Hospital Teaching Intensity and Mortality for Acute Myocardial Infarction, Heart Failure, and Pneumonia

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Background: Under the Affordable Care Act, health care reimbursement will increasingly be linked to quality and costs. In this environment, teaching hospitals will be closely scrutinized, as their care is often more expensive. Furthermore, although they serve vital roles in education, research, management of complex diseases, and care of vulnerable populations, debate continues as to whether teaching hospitals deliver better outcomes for common conditions.

Objective: To determine the association between risk-standardized mortality and teaching intensity for 3 common conditions.

Research Design: Using CMS models, 30-day risk-standardized mortality rates were compared among US hospitals classified as Council of Teaching Hospital (COTH) members, non-COTH teaching hospitals, or nonteaching hospitals. These analyses were repeated using ratios of interns and residents to beds to classify teaching intensity.

Subjects: The study cohort included Medicare fee-for-service beneficiaries aged 66 years or older hospitalized in acute care hospitals during 2009–2010 for acute myocardial infarction (N = 342,145), heart failure (N = 647,081), or pneumonia (N = 598,366).

Outcome Measure: The 30-day risk-standardized mortality rates for each condition, stratified by teaching intensity.

Results: For each diagnosis, compared with nonteaching hospitals there was a 10% relative reduction in the adjusted odds of mortality for patients admitted to COTH hospitals and a 6%–7% relative reduction for patients admitted to non-COTH teaching hospitals. These findings were insensitive to the method of classifying teaching intensity and only partially explained by higher teaching hospital volumes.

Conclusions: Health care reimbursement strategies designed to increase value should consider not only the costs but also the superior clinical outcomes at teaching hospitals for certain common conditions.

Key Words: academic medical center, clinical outcomes, health care reform

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Academic medical centers (AMCs) play a central role in American health care. They are the primary site where doctors, nurses, and other health providers are educated, and where basic and clinical research is conducted to improve patient care and health care delivery. AMCs also provide specialized tertiary referral services for complex and severely ill patients and are often the major source of health services for vulnerable urban populations.[1–3]

In the current health care reform environment, 2 major goals are lower costs and higher quality, as exemplified by the Medicare Value-Based Purchasing and Shared Saving Programs. In these and other value-oriented reimbursement initiatives being implemented by government and commercial payers, both the relative costs and quality of participating hospitals will come under increasing scrutiny. This is especially relevant for AMCs, whose average costs are higher[4,5] than those of nonteaching hospitals. It is generally accepted that for very specialized medical and surgical conditions, outcomes are better at large referral centers, most of which are AMCs. However, given their higher costs, there has been a longstanding and now intensifying debate regarding the incremental quality of care provided by AMCs for more common conditions. Some studies show better outcomes at teaching hospitals[3,6–19] whereas others do not,[20–23] leading some commentators to challenge the added value of AMCs.[24,25] Notably, most of these studies have relied on older data and analyses that preceded the development of nationally endorsed risk models that account for patient severity. Among recent investigations, Mueller et al[26] used a national sample of 2008 data from the Hospital Quality Alliance, and analyses were performed at the aggregate hospital level. In that study, increasing hospital teaching intensity was associated with higher risk-adjusted readmission rates for acute myocardial infarction, heart failure, and pneumonia but lower risk-adjusted mortality for the first 2 of these conditions.

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If Congress reconsiders policies such as CMS support for indirect costs of graduate medical education, and if commercial insurers attempt to "steer" patients away from higher cost AMCs, it is critical to reexamine the question of AMC outcomes. In the current study, we address the limitations of prior investigations by using contemporary, nationally inclusive, patient-level Medicare data for 3 common conditions. We focus on 30-day mortality, the most substantive and fundamental outcomes measure, and we apply the exact National Quality Forum–endorsed risk-adjustment methodologies[27–29] used by the Centers for Medicare and Medicaid Services (CMS) in their Hospital Compare public reporting initiative. We use sensitivity analyses to characterize the robustness of our findings to several key assumptions in our methodology. These include the categorization of teaching intensity, the attribution of transfer patients to specific hospitals, and the disentangling of teaching intensity and volume associations with mortality. Finally, because patients are not randomized to AMCs, we determine the strength and relative prevalence of a hypothetical confounder that would be required to change our conclusions.

METHODS

Institutional Review

This study was approved by Partners Human Research Committee (Protocol #: 2009-P-001791/1).

Study Cohort

The study cohort included Medicare beneficiaries 66 years or older from the 50 states, the District of Columbia, Puerto Rico, Guam, and Virgin Islands who were hospitalized in short-term, acute care, general hospitals during 2009–2010 with a principal discharge diagnosis of acute myocardial infarction, heart failure, or pneumonia.

