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SECTION II
ORIGINAL ARTICLES

The Association between Hospital Volume and Total Shoulder Arthroplasty Outcomes

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The purpose of this study was to evaluate the relationship between increasing hospital volume and the following outcomes for total shoulder arthroplasties done in the state of New York: length of stay, hospital costs, readmission within 60 days, revision surgery within 24 months, and death within 60 days. The Statewide Planning and Research Cooperative System (SPARCS) database from the New York State Department of Health, a census of all hospital discharges in the state, was used to evaluate the relationship between hospital volume and outcomes for total shoulder arthroplasties for 1996 to 1999. One thousand three hundred seven total shoulder arthroplasties were done in New York from 1996 to 1999. Nearly ½ were done at the five highest-volume hospitals. Middle-volume hospitals has the least lengths of stay and hospital costs. Independent of age and comorbidities, patients at hospitals with greater volumes of total shoulder arthroplasties were at reduced risk of patients being readmitted within 60 days. No other outcomes were significantly associated with hospital volume. The finding that greater hospital volume decreases risk of readmission may have important public health implications, but additional research is needed before implementing policy changes.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See the Guidelines for Authors for a complete description of levels of evidence.

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Outcomes for total hip and total knee arthroplasties have been associated with surgeon and hospital procedure volume.[7,11–13,15,16,18] Improved outcomes found to be associated with increased volume include decreased risk of in-hospital complications and mortality, decreased length of stay, posthospital complications (including dislocation, infection, and pulmonary embolus), revision surgery, and posthospital death.[7,11–13,15,16,18] Similar associations have been found for patients admitted for hip fractures.[9] Hammond et al evaluated the relationship between surgeon and hospital volume for total shoulder arthroplasties and hemiarthroplasties combined.[8] They found that surgeons who did high volumes of surgeries had fewer complications and shorter lengths of stay compared with surgeons who did low volumes of shoulder arthroplasties, but they did not consider longer-term outcomes such as readmission, reoperation, or posthospital mortality.

Although total shoulder arthroplasty is not as common as total hip or knee replacement, there were approximately 8000 total shoulder arthroplasties done in the US in 1999 according to data from the National Hospital Discharge Survey provided by the Centers for Disease Control and Prevention. Previous studies have shown that total shoulder arthroplasty improves pain, function, and satisfaction for patients with various orthopaedic and rheumatologic diagnoses.[17,21,22] The purpose of our study was to evaluate the relationship between increasing hospital volume and the following outcomes for total shoulder arthroplasty done in New York: length of stay, hospital costs, readmission within 60 days, revision surgery within 24 months, and death within 60 days.

MATERIALS AND METHODS

The Statewide Planning and Research Cooperative System (SPARCS) database from the New York State Department of Health, a census of all hospital discharges in the state, was used to evaluate the relationship between hospital volume and outcomes for total shoulder arthroplasties. The Statewide Planning and Research Cooperative System has been operational since 1982 and provides more than 20 years of hospital discharge data for the state. However, unique patient identifiers were not available until recently. Therefore, this study was restricted to SPARCS records for 1996 to 1999.

Subjects were enrolled in this study if they had a total shoulder arthroplasty (ICD-9-CM procedure 81.80) done in a New York hospital from 1996 to 1999. Hemiarthroplasty of the shoulder was not included to keep the subjects as similar as possible. Patients were excluded from the analysis if their total shoulder arthroplasty was done because of a fracture or other acute trauma (ICD-9-CM diagnoses of 716.12, 718.31, 727.61, 811.00, 812.00-812.09, 812.20, 812.21, 831.00-831.02, and 840.4 were excluded). All other diagnoses were considered nonemergent, assuring the study population included only elective procedures.

Outcomes of interest available in the SPARCS database included death, readmission, revision surgery, length of stay, and hospital costs. Readmission or death within 60 days of discharge from the index surgical admission and revision total shoulder arthroplasty within 12 to 24 months of surgery were considered clinically meaningful outcomes. Secondary outcomes include length of stay and adjusted cost of hospitalization. Hospital costs included total hospital charges reported on the inpatient bill for each patient. Cost adjustments were made using the area wage index used by Medicare.[19] This was done to account for the wide variation in the cost of hospital care in the state. This variation is most apparent for New York City compared with the remainder of the state. However, the area wage index is based on selected hospital employee salaries and does not consider the potentially large differences in other costs, such as real estate, building maintenance, utilities, and supplies.

Patients residing outside New York state were only included in the analysis of length of stay and hospitalization cost because these patients may have had readmission, death, or revision surgery in their home state.

