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A Comparison of Total Hip and Knee Replacement in Specialty and General Hospitals

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Background: The emergence of specialty orthopaedic hospitals has generated widespread controversy, but little is known about the quality of care they deliver. Our objective was to compare the characteristics and outcomes of patients undergoing major joint replacement in specialty orthopaedic and general hospitals.

Methods: We conducted a retrospective cohort study of 51,788 Medicare beneficiaries who underwent total hip replacement and 99,765 who underwent total knee replacement in thirty-eight specialty orthopaedic hospitals and 517 general hospitals between 1999 and 2003. We compared demographic data, rates of comorbid illness, and socioeconomic status of patients treated in specialty and general hospitals. Logistic regression was used to calculate the odds of an adverse outcome (death or selected surgical complications) after adjustment for patient characteristics and hospital procedural volume.

Results: The demographic data and the ratio of primary to revision arthroplasties were similar, but patients who received care in specialty hospitals had less comorbidity and resided in more affluent zip codes than their counterparts in general hospitals in 2003. Specialty hospitals had significantly greater mean procedural volumes in 2003 than did general hospitals for both total hip replacement (thirty-three compared with twenty procedures; $p = 0.05$) and total knee replacement (seventy-five compared with forty procedures; $p = 0.006$). The unadjusted rate of adverse outcomes was lower in specialty hospitals than in general hospitals for total hip replacement (3.0% compared with 6.9%; $p < 0.001$) and total knee replacement (2.1% compared with 3.9%; $p < 0.001$). After adjusting for patient characteristics and procedural volume, the odds of adverse outcomes occurring were significantly lower for patients in specialty hospitals than for those in general hospitals for both primary joint replacement (odds ratio, 0.64; 95% confidence interval, 0.56 to 0.75; $p < 0.001$) and revision joint replacement (odds ratio, 0.49; 95% confidence interval, 0.36 to 0.66; $p < 0.001$).

Conclusions: After adjustment for patient characteristics and hospital volume, the specialty orthopaedic hospitals had better patient outcomes, as measured by Medicare administrative data, than did the general hospitals.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

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The recent emergence of specialty hospitals focusing on procedural aspects of medicine has generated widespread controversy[1,2]. Supporters have suggested that a focused approach improves outcomes and reduces cost[3,4], whereas opponents have countered that specialty hospitals select patients who are the most profitable and with the lowest risk of complications without improving outcomes[5,6]. Moreover, critics have claimed that specialty hospitals focus on efficiency and profitability while forsaking important societal obligations including the delivery of emergency services and charity care[7,8]. This controversy has evolved into a polarizing debate involving hospital trade groups, the American Medical Association, and the lay press[3,9-12].

Despite the controversy, rigorous data addressing the quality of care delivered by specialty hospitals remain limited and largely derived from cardiac hospitals[13,14]. Only a single preliminary investigation has assessed outcomes in specialty orthopaedic hospitals, the single largest category of specialty hospital[6,15]. That analysis, performed by consultants for the Centers for Medicare and Medicaid Services (CMS), found evidence of improved outcomes in specialty orthopaedic hospitals[16], but interpretation of these results is complicated by important methodological limitations[17].

Thus, we conducted a retrospective cohort study of all Medicare beneficiaries who underwent total hip replacement or total knee replacement in specialty orthopaedic and general hospitals in the same geographic regions between 1999 and 2003 to compare the demographic data, rates of comorbid illnesses, socioeconomic status, and risk-adjusted outcomes. We hypothesized that specialty hospitals would care for patients with a lower prevalence of comorbidities and a higher socioeconomic status than those in the comparison group of general hospitals. We also hypothesized that after adjusting for patient characteristics and hospital procedural volume, outcomes would be similar in specialty and general hospitals.

Materials and Methods

Data

A consecutive series of Medicare beneficiaries who were sixty-five years of age or older and underwent a major joint replacement (432,579 who had total hip replacement and 719,482 who had total knee replacement) between 1999 and 2003 were identified from the Medicare Provider Analysis and Review (MedPAR) Part-A data files with use of the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes (81.51 for primary total hip replacement, 81.53 for revision total hip replacement, 81.54 for primary total knee replacement, and 81.55 for revision total knee replacement)[18]. Data elements included demographic data, zip code and state of residence, primary and secondary diagnoses and procedures, admission source (e.g., outside hospital or emergency department), admission and discharge dates, discharge disposition (e.g., home or another acute care hospital), date of death up to three years after discharge, the Medicare beneficiary number of each patient, and the unique Medicare identifier of each hospital. Socioeconomic measures, including median home values and per capita income, were determined at the zip code level for each patient by linking zip code of residence with zip code-specific United States Census data[19].

Each hospital performing total hip replacement or total knee replacement was assigned to one of 307 unique hospital referral regions with use of hospital zip code-based algorithms available from the *Dartmouth Atlas of Health Care*[20]. Hospital referral regions represent distinct regional markets for medical care. Additional hospital-level information was obtained from the American Hospital Association Annual Survey Database for fiscal year 2000, including hospital teaching status and ownership (i.e., for profit or not for profit)[21,22].

Definition of Specialty Orthopaedic Hospitals and General Hospitals

There is no established definition of a specialty orthopaedic hospital, but previous studies have identified specialty hospitals with use of the ratio of orthopaedic admissions to total admissions[6]. We built on this approach by first developing an index of orthopaedic specialization, defined for each hospital as the proportion of all 2003 Medicare admissions categorized as Major Diagnostic Category 8 (diseases of the musculoskeletal system). Thus, each hospital's specialization index was between 0 (no admissions within Major Diagnostic Category 8) and 1.0 (all admissions within Major Diagnostic Category 8), with a higher index correlating with a greater degree of orthopaedic specialization. The index was used to identify the 100 hospitals with the greatest orthopaedic specialization (i.e., highest specialization index). From this list of 100 hospitals, we then excluded all fifty-five general hospitals, defined as those hospitals that provided obstetric and/or general pediatric services and all seven hospitals with formal medical school affiliations as defined in the American Hospital Association survey, because we assumed that the new specialty hospitals generally do not play a major role in the training of medical students or residents[5,6]. This resulted in the identification of thirty-eight specialty orthopaedic hospitals whose specialization was verified by a review of hospital web sites and/or confirmatory telephone calls.