We obtained data from the CMS Medicare Provider Analysis and Review (MEDPAR) file, including patient demographic information, principal and secondary diagnoses, procedure codes, and admission characteristics. Study cases were identified using International Classification of Disease version 9 (ICD-9) codes (Table, Supplemental Digital Content 1, http://links.lww.com/MLR/A586).

We applied inclusion and exclusion criteria from the CMS 30-day mortality measure models.[27–30] Using the 2008–2010 Medicare denominator files, we included only fee-for-service patients with at least 12 months of continuous Medicare enrollment before the index admission. We excluded patients who left against medical advice or were discharged alive within 1 day after admission (not transferred to another hospital), the latter scenario suggesting an inaccurate principal diagnosis for the 3 conditions we studied. Consistent with CMS practice, for patients having multiple admissions for the same disease during each study year, we randomly selected 1 admission per year for inclusion and based our 30-day mortality determination on that admission. We excluded patients discharged from hospitals with <10 cases of the specific condition during the 2-year study period.

Hospital Teaching Intensity

Our primary analysis used a common method to classify hospital teaching intensity into 3 categories[7–9,17]: AMC hospitals that were Council of Teaching Hospitals (COTH) members, teaching hospitals that were not COTH members but had some residency programs, and nonteaching hospitals that met neither criteria. COTH status was determined from that organization's membership directory, and non-COTH hospital teaching status was identified from Medicare Cost Reports. We used hospital Medicare identification codes to link MEDPAR data.

Outcome

The outcome was all-cause 30-day mortality measured from the first day of the index admission. For our primary analyses, mortalities among transfer patients were attributed to the initial admitting hospital, per CMS policy. Transfer patients accounted for 6.8% of acute myocardial infarction discharges, 1.0% of heart failure discharges, and 0.4% of pneumonia discharges. Dates of death were identified from MEDPAR files.

Covariates

We used patient risk factors from published CMS mortality risk models.[30] One-year "look back" data were obtained from MEDPAR 2008–2010 inpatient records to confirm each patient's past history and comorbidities. If a potential comorbidity on the index admission was noted during a previous admission, it was less likely to be a complication of care. Our study models included patient characteristics such as age and sex as well as 10 medical diagnoses and 15 comorbidities for myocardial infarction, 8 medical diagnoses and 14 comorbidities for heart failure, and 7 medical diagnoses and 22 comorbidities for pneumonia.

For patients who were transferred from one hospital to another, medical history and comorbidities for both admissions were generally derived from the first hospital to avoid classifying complications from an initial hospitalization as comorbidities in a subsequent admission.

Statistical Analysis

We compared demographic and clinical characteristics, and observed 30-day mortality for all eligible discharges, by teaching intensity. Because of the large numbers of patients, we focused on differences of practical significance and with *P*-values of ≤ 0.0001. We linked approximately 99% of hospitals in our study with the 2007 American Hospital Association survey to ascertain hospital characteristics such as ownership status and the capability to perform coronary revascularization [percutaneous coronary intervention (PCI) and coronary-artery bypass grafting (CABG)]. For each condition, we used box plots to graphically examine the distribution of observed 30-day mortality rates by hospital teaching intensity.

We used hierarchical logistic regression models (SAS GLIMMIX; SAS Institute Inc., Cary, NC) to estimate the association between hospital teaching intensity and all-cause 30-day mortality for each condition, controlling for individual patient covariates. Hospital Medicare identification codes were included as random intercepts to control for patient clustering within the same hospital; patient risk factors and hospital teaching intensity were included as fixed effects. This model provided estimates of hospital-specific effects and facilitated separation of within-hospital and between-hospital variation, adjusting for patient and hospital characteristics.

We estimated adjusted odds ratios (OR) and 95% confidence intervals (CI) of 30-day mortality associated with COTH or non-COTH teaching hospitals compared with nonteaching hospitals. For the primary endpoint of mortality, we also estimated the attributable risk percent[31,32] (95% CI) for treatment by a nonteaching as opposed to a COTH hospital using OR derived from our primary analyses (for this calculation, using COTH hospitals as the reference and nonteaching hospitals as the "exposure").

Hospital Characteristics

Volume

To account for potential confounding by hospital volume, we estimated additional models that also included volume as a covariate. We categorized all hospitals into high, medium, and low volume using tertiles of hospital volume distribution (see Table, Supplemental Digital Content 2, http://links.lww.com/MLR/A587). Because the goal was to assess overall institutional experience with each condition, we defined hospital volume as the disease-specific average annual discharges over the 2-year study period before applying any exclusion criteria.

Ownership and Revascularization Services

We investigated 2 other factors excluded from the CMS risk models which could potentially influence outcomes. For all 3 conditions, we repeated our analyses adding hospital ownership (government, not-for-profit, and for-profit); for myocardial infarction and heart failure analyses, we also added an indicator for the availability of PCI, CABG, or both at a given hospital.