The primary risk factor of interest was the number of total shoulder arthroplasties done at the hospital during the 4-year period for which data were collected (1996–1999). This variable was divided in tertiles. The comparison group (low-volume hospitals) included centers in which fewer than one total shoulder arthroplasty per quarter year (1–15 cases during study period) was done. Middle-volume hospitals were those in which one or more total shoulder arthroplasties were done per quarter, but less than one per month was done (16–47 cases). High-volume hospitals were those in which at least one total shoulder arthroplasty was done per month (48 or more cases). These tertiles were chosen as clinically relevant groupings of the frequency of total shoulder arthroplasties done in New York hospitals. Because of the relative rarity of these procedures, surgeons from numerous hospitals do these procedures less than once per quarter and others less than once per month. These represented the low-volume and middle-volume hospitals respectively.

Covariates of interest included age, gender, race/ethnicity, and comorbidities. Comorbidities were defined using the comorbidity scale described by Charlson et al,[4] adjusted for use with administrative data as described by Deyo et al.[5] This adjustment accounts for acute comorbidities that may have occurred during the admission of interest rather than being part of the preexisting comorbidity profile. This comorbidity index was developed to predict death during cardiac admissions, but is used as a measure of comorbid conditions for various medical outcomes.

Statistical analysis consisted of descriptive and inferential statistics. Variables were described using means, medians, minimums, maximums, and standard deviations for continuous variables and counts and percentages for categorical variables. Inferential analysis was done using the Fisher's exact test because of the small number of events for some outcome variables (eg, death within 60 days). Skewed continuous outcome measures (length of stay and adjusted hospital costs) were analyzed using the Kruskal-Wallis test for nonnormally distributed data with a post hoc Mann-Whitney U test for pair-wise comparisons. Comparisons of ordinal variables with adequate sample size were done using a Cochran Mantel-Haenszel Nonzero Correlation Coefficient to test for linear trend.

A generalized estimating equation was used for multivariable analysis of the outcome of readmission within 60 days to control for clustering of a large number of patients in a small number of hospitals, particularly in the high-volume category. Readmission at 60 days was the only study outcome that occurred with sufficient frequency to build a stable generalized estimating question. Generalized estimating equations were built by forcing the primary exposure variable of interest (hospital volume) into the model. All potential covariates were tested using simple generalized estimating equations. These covariates also were included in bivariable generalized estimating equations with hospital volume. Those that were significant predictors of readmission in simple and bivariable models were considered for inclusion in the full model. The most parsimonious model was that in which each independent variable in addition to hospital volume was associated with readmission ($p = < 0.10$), but in which no additional measured covariates would be significantly associated with readmission when placed into the model.

Collinearity was measured for variables that were thought to be potentially highly correlated such as age and the Charlson comorbidity score using linear regression plots. R^2 values greater that 0.90 were considered collinear and those variables would not be placed into the same logistic models. No collinear variables were identified in this analysis.

RESULTS

There were 1307 total shoulder arthroplasties used for these analyses (Table 1). The patients included 57%

TABLE 1. Description of Study Subjects

Variables	Count	Percent
Numerator	1307	–
Age (years)		
69 or younger	733	56.1
70–79	445	34.0
80 or older	129	9.9
Gender		
Men	566	43.3
Women	741	56.7
Outcome		
Readmission within 60 days of TSA	87	6.7
Death within 60 days of TSA	3	0.2
Revision of TSA within 12 months	21	1.6
Revision of TSA within 24 months	30	2.3
Length of stay (mean, 3.6 days)		
1–3 days	827	63.3
4–7 days	426	32.6
8–14 days	39	3.0
15–21 days	6	0.5
22–47 days	9	0.7
Adjusted hospital costs (mean, $9120)		
$4999 or less	151	11.6
$5000 to $9999	691	52.9
$10,000 to $14,999	397	30.4
$15,000 to $19,999	41	3.1
$20,000 to $33,083	27	2.1
Exposure		
Low volume – 1 to 15 TSA (103 hospitals)	463	35.4
Middle volume – 16 to 47 TSA (10 hospitals)	232	17.8
High volume – 48+ TSA (5 hospitals)	612	46.8
Charlson score (comorbidity measure)		
0	994	76.1
1	198	15.1
2+	115	8.8

women, 10% were ethnic or racial minorities, and the mean age at surgery was 65.6 years. Most of the patients were hospitalized for less than 4 days (63.3%), and most had adjusted hospital costs less than $10,000 (64.5%). Nearly ½ of the patients (46.8%) has surgery at the five high-volume hospitals, which averaged 41.6 patients per study year. Comparatively, the low-volume hospitals averaged 2.0 patients per study year and the middle-volume hospitals averaged 6.6 patients per study year. Seventy-six percent of the patients had no comorbidities using the Charlson score with Deyo modification. Eighty-seven patients were readmitted to the hospital within 60 days of discharge after total shoulder arthroplasty. Three patients died within 60 days. Thirty patients required revision total shoulder arthroplasty within 2 years of the index surgery, 21 of these during the first year.

