The effect of surgeon and hospital volume on shoulder arthroplasty perioperative quality metrics

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Background: There has been a significant increase in both the incidence of shoulder arthroplasty and the number of surgeons performing these procedures. Literature regarding the relationship between surgeon or hospital volume and the performance of modern shoulder arthroplasty is limited. This study examines the effect of surgeon or hospital shoulder arthroplasty volume on perioperative metrics related to shoulder hemiarthroplasty, total shoulder arthroplasty, and reverse shoulder arthroplasty. Blood loss, length of stay, and operative time were the main endpoints analyzed.

Methods: Prospective data were analyzed from a multicenter shoulder arthroplasty registry; 1176 primary shoulder arthroplasty cases were analyzed. Correlation and analysis of covariance were used to examine the association between surgeon and hospital volume and perioperative metrics adjusting for age, sex, and body mass index.

Results: Surgeon volume is inversely correlated with length of stay for hemiarthroplasty and total shoulder arthroplasty and with blood loss and operative time for all 3 procedures. Hospital volume is inversely correlated with length of stay for hemiarthroplasty, with blood loss for total and reverse shoulder arthroplasty, and with operative time for all 3 procedures. High-volume surgeons performed shoulder arthroplasty 30 to 50 minutes faster than low-volume surgeons did.

Conclusions: Higher surgeon and hospital case volumes led to improved perioperative metrics with all shoulder arthroplasty procedures, including reverse total shoulder arthroplasty, which has not been previously described in the literature. Surgeon volume had a larger effect on metrics than hospital volume did. This study supports the concept that complex shoulder procedures are, on average, performed more efficiently by higher volume surgeons in higher volume centers.

Level of evidence: Level III, Retrospective Cohort Design, Treatment Study.

Keywords: Shoulder arthroplasty; surgeon volume; hospital volume

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Since 1993, the rate of shoulder arthroplasty procedures has increased rapidly in the United States, mirroring the aging population, increase in number of practicing orthopaedic surgeons, technologic advances, and expanding indications for these procedures. Whereas the total number of hip and knee arthroplasties remains an order of magnitude higher than shoulder arthroplasties, the annual incidence of shoulder arthroplasty is increasing by a greater percentage every year.11

There are several reasons that new outcome and efficiency data regarding shoulder arthroplasty are important. First, there have been several fundamental changes in the biomechanics of total shoulder replacement. In the past decade, we have seen the advent of anatomic systems instead of a standard “one size fits all” approach. Uncemented implants are now common, and subscapularis repair technique has undergone significant innovations.14 The most radical development has been the widespread use of the reverse total shoulder,1,5 which was approved by the Food and Drug Administration in 2004. There are no studies of reverse total shoulder arthroplasty and clinical volume despite the technical complexity of the procedure.

Second, shoulder arthroplasty is a relatively rare procedure. In 2003, Hasan and Matsen found that more than 75% of surgeons who perform shoulder arthroplasty perform 1 or 2 procedures per year. Conversely, a 2004 study by Katz demonstrated that 75% of surgeons who perform total knee arthroplasty perform at least 13 procedures annually.15 This trend may be of concern as the published complication rate of the reverse total shoulder arthroplasty varies from 1% to more than 65% even in the hands of experienced designing surgeons.39 The reported intraoperative complications that the surgeon has to control for are myriad, including neurologic injury, intraoperative fracture, acromial fracture, hematoma, and instability.41

Finally, a higher percentage of shoulder arthroplasty cases are revised compared with hip and knee arthroplasty, and revision cases have a worse outcome than primary shoulder arthroplasty. In the largest and longest prospective cohort of reverse total shoulder arthroplasty, a French registry has demonstrated that conversion to reverse total shoulder arthroplasty, regardless of the reason for revision, is associated with worse outcomes than any other indication for reverse total shoulder arthroplasty. Therefore, it is crucial that orthopaedic surgeons understand the factors for the optimal performance of primary shoulder replacement as individuals requiring a revision can expect generally compromised outcomes.

There is a body of literature supporting the concept that high-volume surgeons and hospitals perform hip and knee replacement in a safer, more expedient, and in some cases less expensive manner.24 Given the relative infrequency of the procedure and the large study cohort required, similar studies of total shoulder arthroplasty are scarce15,17,22 and absent concerning reverse total shoulder arthroplasty.

The purpose of this investigation was to determine the effect of surgeon and hospital volume on the perioperative performance of shoulder hemiarthroplasty (HA), total shoulder arthroplasty (TSA), and reverse total shoulder replacement (RSA). We test the hypothesis that the volume of shoulder arthroplasty cases influences length of stay, blood loss, and surgical time.