Unexplained Between-Hospital Variation

To determine whether adjustment for hospital characteristics changed our findings, we estimated unexplained between-hospital variation for models including only patient characteristics; models with patient characteristics and teaching intensity; models including these factors plus volume; and models that included all these factors plus ownership and revascularization availability.

Potential Unmeasured Confounders

In any observational study, there is the potential for unmeasured confounders. We assessed this using the method of Lin et al[33] to estimate the increased prevalence of an unmeasured confounder(s) in nonteaching hospitals compared with COTH hospitals, and the effect strength of this confounder(s), that would be required to make the mortality OR equal to 1 (ie, no significant association of teaching intensity with mortality).

Alternative Classification of Teaching Intensity

We repeated all analyses using the ratio of interns and residents to beds (IRB), another method to classify teaching intensity.[34,35] Hospitals were defined as nonteaching if they indicated that their hospital teaching status was "no" in Medicare Cost Reports. For teaching hospitals ("yes" for teaching status in Medicare Cost Reports), we distinguished major and minor teaching intensity according to 3 different IRB criteria: 0.097 (median IRB of all teaching hospitals), 0.278 (75th percentile), and 0.629 (90th percentile). For this calculation, we included all hospitals (1069 teaching and 2203 nonteaching hospitals) having at least 1 Medicare myocardial infarction, heart failure, or pneumonia fee-for-service discharge during the 2-year study period before we made further exclusions to derive our final study cohort.

Transfer Patient Attribution

In addition to the standard CMS rule for attributing transfer patient responsibility to the first hospital, we investigated 3 alternative approaches: attribution to the final hospital, attribution to the final hospital unless the patient was at the first hospital for longer than 1 day, and excluding all transfer patients.

Statistical Software

All statistical analyses were performed with SAS software, Version 9.3 (SAS Institute Inc.).

RESULTS

Patient Characteristics

We determined the patient demographic characteristics, history, and comorbidities of the 342,145 acute myocardial infarction, 647,081 heart failure, and 598,366 pneumonia discharges included in this study (Table 1). Average unadjusted mortality rates were 15.3% for acute myocardial infarction (range, 13.9% for COTH hospitals to 16.1% for nonteaching hospitals), 12.1% for heart failure (range, 11.2% for COTH hospitals to 12.4% for nonteaching hospitals), and 12.7% for pneumonia discharges (range, 12.5% for COTH hospitals to 12.7% for nonteaching hospitals).

Hospital Characteristics

The annual volume of admissions per hospital for each condition increased monotonically with teaching intensity (Table 2), reflecting the larger size of teaching hospitals. COTH hospitals were, on average, about 7 times less likely to be for-profit compared with nonteaching hospitals, and they provided the majority of coronary revascularization services.

Primary Outcome

For each condition, the interquartile range of the hospital-specific observed 30-day mortality rates is greatest for nonteaching hospitals, largely due to their smaller number of patients (Fig. 1). Hospital-specific 30-day mortality rates for myocardial infarction are most striking, with substantially higher observed mean and median death rates and considerably more between-hospital variation among nonteaching hospitals.