A comparison group of hospitals was identified by selecting all general hospitals performing major joint replacement in the same hospital referral region as the specialty hospitals. The comparison group was limited to hospitals within the same hospital referral regions to minimize bias introduced due to regional variations in care[23,24].

Outcomes of Interest

We developed a composite end point of death and preventable surgical complications by combining outcomes assessed in previous studies with use of administrative data to assess orthopaedic outcomes[25-28] with selected Patient Safety Indicators developed by the Agency for Healthcare Research and Quality (AHRQ) that are most relevant to surgical quality[29]. The resulting composite end point consisted of six separate outcomes occurring within ninety days of surgery: sepsis, hemorrhage, pulmonary embolism, deep vein thrombosis, wound

infection requiring readmission, or death. Secondary outcomes included postoperative hospital length of stay and the proportion of patients requiring transfer from the hospital where they underwent the initial arthroplasty to another acute care hospital (a potential measure of complications that could not be managed in the primary hospital).

Statistical Analyses

Differences between the patients in the specialty hospitals and those in the general hospitals with regard to demographic data, the mean number of comorbid conditions as measured by Elixhauser et al.[30], predicted risk of the composite outcome, unadjusted outcomes, and hospital length of stay were compared with use of the chi-square statistic or Wilcoxon signed-rank test. The characteristics of the specialty and general hospitals (e.g., procedural volume) were assessed with use of similar tests on the basis of 2003 Medicare data to reflect the fact that procedural volume benchmarks set by external agencies (e.g., the Leapfrog Group) are usually based on annual volume.

Multivariable models were developed from patient characteristics available in the MedPAR database. Candidate variables included demographic data, admission source, surgical priority (i.e., emergent, urgent, or elective), and comorbid conditions. Comorbid conditions were defined with use of algorithms developed by Elixhauser et al.[30]. The algorithms were developed to identify common comorbid medical conditions that were associated with adverse outcomes for a wide array of medical and surgical diagnoses and were expressly designed for use with administrative data. A list of these conditions is provided in the Appendix. Additional high-risk conditions specific to joint replacement surgery (prior joint replacement, active joint infection, acute fracture, and cancer with bone involvement) were identified with use of published algorithms[28,31,32].

Multivariable models were initially developed independently for primary and revision total hip replacement and total knee replacement cohorts. However, because we found these models to be similar, patients who had total hip replacement and those who had total knee replacement were combined with use of separate indicator variables to represent the surgical procedure each patient underwent (e.g., primary total hip replacement or revision total hip replacement). Fifty-seven candidate variables associated with mortality in bivariate analyses (with use of a statistical criterion of alpha = 0.05) were entered into stepwise logistic regression analyses; variables were retained in the model if they demonstrated independent association with mortality (with use of alpha = 0.01)[33,34]. The final risk adjustment models contained thirty-three variables that are listed in the Appendix. These models were used to provide estimates of the predicted risk of an adverse outcome for each patient, a composite measure of case complexity.

Generalized estimating equations were used to compare the occurrence of the composite end point in specialty hospitals relative to general hospitals after accounting for clustering of patients within hospitals[35,36]. A series of three sequential analyses were conducted. First, the unadjusted odds of the composite outcome was calculated. Second, the odds ratio was adjusted for the patient characteristics identified above and, third, it was adjusted for patient characteristics and hospital procedural volume.

To investigate the possibility that specialty hospital performance differed for specific patient populations, a number of analyses were conducted with use of the models described above for defined patient subgroups. First, we conducted analyses for all patients in aggregate, patients who had primary joint replacement alone, and patients who had revision joint replacement alone. Second, we stratified all patients into three subgroups on the basis of the number of comorbid conditions (zero or one comorbid condition, two or three comorbid conditions, and four or more comorbid conditions), as measured according to Elixhauser et al.[30]. In these analyses, we controlled for the type of procedure (primary total hip replacement, primary total knee replacement, revision total hip replacement, or revision total knee replacement) using indicator variables. Then, we assessed the performance of specialty hospitals and general hospitals separately for each subgroup to further investigate whether specialty hospitals performed better (or worse) for specific patient groups. Third, we compared outcomes after grouping hospitals into low-volume (fifty or fewer major joint replacement procedures in 2003), intermediate-volume (fifty-one to 250 procedures), and high-volume (>250 procedures) strata. Finally, linear regression models were used to compare unadjusted and adjusted log-transformed hospital length of stay in specialty and general hospitals.

Sensitivity Analyses

The analyses described above were also conducted separately for each component of the composite outcome, and the results were similar to the findings for the composite outcome. Similar analyses were conducted after excluding patients admitted as transfers from outside hospitals and patients admitted through the emergency department, and outcomes were again similar. To confirm that the effects of specialty hospitals were similar for patients who had total hip replacement and those who had total knee replacement, additional models that included interactions between specialty hospital status and type of procedure were developed; none of the interactions were significant ($p > 0.05$). All analyses were performed with use of Stata SE 8.2 (Stata, College Station, Texas).