A trend ($p = 0.02$) was seen between age and hospital volume with younger patients having, on average, surgery at higher-volume centers compared with older patients (Table 2). This inverse association also was seen between adjusted Charlson comorbidity score and hospital volume with patients from low-volume hospitals having more comorbid conditions than patients from high-volume hospitals ($p < 0.001$).

Length of stay was longest for patients in the low-volume hospitals with a stay length longer than for patients in middle-volume hospitals, but not longer than for patients in high-volume hospitals ($p < 0.01$) (Table 3). Likewise, patients in high-volume hospitals had a longer stay length than patients in middle-volume hospitals ($p < 0.01$).

Hospital charges were significantly different ($p < 0.01$) between low-, middle-, and high-volume hospitals with the highest charges in the high-volume hospitals and the lowest charges in the middle-volume hospitals (Table 4). These associations were maintained when a log transformation was done to normalize length of stay and hospital charges and analyzed using a one-way analysis of variance.

Of all other outcome measures, only readmission within 60 days was associated with ($p < 0.01$) hospital volume in bivariable analysis (Table 5). Readmission within 60 days

TABLE 2. Age and Adjusted Charlson Comorbidity Rating by Hospital Volume

Variable	Low Volume Number (%)	Middle Volume Number (%)	High Volume Number (%)
Age category (years)			
69 or younger	243 (52.5)	130 (56.0)	360 (58.8)
70–79	164 (35.4)	81 (34.9)	200 (32.7)
80 or older	56 (12.1)	21 (9.1)	52 (8.5)
p value = 0.02*			
Adjusted Charlson score			
0	315 (68.0)	178 (76.7)	501 (81.9)
1	87 (18.8)	31 (13.4)	80 (13.1)
2+	61 (13.2)	23 (9.9)	31 (5.1)
p value < 0.001*			

*Cochrane Mantel-Haenszel linear test for trend (Nonzero Correlation Statistic)

TABLE 3. Length of Stay by Hospital Volume

Length of Stay (in days)	Low Volume (1–15)	Middle Volume (16–47)	High Volume (48+)
Median	3	3	3
Mean*,†	3.9	3.1	3.6
Standard deviation	3.8	2.5	2.1
Minimum - Maximum	1–47	1–23	1–26

*Kruskal-Wallis ($p < 0.01$); †Mann-Whitney U middle volume versus low and high volume ($p < 0.01$)

was highest among patients from low-volume hospitals (9.5%) and lowest among patients from high-volume hospitals (4.6%). However, for revision surgery and death within 60 days, the high-volume hospitals had lower frequencies than the low- or middle-volume hospitals. No deaths occurred in the high-volume hospitals despite the high-volume category representing nearly ½ of all patients.

A generalized estimating equation was modeled to evaluate the effect of the available independent variables on the risk of readmission within 60 days (Table 6). Hospital volume, age, and Deyo-modified Charlson score were all independent predictors of hospital readmission. It seems that there is a reduction in readmission risk within 60 days for all hospital with volumes of 16 cases or greater, although the reduction is not statistically significant until the high-volume category is attained (48+ cases). Likewise, patients were more likely to be readmitted as they aged regardless of comorbidities or hospital volume ($p < 0.01$). Only patients with comorbidity scores of 2 or greater were found to have a modest, nonsignificant increased risk of readmission after adjustment for age and hospital volume ($p = 0.06$), but they were included in the model because of the model building criteria ($p < 0.10$ were retained). Gender and race were not independent predictors of readmission.

DISCUSSION

Previous studies have documented that the outcomes of many operations are related to the volume of that procedure done at an institution.[1–3,6,7,11–15,16,18,20] To date, there are no data on the relationship between institution volume and posthospital outcomes of total shoulder arthroplasty. The other studies evaluating shoulder arthroplasty volume and outcome only considered length of stay, in-hospital complications, and death while combining total shoulder arthroplasties and hemiarthroplasties.[9,10]

A limitation with any study using administrative data is the paucity of clinical information available on the patients. There is no information regarding pain or functional status of these patients, relying solely on risk of readmission, revision surgery, and death as proxies for these outcomes. Furthermore, there is no information available on the return to activities of daily living or any patient-based measures of quality of life. However, these limitations are offset by the enormous volumes available for analysis using these databases.

Although some information was lost by converting hospital volume from a continuous to categorical variable, clinically relevant categories of total shoulder arthroplasties were identified. Furthermore, there were a large number of low-volume hospitals (103) in the state contributing fewer operations (463) than a small number of high-volume hospitals (612 operations in five hospitals). However, this was accounted for by using a generalized estimating equation. Something not accounted for in this study is surgeon volume. This study reflects hospital volume only, which may be a more relevant factor if the volume-outcomes relationship is precipitated by the ability of the institution and ancillary staff to care for these patients before and after surgery.