TABLE 1. Study Patient Characteristics

	Acute Myocardial Infarction				Heart Failure				Pneumonia			
Characteristics	**All Patients**	**COTH**	**Non-COTH**	**Non-teaching**	**All Patients**	**COTH**	**Non-COTH**	**Non-teaching**	**All Patients**	**COTH**	**Non-COTH**	**Non-teaching**
No. patients (%)	342,145 (100)	61,823 (18.1)	119,044 (34.8)	161,278 (47.1)	647,081 (100)	98,359 (15.2)	209,719 (32.4)	339,003 (52.4)	598,366 (100)	69,354 (11.6)	179,235 (30.0)	349,777 (58.5)
30 d mortality (%)	15.3	13.9	14.8	16.1	12.1	11.2	12.0	12.4	12.7	12.5	12.6	12.7
Percent of 30 d deaths occurring during index hospitalization	59.5	64.7	60.8	57.0	37.7	40.8	37.7	36.8	45.0	47.4	45.3	44.4
Mean length of stay (SD)	5.6 (5.5)	6.5 (6.9)	5.8 (5.7)	5.2 (4.7)	5.6 (4.8)	6.3 (6.6)	5.8 (4.9)	5.3 (4.1)	5.9 (4.8)	6.4 (5.9)	6.1 (5.1)	5.8 (4.4)
Demographic												
Mean age (SD) (y)	79.8 (8.2)	79.3 (8.0)	79.6 (8.1)	80.1 (8.3)	81.9 (8.0)	81.2 (8.1)	82.0 (8.0)	82.0 (8.0)	81.0 (8.2)	81.1 (8.3)	81.1 (8.1)	81.0 (8.1)
Male (%)	49.8	50.8	50.4	49.0	43.3	45.5	43.1	42.9	44.5	44.9	44.3	44.5
Cardiovascular history (%)												
PCI	10.4	10.8	10.4	10.2	8.7	9.5	8.8	8.4	5.0	5.4	5.1	4.9
CABG	9.2	9.1	8.8	9.6	14.0	14.8	13.6	13.9	6.9	7.2	6.9	6.9
Heart failure	18.1	18.4	17.4	18.5	45.4	48.5	45.8	44.3	21.9	23.3	22.3	21.5
MI	9.9	10.9	9.3	9.9	7.3	7.8	7.3	7.1	3.0	3.3	3.1	2.9
Anterior MI	9.1	9.9	9.5	8.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Inferior/lateral/ posterior MI	12.7	14.2	13.3	11.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unstable angina	4.9	6.1	4.7	4.5	4.1	4.4	4.1	4.1	2.0	2.2	2.0	2.0
Chronic atherosclerosis	71.9	75.1	73.4	69.7	56.4	57.4	56.7	55.9	35.1	35.2	35.3	34.9
Respiratory failure	6.1	6.2	5.7	6.3	12.4	12.2	12.6	12.3	11.9	12.2	12.4	11.7
Valvular heart disease	5.7	5.9	5.4	5.8	12.9	14.1	13.1	12.5	N/A	N/A	N/A	N/A
Coexisting conditions (%)												
Hypertension	68.7	69.4	68.4	68.6	70.8	72.0	71.0	70.3	68.0	69.4	68.5	67.5
Stroke	2.3	2.2	2.2	2.3	2.8	2.8	2.8	2.8	2.9	3.3	3.0	2.9
Cerebrovascular disease	4.7	4.5	4.5	4.8	N/A	N/A	N/A	N/A	5.6	5.7	5.5	5.7
Renal failure	13.9	15.0	13.6	13.7	28.4	31.9	29.0	27.0	16.4	19.7	17.3	15.2
COPD	21.5	18.7	20.8	23.1	35.8	31.1	35.4	37.5	45.9	39.6	45.3	47.4
Pneumonia	8.4	8.2	7.9	8.9	16.6	15.5	16.3	17.1	21.9	22.4	21.6	21.9
Diabetes	32.1	32.5	31.6	32.3	38.7	39.2	38.5	38.7	N/A	N/A	N/A	N/A
Protein-calorie malnutrition	5.3	5.0	5.4	5.2	7.9	7.8	8.3	7.7	11.9	12.4	12.9	11.3
Dementia	12.3	10.7	11.9	13.2	14.2	12.5	14.2	14.8	21.7	21.2	21.7	21.8
Functional disability	3.3	3.3	3.2	3.4	4.3	4.4	4.2	4.3	4.9	5.6	4.9	4.7
Peripheral vascular	7.9	8.1	7.8	7.9	11.2	11.8	11.3	11.0	9.2	10.1	9.4	8.9
Metastatic cancer	2.7	2.9	2.6	2.7	2.9	3.4	2.9	2.8	7.3	9.6	7.5	6.8
Trauma in last year	4.9	4.7	4.8	5.1	7.8	7.4	7.9	7.8	8.2	8.6	8.4	8.1
Major psychiatric	2.3	2.3	2.3	2.4	3.1	3.0	3.1	3.1	4.8	5.1	5.0	4.6
Chronic liver disease	0.7	0.7	0.7	0.6	1.4	1.9	1.4	1.4	1.1	1.4	1.1	1.0
Severe blood disease	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.3	4.2	3.4	3.1
Anemia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34.6	34.4	35.1	34.3
Depression	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.4	7.6	7.4	7.4
Parkinson or Huntington disease	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.1	3.0	3.1	3.1
Seizure disorder	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.5	4.0	3.5	3.4
Fibrosis of lung	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.6	8.2	7.7	7.5
Asthma	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.7	5.4	4.8	4.6
Vertebral fractures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.9	2.1	2.0	1.9

CABG indicates coronary-artery bypass grafting; COTH, Council of Teaching Hospital; MI, myocardial infarction; N/A, not available; PCI, percutaneous coronary intervention.