Results

Patient Characteristics

For total hip replacement, the thirty-eight specialty orthopaedic hospitals performed 4683 procedures, while the comparison group of 517 general hospitals performed 47,105 procedures on Medicare beneficiaries between 1999 and 2003. The percentage of total hip replacements that were classified as revisions was smaller for specialty hospitals (mean, 8.2%; range, 1.8% to 20.0%) than for general hospitals (mean, 12.8%; range, 1.3% to 33.3%), but this difference was not significant ($p = 0.19$)

The patients who underwent total hip replacement in specialty hospitals were less likely than the patients in general

TABLE I Demographic Data, Socioeconomic Measures, and Comorbidity of Patients Who Underwent Total Hip Replacement and Total Knee Replacement in Specialty Orthopaedic Hospitals and General Hospitals

	Total Hip Replacement			Total Knee Replacement		
Characteristic	Specialty Hospital (n = 4683)	General Hospital (n = 47,105)	P Value	Specialty Hospital (n = 10,234)	General Hospital (n = 89,531)	P Value
Demographic data						
Age* *(yr)*	75.0 ± 6.2	75.0 ± 6.3	0.43	75.0 ± 6.2	75.0 ± 6.2	0.57
Female patients (%)	2958 (63.2)	30,749 (65.3)	0.004	6584 (64.3)	58,678 (65.5)	0.02
Race						
Non-Hispanic white patients (%)	4393 (93.8)	43,279 (91.8)	0.01	9271 (90.6)	80,621 (90.1)	<0.008
Black patients (%)	198 (4.2)	2203 (4.7)	0.17	494 (4.8)	4984 (5.6)	0.002
Comorbidity						
Diabetes†						
All patients	494 (10.5)	5520 (11.7)	0.02	1329 (13.0)	14,131 (15.8)	<0.001
Patients with complications	17 (0.4)	345 (0.7)	0.004	54 (0.5)	731 (0.8)	0.002
Congestive heart failure†	136 (2.9)	2998 (6.4)	<0.001	218 (2.1)	3956 (4.4)	<0.001
Renal failure†	12 (0.3)	432 (0.9)	<0.001	38 (0.3)	480 (0.5)	0.03
Obesity†	163 (3.5)	1587 (3.4)	0.67	578 (5.6)	5306 (5.9)	0.25
Comorbid conditions according to Elixhauser et al.[30]*	2.1 ± 1.7	2.3 ± 1.6	<0.001	2.1 ± 1.6	2.3 ± 1.6	<0.001
High-risk conditions†						
Previous joint replacement	802 (17.1)	9514 (20.2)	<0.001	647 (6.3)	5834 (6.5)	0.45
Joint infection	‡	269 (0.6)	0.001	46 (0.4)	518 (0.6)	0.10
Fracture	125 (2.7)	5215 (11.1)	<0.001	‡	103 (0.12)	0.10
Admission source†						
Admitted from emergency department	‡	4162 (8.8)	<0.001	‡	531 (0.6)	<0.001
Admitted from outside hospital	42 (0.9)	438 (0.9)	0.82	‡	106 (0.12)	0.15
Socioeconomic measures*						
Home value *($)*	105,525 ± 61,350	99,685 ± 58,734	<0.001	101,613 ± 60,235	93,583 ± 52,109	<0.001
Per capita income *($)*	21,374 ± 8666	20,855 ± 9398	<0.001	20,599 ± 8409	20,007 ± 7698	<0.001
Predicted risk of adverse event *(%)*	4.2 ± 2.9	6.7 ± 6.9	<0.001	3.2 ± 1.8	3.7 ± 2.9	<0.001

*The data are given as the mean and the standard deviation. †The values are given as the number of patients with the percentage in parentheses. ‡Fewer than eleven patients were in this category so cell was suppressed to comply with CMS privacy guidelines.

hospitals to have diabetes (10.5% and 11.7%, respectively; $p = 0.02$), congestive heart failure (2.9% and 6.4%; $p < 0.001$), and renal failure (0.3% and 0.9%; $p < 0.001$). The patients in specialty hospitals also had a smaller number of comorbid conditions, as measured by Elixhauser et al.[30], than the patients in general hospitals (mean, 2.1 [range, zero to nine conditions] and 2.3 [range, zero to nine conditions], respectively) ($p < 0.001$), were less likely to have a number of important high-risk orthopaedic conditions such as an acute fracture (2.7% and 11.1%; $p < 0.001$), and were less likely to be admitted from the emergency department ($p < 0.001$) (Table I). In addition, the patients treated in specialty hospitals resided in zip codes with higher home values and per capita incomes ($p < 0.001$ for both). The mean predicted risk of the composite outcome, a summary estimate of case complexity, was lower for the patients who underwent total hip replacement in specialty hospitals (4.2%) than for those treated in general hospitals (6.7%) ($p < 0.001$).

For total knee replacement, the thirty-eight specialty hospitals performed 10,234 procedures while the 517 general hospitals performed 89,531 procedures. The percentage of total knee replacements that were classified as revisions was larger for the specialty hospitals (mean, 6.3%; range, 0.7% to 50.0%) than for the general hospitals (mean, 5.4%; range, 0.8% to 50.0%), but this difference was not significant ($p = 0.63$). The patients in specialty hospitals had lower rates of most comorbid conditions

TABLE II Characteristics of Specialty Orthopaedic and General Hospitals Performing Total Hip Replacement and Total Knee Replacement in 2003

Characteristic	Specialty Hospital (n = 38)	General Hospital (n = 517)	P Value
Major joint replacements*	108 ± 163	60 ± 107	0.01
Total hip replacement volume*	33 ± 61	20 ± 36	0.05
Total knee replacement volume*	75 ± 105	40 ± 72	0.006
Percentage of major joint replacements that were revisions*	5.9 ± 5.0	6.0 ± 10.0	0.92
Total no. of Medicare admissions in 2003*	250 ± 377	2261 ± 2496	<0.001
Proportion of total Medicare admissions within MDC8 in 2003*	0.82 ± 0.18	0.22 ± 0.07	<0.001
For-profit ownership *(no. [%] of hospitals)*	14 (37)	121 (23)	0.06