TABLE 4. Adjusted Hospital Costs by Hospital Volume

Adjusted Hospital Costs	Low Volume (1–15)	Middle Volume (16–47)	High Volume (48+)
Median	$8793	$7542	$9288
Mean*,†,‡	$9257	$8206	$9364
Standard deviation	$4695	$3414	$3580
Minimum - Maximum	$583–$33,083	$1279–$22,464	$839–$29,511

*Kruskal-Wallis ($p < 0.01$); †Mann-Whitney U low volume versus high volume ($p = 0.03$); ‡Mann-Whitney U middle volume versus low and high volume ($p < 0.01$)

TABLE 5. Univariate Analyses for Outcome Measures

Outcome	Low Volume (1–15)	Middle Volume (16–47)	High Volume (48+)	p Value*
Readmission within 60 days	44 (9.5%)	15 (6.5%)	28 (4.6%)	< 0.01
Revision within 12 months	8 (1.7%)	6 (2.6%)	7 (1.1%)	0.33
Revision within 24 months	12 (2.6%)	7 (3.0%)	11 (1.8%)	0.44
Death within 60 days	2 (0.4%)	1 (0.4%)	0 (0.0%)	0.19
Total cases	461	231	612	

*Fisher's exact test for trend

In this study, many of the outcomes were relatively infrequent such as revision surgery and death. The most frequent adverse outcome was readmission to the hospital within 60 days; therefore, this variable was most suitable for additional analysis. Moreover, this is a very clinically relevant outcome, as readmission is a major inconvenience to the patient and often is related to a significant adverse health outcome. Furthermore, there are important cost implications related to readmission to hospital.

In this analysis, the high-volume hospitals had a lower readmission rate compared with the middle- and low-volume hospitals even after adjustment for age and comorbid conditions. There was a trend toward lower readmission rates in hospitals with higher volumes, although the relationship was only statistically significant between the highest- and lowest-volume institutions. The lower readmission rates in the middle- and high-volume hospitals reflects a clinically significant finding.

Other adverse outcomes, such as revision surgery, major complications, and death, also had lower rates in the high-volume hospitals; however, these trends were not statistically significant because of the infrequency of these outcomes and the resulting lack of statistical power.

TABLE 6. Generalized Estimating Equation for Readmission within 60 Days

Variables	Odds Ratio	95% C.I.	p Value*
Total hospital volume			
1–15	Referent	–	0.02
15–47	0.74	0.39, 1.40	
48+	0.44	0.21, 0.89	
Age of patient (years)			
10–69	Referent	–	< 0.01
70–79	1.72	1,01, 2.93	
80+	3.03	1.50, 6.11	
Charlson score			
0	Referent	–	0.06
1	1.23	0.77, 1.97	
2+	2.19	0.99, 4.83	

*Test for trend; C.I. = confidence interval

The length of stay overall was not widely different among the strata of hospital volume (range, 3.1–3.9 days). The shortest lengths of stay were in the middle-volume hospitals, which is consistent with the findings from a previous evaluation of length of stay and hospital volume,[9] but not another.[10] Not surprisingly, the length of stay was related to adjusted hospital costs. The middle-volume hospitals had the lowest adjusted hospital costs, as compared with the low- and high-volume institutions. This also was consistent with results of a previous study in which investigators found that middle-volume hospitals had the shortest length of stay.[9] The middle-volume hospitals also had the shortest mean length of stay, which may account for some of the difference in adjusted hospital costs. The hospital costs in high-volume hospitals were greater than the costs in low-volume hospitals despite low-volume hospitals having older patients with more comorbidities. This disparity may represent a deficiency in the adjustment method for calculating hospital costs. Four of the five high-volume hospitals were in Manhattan (the other on Long Island), which likely would have much higher operating costs than anywhere else in the state.

Overall, this study showed there were lower, but not necessarily significant, rates of all adverse outcomesin patients having a total shoulder arthroplasty in hospitals with higher volume; but only readmission within 60 days was statistically significant. Patients in the low-volume institutions tended to be older and had higher comorbidity scores, thus indicating that they were less healthy. However, when readmission rates were adjusted for age and comorbidity, hospital volume remained a statistically significant predictor.

The fact that older patients who were sicker tended to go to lower-volume institutions as compared with younger, healthier patients, may reflect a lack of access to the high-volume centers for patients who are older and infirm. The inconvenience and costs of travel may reflect a barrier for these individuals.

Our study is the first to show a relationship between an increased hospital volume of total shoulder arthroplasties and improved outcome, particularly a decreased risk of readmission within 60 days. This may have important health policy implications, although the relationship needs additional study with a larger cohort before implementation of any policy changes.

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