TABLE 2. Hospital Characteristics

Variables	Acute Myocardial Infarction All Patients	Acute Myocardial Infarction COTH	Acute Myocardial Infarction Non-COTH	Acute Myocardial Infarction Non-teaching	Heart Failure All Patients	Heart Failure COTH	Heart Failure Non-COTH	Heart Failure Non-teaching	Pneumonia All Patients	Pneumonia COTH	Pneumonia Non-COTH	Pneumonia Non-teaching
No. hospitals (%)*	2815 (100)	266 (9.5)	737 (26.2)	1812 (64.4)	3142 (100)	269 (8.6)	769 (24.5)	2104 (66.9)	3160 (100)	269 (8.5)	770 (24.4)	2121 (67.1)
Mean total annual admissions† (SD)	120.2 (130.3)	265.1 (191.4)	166.6 (139.3)	80.3 (87.0)	235.6 (220.7)	506.6 (339.3)	327.7 (220.1)	167.4 (152.5)	174.2 (130.0)	281.4 (185.6)	226.7 (141.3)	141.6 (100.3)
Mean annual admissions in cohort‡ (SD)	60.8 (62.9)	116.2 (89.7)	80.8 (67.6)	44.5 (47.3)	103.0 (93.1)	182.8 (138.7)	136.4 (97.0)	80.6 (73.1)	94.7 (71.4)	128.9 (102.1)	116.4 (78.6)	82.5 (59.7)
Hospital ownership (%)												
Government	14.7	24.8	8.5	15.7	16.9	25.7	9.2	18.6	17.0	25.3	9.3	18.7
Not-for-profit	66.8	71.8	79.2	61.0	63.8	71.0	78.4	57.6	63.8	71.4	78.4	57.6
For-profit	18.5	3.4	12.4	23.3	19.3	3.4	12.4	23.9	19.2	3.4	12.2	23.7
Cardiac revascularization provided by hospital (%)												
PCI	52.8	94.0	72.5	38.0	48.3	94.1	70.8	33.6	47.9	94.1	70.4	33.2
CABG	41.9	88.5	59.4	27.2	38.3	88.1	57.9	24.1	38.0	88.1	57.6	23.8
PCI or CABG	53.7	94.8	73.1	39.0	49.2	94.9	71.4	34.6	48.8	94.8	71.0	34.2

*% is row percentage and represents the proportion in each type of teaching hospitals.
†Mean annual discharges: disease-specific average annual discharges per hospital before applying all exclusions.
‡Number of cases used for statistical models, after applying all exclusion criteria in our study cohort.
CABG indicates coronary-artery bypass grafting; COTH, Council of Teaching Hospital; PCI, percutaneous coronary intervention.

COTH teaching hospitals have, on average, about 10% lower adjusted odds of mortality compared with nonteaching hospitals (Table 3). Non-COTH teaching hospitals have 6%–7% lower adjusted odds of mortality compared with nonteaching hospitals. These findings were consistent across all methods for classifying teaching intensity.

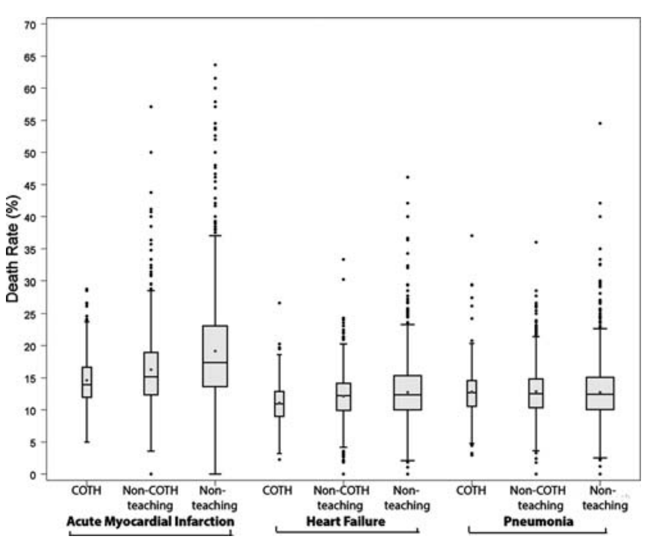

FIGURE 1. Box plots of unadjusted hospital-specific 30-day mortality rates by teaching intensity for 3 medical conditions. Upper fence = 75th percentile (upper edge of the box) plus 1.5 times the IQR. Lower fence = 25th percentile (lower edge of the box) minus 1.5 times the IQR. Horizontal line in each box = median; dot = mean. Observations outside fences = outliers. COTH indicates Council of Teaching Hospital; IQR, interquartile range.

Attributable Risk of Treatment at Nonteaching Hospitals

After adjustment for all confounders except volume, the attributable risk for acute myocardial infarction was 9.9% (95% CI, 7.1%, 12.5%), suggesting that about 10% of deaths in nonteaching hospitals might have been averted if patients in these hospitals had been treated in COTH teaching hospitals. The attributable risks were 10.2% (95% CI, 7.3%, 13.5%) for heart failure and 8.7% (95% CI, 5.7%, 12.0%) for pneumonia. In models including volume, the attributable risks were 5.6% (95% CI, 1.7%, 8.5%) for myocardial infarction, 5.8% (95% CI, 2.6%, 10.2%) for heart failure, and 7.2% (95% CI, 4.2%, 10.7%) for pneumonia.

