller hospitals,²⁸ those hospitals that spend more per patient may be expected to have better outcomes than those hospitals that spend less. The impact of an equivalent increase in spending may not be as great in teaching and large hospitals where expensive resources are already more utilized. Although no statistically significant difference was noted between nonprofit/public hospitals and for-profit hospitals, the negative association between hospital spending and inpatient mortality was statistically significant only among nonprofit/public hospitals, which again might have fewer resources.²⁹

Our study has several limitations. Most importantly, our analysis was observational and may not have fully accounted for factors that could confound the estimated association between hospital spending and inpatient mortality, despite basing hospital spending on patients at the end of life, accounting for underlying inpatient mortality risk, and controlling for several patient demographic and hospital characteristics. If patients admitted to higher-spending hospitals were healthier than our risk adjustment model predicted, our approach would be biased in favor of finding a beneficial effect of spending on inpatient mortality.

This bias may occur if patients who live near higher-spending hospitals are generally healthier than predicted, or if higher-spending hospitals have lower thresholds for hospi-

tal admission, so that patients admitted to those hospitals are at lower risk of mortality than was predicted. In response to the first concern, our sensitivity analyses indicated that unmeasured mortality risk would need to have a strong negative association with spending to explain the measured spending-mortality relationship. In fact, higher-spending hospitals tended to treat patients with higher mortality risk, based on AHRQ measures. For example, the correlation was +0.064 for stroke (the association between AHRQ mortality risk and actual mortality is stronger still). This evidence suggests that high-spending hospitals might also have treated patients with higher unmeasured risk.³⁰⁻³³ If so, the spending-mortality associations that we found would understate the strength of the true association. In response to the second concern, it is important to note that among the highest acuity conditions we considered (AMI and stroke), there was a negative association between hospital spending and inpatient mortality. It is unlikely that hospitals would differ on criteria for admission for these 2 high-mortality conditions.

Lower mortality at higher-spending hospitals could result not from higher spending, but from hard-to-measure hospital attributes such as leadership and culture,^{34,35} which could be positively correlated with spending.³⁶ Our sensitivity analyses indicate that unmeasured confounders would need to have a strong association with both mortality and spending to account for our findings. Nevertheless, it is possible that the measured association is spurious.

Our measure of hospital spending may mis-specify the intensity of spending in hospitals. Hospital spending in the *Dartmouth Atlas of Health Care* is an aggregation of acute care and physician spending among chronically ill Medicare patients at the end of life and may not be a specific enough exposure for the patient populations that we studied. Some have suggested that hospital spending in the *Dartmouth Atlas of Health Care* is only moderately correlated with objective measures of resource utilization such as intensive care unit and life-sustaining treatment use³⁷; still others have found a strong positive correlation between end-of-life spending and forward-looking measures of hospital costs.^{5,18} Although population-specific measures of hospital intensity are useful exposure variables to consider,^{9,37} defining exposure more narrowly had no effect on the association between hospital spending and inpatient mortality in earlier work of ours using California hospitalization data.⁶ Variation in Medicare spending is largely attributable to utilization rather than price differences,³⁸ in contrast with private hospital spending.³⁹ Our use of indicator variables for hospital regions captured variation in Medicare payment rates (eg, adjustments for local labor costs based on the hospital wage index) that could have resulted in attenuation bias in the measured spending-mortality relationship.

Previous work suggests that higher-spending regions may not only spend more per diagnosis, but may also bill insurers for a larger number of diagnoses for a given patient.^{21,22} As NIS is based on recorded diagnoses and procedure codes, patients admitted to higher-spending hospitals may appear at higher mortality risk than they truly are if those hospitals code diagnoses and procedures more aggressively. Although this would also bias us toward finding a negative association between hospital spending and inpatient mortality, our analysis adjusted for regional diagnostic intensity. In addition, our results were unaffected by exclusion of the number of comorbid conditions from the analysis.

An additional limitation of our analysis is that it focused on inpatient mortality rather than postdischarge mortality (eg, death at 30 days). Whether greater hospital spending is a cost-effective use of scarce resources relies on an assessment of life expectancy gains arising from that spending.^{7,8,40} Another issue is that some hospitals might achieve lower inpatient mortality by discharging patients sooner.⁴¹ In the present analysis, however, higher-spending hospitals tended to have longer lengths of stay (with correlations ranging from +0.077 to +0.130, depending on the condition.) Moreover, if the analysis is stratified by short versus long stays (defined by the median value), the results are qualitatively similar, though less precise.

Altogether, our findings add to growing evidence that greater hospital spending is associated with lower inpatient mortality for common, acute medical conditions. Important questions remain to be answered about what specific types of treatments and hospital care delivery systems may explain this association.

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