Materials and methods

Selection of the study cohort

In 2007, Institutional Review Board approval was obtained to commence prospective data collection for a multicenter institutional Shoulder Arthroplasty Registry within a large integrated health care system that serves more than 5 million individuals. Fifteen percent of members are older than 60 years, a good approximation of the U.S. population. A retrospective cohort study was performed with data including demographic information, comorbidities, ICD-9 codes, implant data, surgical metrics, and hospital readmissions. Data were extracted through electronic administrative databases and medical records systems and validated by the authors. A trained clinical content expert (M.F.B.), with extensive knowledge of the clinical definitions relevant to this study, reviewed and monitored the patients’ electronic medical records quarterly.

The study population was composed of 1176 elective primary TSA, RSA, and HA procedures between January 2009 and December 2010. Patients with traumatic fractures of the shoulder and their sequelae were excluded from the study as these patients have a significantly higher short-term complication rate and would bias the HA results.

Definitions of variables

Patients were stratified into 2 groups including annual surgeon volume and annual hospital volume (2009-2010) according to their primary shoulder arthroplasty procedure. Surgeon volume was based on a simple tertial cut of the distribution of cases performed by individual surgeons. The cutoffs were made such that one third of the surgeons were in each group, regardless of the number of cases in each tertial. Hospital volume was cut off at tertial boundaries in the same manner.

Length of stay was calculated by admission and discharge dates. Incision time (cut to close) was used to determine operative time. Blood loss in milliliters was extracted from each patient’s chart as recorded in the operative report of the surgeon and nursing notes. Length of stay was extracted from the electronic medical record and is the number of inpatient days a patient was admitted.

Data analysis

Patient characteristics were presented as mean and standard deviation for TSA, HA, and RSA. Analysis of covariance was used for continuous variables, followed by Tukey adjusted multiple comparison to compare the mean difference among the 3
surgical procedures. The \( \chi^2 \) test or Fisher exact test was used for categorical variables to test proportional difference among the 3 procedures. Similar analysis was performed to compare mean difference among the 3 procedures within low, medium, and high surgical or hospital volume, which was defined as tertial cut for each procedure. Correlation was used to assess the relationship between surgical and hospital volume and the 3 primary metrics of interest: length of stay, estimated blood loss, and operative time.

**Results**

**Demographics**

The average age for RSA (74.9 years [±7.67]) was significantly older than the average age for TSA (69.1 years [±8.93]) or HA (65.9 [±11.8]) (\( P < .001 \)). The proportion of genders was comparable across procedure groups, with men representing 49.1% of TSA cases, 50.9% of HA cases, and 42% of RSA cases (\( P = .14 \)). Body mass index within 90 days of surgery was lower in RSA, 28.4 (±5.62), compared with TSA 30.3 (±5.89) and HA 30.0 (±6.17) (\( P < .005 \)). The demographic results are summarized in Table I.

In terms of the surgical diagnosis, TSA was most commonly performed for osteoarthritis (96%) and rheumatoid arthritis (2.4%). The indications for HA were most commonly osteoarthritis (77.6%) and rotator cuff tear arthropathy (11.6%). RSA was overwhelmingly performed in cases of rotator cuff tear arthropathy (89.4%).

<table>
<thead>
<tr>
<th>Demographic</th>
<th>( n )</th>
<th>Total shoulder arthroplasty (( n = 711 ))</th>
<th>Hemiarthroplasty (( n = 277 ))</th>
<th>Reverse total shoulder arthroplasty (( n = 188 ))</th>
<th>Overall * ( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>1176</td>
<td>69.1 (8.93)</td>
<td>65.9 (11.84)</td>
<td>74.9 (7.67)</td>
<td>( &lt; .0001 )</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>607</td>
<td>362 (50.9%)</td>
<td>136 (49.1%)</td>
<td>109 (58%)</td>
<td>.14</td>
</tr>
<tr>
<td>Male</td>
<td>569</td>
<td>349 (49.1%)</td>
<td>141 (50.9%)</td>
<td>79 (42%)</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>1176</td>
<td>30.3 (5.89)</td>
<td>30.0 (6.17)</td>
<td>28.4 (5.62)</td>
<td>.003</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instability</td>
<td>6</td>
<td>0 (0%)</td>
<td>4 (1.4%)</td>
<td>2 (1.1%)</td>
<td>N/A</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>901</td>
<td>682 (96.0%)</td>
<td>215 (77.6%)</td>
<td>4 (2.1%)</td>
<td></td>
</tr>
<tr>
<td>Osteonecrosis, avascular necrosis</td>
<td>30</td>
<td>12 (1.7%)</td>
<td>17 (6.1%)</td>
<td>1 (0.5%)</td>
<td></td>
</tr>
<tr>
<td>Cuff tear arthropathy</td>
<td>200</td>
<td>0 (0%)</td>
<td>32 (11.6%)</td>
<td>168 (89.4%)</td>
<td></td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>25</td>
<td>17 (2.4%)</td>
<td>7 (2.5%)</td>
<td>1 (0.5%)</td>
<td></td>
</tr>
<tr>
<td>Rotator cuff tear</td>
<td>13</td>
<td>0 (0%)</td>
<td>2 (0.7%)</td>
<td>12 (6.4%)</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical volume</td>
<td>1176</td>
<td>11.1 (8.74)</td>
<td>3.9 (3.43)</td>
<td>5.3 (3.03)</td>
<td>( &lt; .0001 )</td>
</tr>
<tr>
<td>Hospital volume</td>
<td>1176</td>
<td>14.5 (5.78)</td>
<td>8.2 (5.76)</td>
<td>6.4 (2.97)</td>
<td>( &lt; .0001 )</td>
</tr>
</tbody>
</table>