*The data are given as the mean and the standard deviation. MDC = major diagnostic category.

than the patients in general hospitals; these included diabetes (13.0% and 15.8%, respectively; $p < 0.001$), heart failure (2.1% and 4.4%; $p < 0.001$), and renal failure (0.3% and 0.5%; $p = 0.03$). The patients in the specialty hospitals had a smaller mean number of comorbid conditions than the patients in the general hospitals (2.1 conditions [range, zero to nine conditions] and 2.3 conditions [range, zero to ten conditions], respectively) ($p < 0.001$), but they had statistically similar rates for all high-risk orthopaedic conditions ($p > 0.05$ for all). In addition, the patients who underwent total knee replacement in the specialty hospitals were less likely ($p < 0.001$) to be admitted from the emergency department and were more likely to live in areas with higher home values and per capita incomes ($p < 0.001$). The mean predicted risk of the composite outcome was also lower for the patients who had total knee replacement in specialty hospitals (3.2%) than for those who had the procedure in general hospitals (3.7%) ($p < 0.001$).

Hospital Characteristics

The mean number of major joint replacements performed in 2003 was higher in the specialty hospitals (108 replacements; range, one to 637 replacements) than in the general hospitals (sixty replacements; range, one to 1045 replacements) ($p = 0.01$), but the percentage of major joint replacements classi-

TABLE III Data on Patients Undergoing Total Hip Replacement or Total Knee Replacement Who Experienced Selected Adverse Outcomes in Specialty and General Hospitals

	Total Hip Replacement*			Total Knee Replacement*		
Outcome	Specialty Hospital (n = 4683)	General Hospital (n = 47,105)	P Value	Specialty Hospital (n = 10,234)	General Hospital (n = 89,531)	P Value
Postoperative sepsis	11 (0.2)	350 (0.7)	<0.001	26 (0.2)	300 (0.3)	0.17
Postoperative hemorrhage	17 (0.4)	437 (0.9)	<0.001	36 (0.3)	442 (0.5)	0.05
Deep vein thrombosis	56 (1.2)	655 (1.4)	0.28	76 (0.7)	767 (0.9)	0.23
Pulmonary embolism	24 (0.5)	258 (0.5)	0.76	40 (0.4)	429 (0.5)	0.21
Postoperative wound infection	31 (0.7)	615 (1.3)	<0.001	66 (0.6)	937 (1.0)	<0.001
Patients who died within 90 days	37 (0.8)	1418 (3.0)	<0.001	43 (0.4)	752 (0.8)	<0.001
Primary joint replacement†	25 (0.6)	1076 (2.7)	<0.001	42 (0.4)	665 (0.8)	<0.001
Revision joint replacement†	12 (1.7)	342 (4.6)	<0.001	‡	87 (1.5)	0.006
Composite outcome for all patients	138 (3.0)	3245 (6.9)	<0.001	219 (2.1)	3500 (3.9)	<0.001
Primary joint replacement	113 (2.8)	2466 (6.2)	<0.001	204 (2.1)	3150 (3.8)	<0.001
Revision joint replacement	25 (3.5)	779 (10.0)	<0.001	15 (2.4)	350 (6.0)	<0.001

*The values are given as the number of patients, with the percentage in parentheses. †Primary and revision total hip replacements were done in 3978 and 705 patients, respectively, in the specialty hospitals and in 39,676 and 7429 patients, respectively, in the general hospitals. Primary and revision total knee replacements were done in 9598 and 636 patients, respectively, in the specialty hospitals and in 83,713 and 5818, respectively, in the general hospitals. ‡Fewer than eleven patients were in this category so cell was suppressed to comply with CMS privacy guidelines.

TABLE IV Unadjusted and Adjusted Odds Ratios of the Composite Adverse Outcome for Patients Who Underwent Total Hip or Total Knee Replacement in Specialty Hospitals Relative to Patients in General Hospitals as Determined by Generalized Estimating Equations

	All*		Primary Joint Replacement†		Revision Joint Replacement‡	
All Hospitals	Odds Ratios (95% Confidence Interval)	P Value	Odds Ratios (95% Confidence Interval)	P Value	Odds Ratios (95% Confidence Interval)	P Value
Unadjusted	0.47 (0.41-0.54)	<0.001	0.50 (0.44-0.58)	<0.001	0.32 (0.25-0.42)	<0.001
After adjustment for patient characteristics	0.57 (0.48-0.68)	<0.001	0.59 (0.51-0.69)	<0.001	0.42 (0.30-0.57)	<0.001
After adjustment for patient characteristics and procedural volume	0.62 (0.54-0.72)	<0.001	0.64 (0.56-0.75)	<0.001	0.49 (0.36-0.66)	<0.001

*The values are based on 14,917 patients with 357 adverse conditions in specialty hospitals and 136,636 patients with 6745 adverse conditions in general hospitals. †The values are based on 13,576 patients with 317 adverse conditions in specialty hospitals and 123,389 patients with 5616 adverse conditions in general hospitals. ‡The values are based on 1341 patients with forty adverse conditions in specialty hospitals and 13,247 patients with 1129 adverse conditions in general hospitals.

fied as revision procedures was similar in specialty and general hospitals (5.9% and 6.0%, respectively; $p = 0.92$) (Table II). As expected, the mean specialization index (i.e., the proportion of Medicare admissions categorized as Major Diagnostic Code 8) was higher for the specialty orthopaedic hospitals than for the general hospitals (0.82 and 0.22; $p < 0.001$). In addition, specialty hospitals were more likely than general hospitals to be for profit (36% and 23%, respectively), although this difference was not significant ($p = 0.06$).