Hospital Volume

Hospital volume confounds the association between teaching intensity and mortality for myocardial infarction and heart failure, but not for pneumonia. For myocardial infarction, the adjusted mortality OR for COTH versus nonteaching hospitals in models excluding volume was 0.89 (0.85, 0.92), whereas it was 0.94 (0.90, 0.98) when volume was included. Moreover, unexplained between-hospital variance in mortality for myocardial infarction patients was 10% smaller (0.0333/0.0371) when adjusting for volume in addition to patient factors and teaching intensity (see Table, Supplemental Digital Content 3, http://links.lww.com/MLR/A588). For heart failure, the adjusted OR was 0.88 (0.85, 0.92) in models excluding volume, and 0.94 (0.90, 0.97) when volume was included.

Confounding Effect of Hospital Ownership and Revascularization Services

The only significant effect of these 2 hospital characteristics was observed when they were included in the

TABLE 3. Adjusted Odds Ratios* (95% CI) for 30-Day Mortality, With and Without Adjustment for Hospital Volume†, Using 4 Methods of Classifying Teaching Intensity

	Hospital Volume Categories					
	Acute Myocardial Infarction		Heart Failure		Pneumonia	
Definition	**Excluded**	**Included**	**Excluded**	**Included**	**Excluded**	**Included**
COTH classification						
COTH vs. nonteaching	0.89 (0.85, 0.92)	0.94 (0.90, 0.98)	0.88 (0.85, 0.92)	0.94 (0.90, 0.97)	0.90 (0.86, 0.94)	0.91 (0.88, 0.96)
Non-COTH vs. nonteaching	0.93 (0.90, 0.96)	0.97 (0.94, 1.00)	0.94 (0.91, 0.96)	0.98 (0.95, 1.00)	0.94 (0.92, 0.97)	0.96 (0.93, 0.99)
50% IRB						
Major teaching vs. nonteaching	0.89 (0.86, 0.92)	0.94 (0.91, 0.97)	0.89 (0.86, 0.92)	0.94 (0.91, 0.97)	0.91 (0.88, 0.94)	0.92 (0.89, 0.95)
Minor teaching vs. nonteaching	0.94 (0.91, 0.97)	0.99 (0.96, 1.02)	0.95 (0.92, 0.98)	0.99 (0.96, 1.02)	0.95 (0.92, 0.98)	0.97 (0.94, 1.00)
75% IRB						
Major teaching vs. nonteaching	0.89 (0.85, 0.92)	0.93 (0.89, 0.97)	0.86 (0.83, 0.90)	0.90 (0.87, 0.94)	0.90 (0.86, 0.95)	0.92 (0.87, 0.96)
Minor teaching vs. nonteaching	0.93 (0.90, 0.95)	0.97 (0.94, 1.00)	0.94 (0.92, 0.96)	0.98 (0.96, 1.01)	0.94 (0.91, 0.97)	0.96 (0.93, 0.98)
90% IRB						
Major teaching vs. nonteaching	0.88 (0.82, 0.94)	0.92 (0.86, 0.99)	0.88 (0.83, 0.94)	0.92 (0.86, 0.98)	0.92 (0.86, 0.99)	0.93 (0.86, 0.99)
Minor teaching vs. nonteaching	0.92 (0.89, 0.95)	0.97 (0.94, 0.99)	0.93 (0.90, 0.95)	0.97 (0.94, 0.99)	0.93 (0.91, 0.96)	0.95 (0.92, 0.97)

*Reference category = nonteaching hospital discharges.
†Volume grouped into 3 categories using tertile distribution of hospital volume (see text).
CI indicates confidence interval; COTH, Council of Teaching Hospital.

myocardial infarction model; the resulting mortality OR for COTH hospitals was 0.94 (0.90, 0.98).

Unmeasured Confounders

Figure 2 illustrates the OR of an unmeasured confounder(s), assuming various levels of increased prevalence at nonteaching hospitals compared with COTH hospitals, which would be required to make the OR point estimate equal to 1 rather than the observed value of 0.89. Similar graphs were constructed for the upper and lower confidence limits (Figures, Supplemental Digital Content 4, http://links.lww.com/MLR/A589 and 5, http://links.lww.com/MLR/A590), and the results are generally similar. For most observed confounders in our study, the absolute difference in prevalence between COTH and nonteaching hospitals ranges from a fraction of a percent to a few percentage points (Table 1). The most extreme difference in prevalence is COPD in pneumonia patients (47.5% nonteaching, 39.6% COTH hospital). Even when we assume that the relative difference is in this range and baseline COTH hospital prevalence is 10%, an extreme combination that was not observed in our study, the OR of an unmeasured confounder would have to exceed 2.8 to make the point estimate for mortality at COTH hospitals equal to 1; for more likely differences in prevalence, the effect size of a theoretical unmeasured confounder would have to be much larger than this. To provide context, most confounders in our models had OR between 1 and 2.5. The only higher OR was metastatic cancer in the pneumonia models (OR, 4.26).