Outcomes

For both total hip and total knee replacement, the patients treated in specialty hospitals were less likely than those treated in general hospitals to experience adverse outcomes such as postoperative hemorrhage, wound infection, and death (Table III). Thus, the composite outcome (defined as the proportion of patients experiencing one or more of the individual outcomes) was less common in the specialty hospitals than in the general hospitals with regard to primary total hip replacement (2.8% and 6.2%, respectively; $p < 0.001$), revision total hip replacement (3.5% and 11.0%; $p < 0.001$), primary total knee replacement (2.1% and 3.8%; $p < 0.001$), and revision total knee replacement (2.4% and 6.0%; $p < 0.001$).

In the regression analyses, the unadjusted odds of the composite outcome among all patients in the specialty hospitals compared with the general hospitals was 0.47 (95% confidence interval, 0.41 to 0.54; $p < 0.001$) (Table IV). After adjustment for patient characteristics, the odds of the composite adverse outcome were 0.57 (95% confidence interval, 0.48 to 0.68; $p < 0.001$), and they remained significant after further adjustment for patient characteristics and hospital procedural volume (odds ratio, 0.62; 95% confidence inter-

TABLE V Unadjusted and Adjusted Odds of the Composite Adverse Outcome for Patients Who Underwent Total Hip Replacement or Total Knee Replacement in Specialty Hospitals Relative to General Hospitals, Stratified According to Number of Comorbid Conditions

	0-1 Comorbid Condition*		2-3 Comorbid Conditions†		>3 Comorbid Conditions‡	
	Odds Ratios (95% Confidence Interval)	P Value	Odds Ratios (95% Confidence Interval)	P Value	Odds Ratios (95% Confidence Interval)	P Value
Unadjusted	0.53 (0.43-0.66)	<0.001	0.47 (0.39-0.57)	<0.001	0.43 (0.34-0.54)	<0.001
After adjustment for patient characteristics	0.62 (0.50-0.77)	<0.001	0.56 (0.47-0.67)	<0.001	0.52 (0.40-0.68)	<0.001
After adjustment for patient characteristics and procedural volume	0.67 (0.54-0.84)	<0.001	0.62 (0.52-0.73)	<0.001	0.57 (0.45-0.73)	<0.001

*The values are based on 5287 patients with 115 adverse outcomes in specialty hospitals and 43,139 patients with 1726 adverse outcomes in general hospitals. †These values are based on 6479 patients with 158 adverse outcomes in specialty hospitals and 61,700 patients with 3115 adverse outcomes in general hospitals. ‡These values are based on 3151 patients with eighty-four adverse outcomes in specialty hospitals and 31,797 patients with 1904 adverse outcomes in general hospitals.

TABLE VI Unadjusted and Adjusted Odds of the Composite Adverse Outcome for Patients Who Underwent Total Hip Replacement or Total Knee Replacement in Specialty Hospitals Relative to Those in General Hospitals, Stratified by Hospital Procedural Volume*

	Low-Volume Hospital†		Intermediate-Volume Hospital‡		High-Volume Hospital§	
	Odds Ratio (95% Confidence Interval)	P Value	Odds Ratio (95% Confidence Interval)	P Value	Odds Ratio (95% Confidence Interval)	P Value
Unadjusted	0.43 (0.28-0.65)	<0.001	0.47 (0.36-0.63)	<0.001	0.49 (0.42-0.59)	<0.001
After adjustment for patient characteristics	0.60 (0.40-0.89)	0.01	0.67 (0.51-0.87)	0.003	0.52 (0.42-0.66)	<0.001
After adjustment for patient characteristics and procedural volume	0.80 (0.51-1.26)	0.34	0.70 (0.55-0.88)	0.003	0.56 (0.46-0.68)	<0.001

*Low-volume hospitals are those that performed ≤50 major joint replacements in 2003; intermediate-volume hospitals, those that performed fifty-one to 250 major joint replacements in 2003; and high-volume hospitals, those that performed ≥251 major joint replacements in 2003. †The values are based on 2450 patients with sixty-three adverse outcomes in twenty-two specialty hospitals and 29,531 patients with 1715 adverse outcomes in 343 general hospitals. ‡The values are based on 4731 patients with 107 adverse outcomes in eleven specialty hospitals and 71,445 patients with 3331 adverse outcomes in 150 general hospitals. §The values are based on 7736 patients with 187 adverse outcomes in five specialty hospitals and 35,660 patients with 1699 adverse outcomes in twenty-four general hospitals.

val, 0.54 to 0.72; $p < 0.001$). In stratified analyses, specialty hospitals demonstrated improved outcomes for both primary joint replacement (odds ratio, 0.64; 95% confidence interval, 0.56 to 0.75; $p < 0.001$) and revision joint replacement (odds ratio, 0.49; 95% confidence interval, 0.36 to 0.66; $p < 0.001$) after adjusting for patient characteristics and hospital procedural volume (Table IV). When patients were stratified according to the number of comorbid conditions, as measured by Elixhauser et al.[30], the risk of adverse outcomes was again lower for patients treated in specialty hospitals for each of the patient subgroups (Table V).

Moreover, adverse outcomes were less common for patients in both high-volume and intermediate-volume specialty hospitals after adjustment for patient characteristics and hospital procedural volume but were statistically similar in low-volume hospitals (Table VI). Additional analyses comparing the occurrence of individual outcomes (e.g., death and joint infection) yielded similar results.

In secondary analyses, patients who were treated in specialty orthopaedic hospitals were more likely than those in general hospitals to require transfer to another acute-care hospital for primary total hip replacement (3.1% and 1.6%, respectively; $p < 0.001$), revision total hip replacement (4.0% and 1.7%; $p < 0.001$), primary total knee replacement (3.0% and 1.6%; $p < 0.001$), and revision total knee replacement (3.6% and 1.0%; $p < 0.001$). The mean length of hospitalization was statistically similar for the patients in specialty and general hospitals for both total hip replacement (4.53 and 4.54 days, respectively; $p = 0.80$) and total knee replacement (4.54 and 4.52 days; $p = 0.64$). After adjustment for patient characteristics and hospital procedural volume, the patients in the specialty hospitals had a 0.6% shorter length of stay for total hip replacement and a 0.5% shorter length of stay for total knee replacement, although neither of these differences was significant.

Discussion

Medicare patients undergoing joint replacement in specialty orthopaedic hospitals had a 50% lower risk of adverse outcomes than patients in a comparison group of general hospitals as measured by administrative data. The differences in outcomes remained after adjustment for patient characteristics and were consistent among both the patients who had a primary total joint replacement and those who had a revision. Specialty hospitals also had higher procedural volumes, but after accounting for this difference as well, the risk of adverse outcomes in specialty hospitals remained 40% lower. The consistency of these findings suggests that specialty orthopaedic hospitals may deliver care that leads to improved outcomes, although interpretation of these findings is limited by our lack of access to important clinical outcomes.

The finding that better outcomes in specialty hospitals persist after adjusting for procedural volume suggests that there may be benefits to the orthopaedic specialization of a hospital above and beyond the benefits of increased procedural volume alone. While the association between increased procedural volume and improved clinical outcomes has been well established[28,37-39], the relationship between hospital specialization and clinical outcomes is unclear[40-42]. The current findings suggest that hospital specialization may lead to improved patient outcomes, although the mechanism through which this might occur is currently unknown. Possible mechanisms may include the procedural volumes performed by individual orthopaedic surgeons, the expertise and experience of ancillary staff, or organizational factors including the use of clinical pathways or communication among the clinical teams[43]. Future studies are required to clarify which of these factors are most important.

The finding that patients admitted to specialty hospitals

for either total hip replacement or total knee replacement were significantly more likely than patients admitted to general hospitals to be transferred to another acute-care hospital following their procedures is also important. The fact that specialty hospitals had higher transfer rates for both primary and revision procedures suggests that this finding should not be attributed solely to the differences in the patient populations served by specialty and general hospitals. There are a number of potential explanations for this finding. Specialty hospitals claim that they are expressly designed to provide care to low-risk patients and that they are not designed to manage all complications that arise; thus, from this standpoint, the higher transfer rate from specialty hospitals may be justified for optimal patient outcomes. Alternatively, prior studies have demonstrated that hospitals may have financial incentives to transfer patients with more complicated (and more expensive) cases to other hospitals under the current Medicare prospective payment system[44,45]. From this perspective, it is possible that specialty hospitals might have other reasons to transfer patients with complications to other hospitals rather than manage such complications on-site.

Our finding that hospital length of stay was similar in specialty and general hospitals is somewhat unexpected, given the fact that specialty hospitals admit less complicated cases and these patients have lower complication rates, both of which would be expected to result in a longer length of stay at general hospitals. Moreover, our recent analysis of specialty cardiac hospitals demonstrated a similar finding[14]. One possible explanation is that general hospitals, under intense financial pressure, have already reduced hospital length of stay as much as possible, resulting in this small difference. Alternatively, it is possible that many new specialty hospitals, having opened relatively recently, have yet to optimize their hospital length of stay, resulting in a higher than expected length of stay.

The current findings add to our understanding of the relative quality of care provided by specialty hospitals in a number of ways. Most prior studies have focused on specialty cardiac hospitals. To our knowledge, the sole previous investigation of quality of care in specialty orthopaedic hospitals was performed by consultants under contract for CMS; the analysis found that after stratifying patients according to severity of illness (with use of the All-Patient Refined Diagnosis-Related Group methodology)[46], specialty orthopaedic hospitals had lower mortality rates than did general hospitals[16]. However, that prior analysis had a number of methodological limitations, which were addressed by the current study, including our use of a more refined risk-adjustment model, examination of a more robust set of adverse outcomes, and our assessment of outcomes in important subpopulations (e.g., patients undergoing primary and revision joint replacement). Moreover, our results suggest that the improved outcomes in specialty orthopaedic hospitals persist after adjustment for differences in hospital volume.

Our finding of significantly improved outcomes in specialty orthopaedic hospitals contrasts with the available data assessing outcomes in specialty cardiac hospitals. While some studies have described mortality rates that were 20% to 50% lower in specialty cardiac hospitals[16], we found that mortality rates in specialty cardiac and general hospitals were similar for percutaneous coronary interventions and coronary artery bypass graft surgery after adjustment for patient characteristics and hospital volume[14]. This led us to conclude that there was no inherent advantage to specialty cardiac hospitals.

There are several possible explanations for the differences between the results of the current study and our prior analysis of cardiac hospitals. One possibility is that the benefits of specialization are greatest in surgical settings. Thus, specialty orthopaedic hospitals receive substantial benefit from their specialization, while specialty cardiac hospitals that typically perform a combination of surgical procedures (e.g., bypass surgery), medical procedures (e.g., angioplasty), and general cardiac care may receive less benefit from specialization. Alternatively, it is possible that the stringent regulation of cardiac care in many states through certificate-of-need programs has resulted in regionalization of cardiac care to a relatively smaller number of hospitals, thereby minimizing the differences in outcomes between specialty and general cardiac hospitals; since major joint replacement has generally not faced such regulatory oversight, differences in outcomes between specialty and general hospitals may be larger[47].