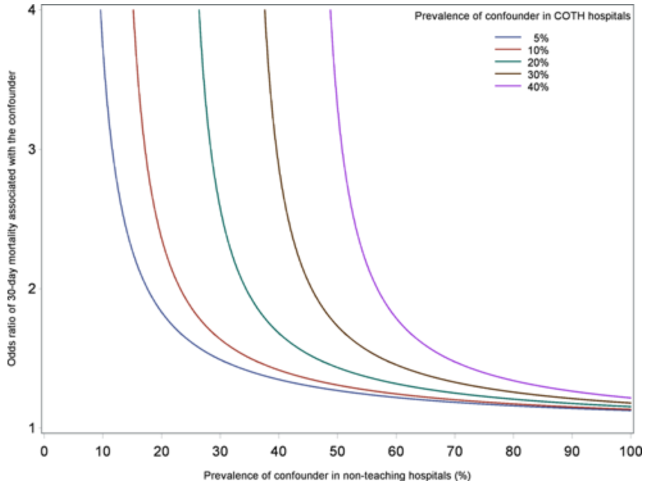

FIGURE 2. For various combinations of nonteaching hospital and COTH hospital prevalence, this graph depicts the magnitude of an unmeasured confounder that would be required for the true odds ratio point estimate to equal 1, given our observed odds ratio point estimate of 0.89. COTH indicates Council of Teaching Hospital.

Transfer Attribution Rules

The effects of different transfer attribution rules varied by diagnosis (Table 4). For heart failure and pneumonia, diagnoses for which transfers are uncommon, results were consistent irrespective of transfer patient attribution. Conversely, acute myocardial infarction patients are often transferred. Many patients receive only initial evaluation and care at the first hospital and are then transferred to tertiary centers for urgent revascularization. For this diagnosis, the differences across levels of teaching intensity were larger when alternative attribution rules were used. When outcomes were assigned to the last hospital for all transfer patients, there was an 18% relative reduction in the adjusted odds of mortality [0.82 (0.79, 0.86)] at COTH hospitals compared with nonteaching hospitals. When the outcome was assigned to the last hospital only when their stay in the first hospital was ≤ 1 day, or when all transfer patients were excluded from the analyses, there was a 16% reduction in the adjusted odds of mortality [0.84 (0.80, 0.87)].

TABLE 4. Adjusted 30-Day Mortality Odds Ratios for 3 Alternative Transfer Attribution Rules

Attribution Rule	Acute Myocardial Infarction	Heart Failure	Pneumonia
Assign outcome to the last hospital for all transfer patients			
COTH vs. nonteaching	0.82 (0.79, 0.86)	0.90 (0.86, 0.93)	0.90 (0.87, 0.94)
Non-COTH vs. nonteaching	0.89 (0.86, 0.92)	0.94 (0.92, 0.96)	0.95 (0.92, 0.97)
Assign outcome to last hospital for transfer patients with ≤1 d stay in first hospital			
COTH vs. nonteaching	0.84 (0.80, 0.87)	0.89 (0.85, 0.92)	0.90 (0.86, 0.94)
Non-COTH vs. nonteaching	0.89 (0.87, 0.92)	0.94 (0.91, 0.96)	0.95 (0.92, 0.97)
Exclude all transfer patients			
COTH vs. nonteaching	0.84 (0.80, 0.87)	0.88 (0.85, 0.92)	0.90 (0.86, 0.94)
Non-COTH vs. nonteaching	0.90 (0.87, 0.93)	0.94 (0.91, 0.96)	0.94 (0.92, 0.97)

COTH indicates Council of Teaching Hospital.

To account for potential patient selection bias related to revascularization capability, additional analyses were performed for acute myocardial infarction which only included patients discharged from PCI-capable hospitals, with mortality assigned to the initial admitting hospital. COTH hospitals still had superior performance compared with nonteaching hospitals [OR, 0.93 (0.89–0.97)].