The policy implications of the current study are important, particularly given the recent decision by the United States Congress to allow a temporary moratorium on specialty hospital growth to expire, thereby setting the stage for further specialty hospital expansion[1,2]. Our results support the contention that specialty hospitals focus primarily on low-risk patients, thus taking advantage of well-documented inconsistencies in Medicare's diagnosis-related-group-based reimbursement system that effectively overreimburses hospitals for providing care to low-risk patients while underreimbursing them for high-risk patients[48]. CMS is aware of this potential problem and is taking steps to update the prospective payment system[49]. By demonstrating improved outcomes in orthopaedic specialty hospitals, the current study is likely to add to the momentum favoring the growth of specialty orthopaedic hospitals. It will be important for general hospitals to investigate the clinical factors (e.g., the use of clinical pathways) and organizational factors (e.g., the composition of patient-care teams) that specialty orthopaedic hospitals are using and consider adapting them to their own institutions.

It is important to acknowledge the potential limitations to our work. First, our analysis was limited to Medicare beneficiaries so extrapolation of the results to other patients must be done with caution; future analyses should include a more heterogeneous mix of patients such as those with Medicaid or private insurance. Second, our analysis relied on claims data, which may underestimate differences in patients treated in specialty and general hospitals. Even though our findings were consistent among patients having primary and revision

joint replacement, it is possible that our models were unable to adequately adjust for differences between the patients in specialty hospitals and those in general hospitals. In addition, our reliance on administrative data may have resulted in the underestimation of the rates of certain adverse outcomes (e.g., deep vein thrombosis)[27]. Third, our results may be subject to systematic differences between specialty and general hospitals in the capture of ICD-9-CM diagnosis and procedure codes, resulting in biased estimates of risk-adjusted differences in outcomes; however, it is unlikely that unadjusted risk would fully account for the 40% reduction in adverse outcomes that was observed in specialty orthopaedic hospitals. Fourth, the study examined a limited number of outcomes and did not consider important clinical outcomes such as functional status or patient satisfaction. Finally, while our definition of specialty orthopaedic hospitals is consistent with definitions used by both policy makers and other investigators, there remains debate over precisely how to define specialty hospitals. In particular, it is unclear to what extent specialty hospitals should be defined by the presence of physician owner-investors and for-profit or not-for-profit status. Future research is needed to clarify these issues.

In summary, the current findings demonstrate lower rates of adverse outcomes in specialty orthopaedic hospitals relative to general hospitals after adjustment for patient characteristics and hospital procedural volume. This suggests that orthopaedic specialization may lead to better patient outcomes. Further analyses with use of clinical registries are warranted to verify our findings.

Appendix

eA Tables showing comorbid conditions, as measured according to Elixhauser et al.[30], and the independent variables included in the final risk adjustment model are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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References

1. Casalino LP, Devers KJ, Brewster LR. Focused factories? Physician-owned specialty facilities. Health Aff (Millwood). 2003;22:56-67.

2. Iglehart JK. The emergence of physician-owned specialty hospitals. N Engl J Med. 2005;352:78-84. Erratum in: N Engl J Med. 2005;352:638.

3. In the (specialty) hospital. Wall Street J. 2005 Jan 3;A8.

4. Urquhart DJB, O'Dell A. A model of focused health care delivery: Shouldice Hospital. In: Herzlinger RE, editor. Consumer-driven health care: implications for providers, payers, and policy makers. San Francisco: Jossey-Bass; 2004. Chapter 58.

5. Report to the Congress. Physician-owned specialty hospitals. Washington, DC: United States General Accounting Office; 2005:1-51. http://www.medpac.gov/publications/congressional_reports/Mar05_SpecHospitals.pdf. Accessed 2007 Jan 17.

6. Specialty Hospitals: information on national market share, physician ownership and patients served. GAO-03-683R. Washington, DC: United States General Accounting Office; 2003:1-20. http://www.gao.gov/new.items/d03683r.pdf. Accessed 2004 Feb 18.

7. Reilly P. Picking patients. GAO: specialty hospitals serve fewer uninsured. Mod Healthc. 2003;33:6-7.

8. Devers KJ, Brewster LR, Ginsburg PB. Specialty hospitals: focused factories or cream skimmers? Issue Brief Cent Stud Health Syst Change. 2003;62:1-4.

9. Voelker R. Specialty hospitals generate revenue and controversy. JAMA. 2003;289:409-10.

10. Groeller G. 'Boutique' hospitals on horizon: state proposal would ease way for specialty hospitals. Orlando Sentinel. 2003 Dec 28;H1.

11. Wilson BC. My hospital was doomed. Wall Street J. 2006 Jan 5;A20.

12. Medicare Prescription Drug, Improvement, and Modernization Act of 2003. Pub. L. 108-173; 2003. http://www.cms.hhs.gov/MMAUpdate/. Accessed 2007 Jun 8.

13. Dobson A, Haught R, Sen N. Specialty heart hospital care: a comparative study. Am Heart Hosp J. 2003;1:21-9.

14. Cram P, Rosenthal GE, Vaughan-Sarrazin MS. Cardiac revascularization in specialty and general hospitals. N Engl J Med. 2005;352:1454-62.

15. Specialty Hospitals: geographic location, services provided, and financial performance. GAO-04-167. Washington, DC: United States General Accounting Office; 2003:1-41. http://www.gao.gov/htext/d04167.html. Accessed 2007 Jun 8.

16. Center for Medicare and Medicaid Services. Study of physician-owned specialty hospitals required in Section 507(c)(2) of the Medicare Prescription Drug, Improvement, and Modernization Act of 2003. 2005. http://www.cms.hhs.gov/MLNProducts/Downloads/RTC-StudyofPhysOwnedSpecHosp.pdf. Accessed 2007 Jun 8.

17. Greenwald L, Cromwell J, Adamache W, Bernard S, Drozd E, Root E, Devers K. Specialty versus community hospitals: referrals, quality, and community benefits. Health Aff (Millwood). 2006;25:106-18.

18. Mitchell JB, Bubolz T, Paul JE, Pashos CL, Escarce JJ, Muhlbaier LH, Wiesman JM, Young WW, Epstein RS, Javitt JC. Using Medicare claims for outcomes research. Med Care. 1994;32(7 Suppl):JS38-51.

19. United States Census Bureau. United States Census 2000. Available at: http://www.census.gov/main/www/cen2000.html. Accessed 2007 June 8.

20. The Dartmouth Atlas of Health Care. Vol. 2004; 2000. Available at: http://www.dartmouthatlas.org/. Accessed 2007 Jan 17.

21. American Hospital Association Annual Surgery Database for fiscal year 2000. Chicago, IL: American Hospital Association. www.ahadata.com.

22. Rosenthal GE, Harper DL, Quinn LM, Cooper GS. Severity-adjusted mortality and length of stay in teaching and nonteaching hospitals. Results of a regional study. JAMA. 1997;278:485-90.

23. Welch WP, Miller ME, Welch HG, Fisher ES, Wennberg JE. Geographic varia-

tion in expenditures for physicians' services in the United States. N Engl J Med. 1993;328:621-7.

24. Birkmeyer JD, Sharp SM, Finlayson SR, Fisher ES, Wennberg JE. Variation profiles of common surgical procedures. Surgery. 1998;124:917-23.

25. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright RJ, Losina E. Association between hospital and surgeon procedure volume and the outcomes of total knee replacement. J Bone Joint Surg Am. 2004;86:1909-16.

26. Norton EC, Garfinkel SA, McQuay LJ, Heck DA, Wright JG, Dittus R, Lubitz RM. The effect of hospital volume on the in-hospital complication rate in knee replacement patients. Health Serv Res. 1998;33:1191-210.

27. Phillips CB, Barrett JA, Losina E, Mahomed NN, Lingard EA, Guadagnoli E, Baron JA, Harris WH, Poss R, Katz JN. Incidence rates of dislocation, pulmonary embolism, and deep infection during the first six months after elective total hip replacement. J Bone Joint Surg Am. 2003;85:20-6.

28. Katz JN, Losina E, Barrett J, Phillips CB, Mahomed NN, Lew RA, Guadagnoli E, Harris WH, Poss R, Baron JA. Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States Medicare population. J Bone Joint Surg Am. 2001;83:1622-9.

29. Patient safety indicators download. AHRQ quality indicators. Rockville, MD: Agency for Healthcare Research and Quality. http://www.qualityindicators.ahrq.gov/psi_download.htm. Accessed 2007 Jun 8.

30. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care. 1998;36:8-27.

31. Katz JN, Losina E, Barrett J, Phillips CB, Mahomed NN, Lew RA, Guadagnoli E, Harris WH, Poss R, Baron JA. Appendix to: Association between hospital and surgeon procedural volume and outcomes of hip replacement in the United States medicare population. J Bone Joint Surg Am. 2001;83:1622-9. http://www.ejbjs.org/cgi/content/full/83/11/1622/DC1. Accessed 2007 Jun 8.

32. Hervey SL, Purves HR, Guller U, Toth AP, Vail TP, Pietrobon R. Provider volume of total knee arthroplasties and patient outcomes in the HCUP-Nationwide Inpatient Sample. J Bone Joint Surg Am. 2003;85:1775-83.

33. Lemeshow S, Hosmer DW Jr. A review of goodness of fit statistics for use in the development of logistic regression models. Am J Epidemiol. 1982; 115:92-106.

34. Ash AS, Schwartz M. Evaluating the performance of risk-adjustment methods: dichotomous outcomes. In: Iezzoni LI, editor. Risk adjustment for measuring health care outcomes. 2nd ed. Chicago: Health Administration Press; 1997. p 427-70.

35. Liang K, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika. 1986;73:13-22.

36. White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica. 1980;48:817-30.

37. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, Welch HG, Wennberg DE. Hospital volume and surgical mortality in the United States. N Engl J Med. 2002;346:1128-37.

38. Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. JAMA. 1998;280:1747-51.

39. Birkmeyer JD, Finlayson EV, Birkmeyer CM. Volume standards for high-risk surgical procedures: potential benefits of the Leapfrog initiative. Surgery. 2001; 130:415-22.

40. Herzlinger RE. Specialization and its discontents: the pernicious impact of regulations against specialization and physician ownership on the US healthcare system. Circulation. 2004;109:2376-78.

41. Casey J. The case for specialty hospitals. MedCath CEO argues that such facilities don't weaken community hospitals. Mod Healthc. 2004;34:21.

42. Herzlinger RE. Hamburgers and hernias. The Economist. 1997 Aug 9;55.

43. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med. 2003;349:2117-27.

44. Koval KJ, Tingey CW, Spratt KF. Are patients being transferred to level-I trauma centers for reasons other than medical necessity? J Bone Joint Surg Am. 2006;88:2124-32.

45. Rosenberg AL, Hofer TP, Strachan C, Watts CM, Hayward RA. Accepting critically ill transfer patients: adverse effect on a referral center's outcome and benchmark measures. Ann Intern Med. 2003;138:882-90.

46. Romano PS, Chan BK. Risk-adjusting acute myocardial infarction mortality: are APR-DRGs the right tool? Health Serv Res. 2000;34:1469-89.

47. Vaughan-Sarrazin MS, Hannan EL, Gormley CJ, Rosenthal GE. Mortality in Medicare beneficiaries following coronary artery bypass graft surgery in states with and without certificate of need regulation. JAMA. 2002;288:1859-66.

48. Gaskin DJ, Hadley J, Freeman VG. Are urban safety-net hospitals losing low-risk Medicaid maternity patients? Health Serv Res. 2001;36:25-51.

49. Guterman S. Specialty hospitals: a problem or a symptom? Health Aff (Millwood). 2006;25:95-105.