DISCUSSION

The US health care reform, including Value-Based Purchasing and the Shared Savings Programs, is focused on improving value by reducing costs and increasing quality. Because AMCs are generally more expensive, their relative quality is an important consideration. Overall, our results suggest that AMCs have very favorable performance in the quality component of the value equation, at least as measured by 30-day risk-adjusted mortality rates for 3 common conditions. Using contemporary Medicare data and nationally endorsed risk models for these 3 conditions, there was a consistent 10% relative reduction in the adjusted odds of survival for patients admitted to COTH hospitals as opposed to nonteaching hospitals, and smaller but usually significant survival advantages for patients admitted to non-COTH teaching hospitals. Results were generally insensitive to the method used to classify teaching status; however, most of the alternative transfer patient attribution rules we studied did increase the apparent benefit conferred by COTH hospitals for acute myocardial infarction. In general, many studies have documented that transfer patients result in higher mortality rates and longer length of stay at the receiving hospital, and this adverse impact on outcomes is not fully accounted for by usual clinical risk factors.[36–45] Attributing responsibility for a patient's death to the first hospital protects receiving hospitals who did not have the opportunity to administer the patient's initial care, and who otherwise might be less willing to accept high-risk patients. Conversely, it makes the first hospital responsible for the ultimate outcomes of patients it transfers to another institution, even if the stay in the initial hospital was quite short (typical for myocardial infarction). If care at the second hospital is excellent, the first hospital reaps the benefits; if that care is less satisfactory, the resulting poor outcomes are still assumed by the first hospital. In either instance, it may be difficult to assess the quality of care delivered at the hospital receiving the transfer. Our analyses suggest that for patients with myocardial infarction, a diagnosis in which transfers are common, attribution of the outcome to the receiving hospital, typically a COTH hospital, nearly doubled the mortality advantage associated with these hospitals.

Major teaching hospitals tend to be larger, and volume has been shown to be associated with better outcomes for many conditions.[46–48] In our study, volume explains only some of the relative reduction in the adjusted odds of mortality at COTH versus nonteaching hospitals, with a residual 6%–9% relative reduction even after volume is included in the models.

Numerous explanations can be hypothesized for the consistently better mortality outcomes at AMCs, but most are speculative and lack empirical validation. For example, because teaching hospitals are major referral centers, their personnel have greater experience dealing with the most complex and severely ill patients, and this may enhance their overall clinical judgment and expertise. Teaching hospital faculty conduct research related to their specialties, and the resulting expertise and depth of knowledge may augment their ability to deliver state-of-the-art clinical care. Teaching hospitals are the major locus for the education of medical students, interns, residents, and fellows. The constant interaction between these trainees and attending staff creates a challenging intellectual environment where evidence-based practice is emphasized, and in which debate and discussion about optimal patient care is encouraged. In teaching hospitals, house staff provide in-hospital physician coverage nights and weekends, although this relative advantage may be diminished by the increasing availability of 24/7 hospitalist coverage in many nonteaching hospitals. Teaching hospitals have specialized services that may contribute to the care of even common conditions such as those we studied (eg, advanced respiratory care units, ECMO, ventricular assist and transplant services). Finally, major teaching hospitals have more commonly been early adopters of electronic health records and sophisticated decision support and medication administration systems. These may enhance quality of care and safety, although the empirical data remain inconclusive.[49,50] In aggregate, the results of our study suggest that some combination of salutary factors at major teaching hospitals result in higher quality of care, and that these factors outweigh potential disadvantages such as the larger number of caregivers and the inexperience of newer trainees.

Our data also showed that there was broad variation in outcome between the best performing and lowest performing hospitals, even after accounting for patient characteristics, hospital teaching intensity, and hospital characteristics. For example, when hospital volume is included, the odds of a patient with acute myocardial infarction dying within 30 days of admission when treated at a hospital 1 SD below "average" quality is 1.44 times than when treated at a hospital 1 SD above "average" quality. The corresponding ORs for heart failure and pneumonia are 1.51 and 1.62.

Limitations

Our study is based on observational claims data with all their inherent limitations. Nonetheless, this is the data source used by CMS for its performance measurement activities, and risk models derived from these data have been validated against clinical data.[27–30]

Our results based on Medicare patients may not be applicable to younger patients. In addition, CMS risk models are designed for performance profiling. By convention, some potentially important confounding variables such as socioeconomic status are not included. Given that a higher proportion of vulnerable patients are treated at urban teaching hospitals, inclusion of socioeconomic variables might increase the beneficial mortality effects at these institutions observed in our study.

Our endpoint was 30-day all-cause mortality, as used by CMS and many other performance assessment programs. As in all such studies, it is possible that deaths may have been unrelated to the original diagnosis, and the potential impact of postdischarge care on survival is not considered. Finally, it must be acknowledged that mortality is only one of many ways to measure hospital quality, although it is historically and currently the most common.

CONCLUSIONS

For 3 common conditions, risk-adjusted results are better at COTH teaching hospitals compared with nonteaching hospitals, and these superior results are generally insensitive to a variety of alternative methodological approaches.

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