Reported as mean (standard deviation), frequency (%).

* Analysis of variance for continuous variables; \( \chi^2 \) test for categorical variables.

<table>
<thead>
<tr>
<th>Categorical description</th>
<th>Total cases</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>387</td>
<td>3.8</td>
<td>2.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Middle</td>
<td>406</td>
<td>13.4</td>
<td>3.1</td>
<td>12.5</td>
</tr>
<tr>
<td>Higher</td>
<td>383</td>
<td>29.7</td>
<td>8.8</td>
<td>29.5</td>
</tr>
</tbody>
</table>

Between January 1, 2009, and December 31, 2010, a total of 1176 primary shoulder replacements were performed by a total of 110 surgeons who participate in the institutional registry. The procedures were performed at 34 different facilities. There were 711 primary TSAs, 277 primary HAs, and 188 primary RSAs in the study group. The distribution of these cases among surgeons is presented in Table II. The average surgeon in the “higher volume” group performed 30 elective shoulder arthroplasty procedures.

In general, higher volume surgeons practiced in higher volume hospitals. However, there was no higher volume institution in which all elective shoulder arthroplasty was performed by a single surgeon. The average hospital had 3 surgeons perform elective shoulder arthroplasty.

**Hemiarthroplasty**

Elective shoulder HA had the lowest annual volume, with a mean of 3.9 cases per surgeon. The most common
indication was osteoarthritis, followed by rotator cuff tear arthropathy. The tertial cutoffs were fewer than 2 cases per year for low-volume practitioners, 2 to 4 cases a year for medium-volume surgeons, and more than 4 cases annually for high-volume surgeons.

After adjustment for age, sex, and body mass index, length of stay averaged 2 days for low-volume surgeons and 1.7 days for medium- and high-volume surgeons \((R = -0.13; P = .03)\). Blood loss averaged 230.7 mL for surgeons with lower volume, 185 mL for surgeons with medium volume, and 162.7 mL for surgeons with higher volume \((r = -0.14; P = .03)\). Operative time was also consistently shorter for more experienced surgeons, averaging 127.7 minutes for lower volume surgeons, 121.9 minutes for medium-volume surgeons, and only 87.1 minutes for higher volume surgeons \((r = -0.37; P < .001)\). For HA, blood loss and operative times were significantly less than for either TSA or RSA, within all tertials of surgeon volume. The results are summarized in Tables III and IV.

There was no significant correlation between blood loss during HA and hospital volume \((r = 0.002; P = .98)\). However, length of stay and operative time were inversely correlated with hospital volume and surgeon volume \((r = -0.18, P = .004\) and \(r = -0.2, P = .02\), respectively). Again, for HA, blood loss and operative times were significantly less than for TSA and RSA, within low and medium facility volumes. Within high-volume facilities, length of stay and operative time were shortest among the 3 procedures. The results are presented in Tables III and V.

**Table III** Correlation between annual surgeon and hospital volume and length of stay, estimated blood loss, and operative time among procedure types

<table>
<thead>
<tr>
<th>Length of stay (days)</th>
<th>Total shoulder arthroplasty</th>
<th>Hemiarthroplasty</th>
<th>Reverse total shoulder arthroplasty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical volume</td>
<td>-0.25 (&lt;.0001)</td>
<td>-0.13 (.03)</td>
<td>-0.14 (.08)</td>
</tr>
<tr>
<td>Hospital volume</td>
<td>0.02 (.64)</td>
<td>-0.18 (.004)</td>
<td>-0.13 (.09)</td>
</tr>
<tr>
<td>Blood loss (mL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical volume</td>
<td>-0.30 (&lt;.0001)</td>
<td>-0.14 (.03)</td>
<td>-0.22 (.08)</td>
</tr>
<tr>
<td>Hospital volume</td>
<td>-0.14 (&lt;.0001)</td>
<td>0.002 (.98)</td>
<td>-0.22 (.01)</td>
</tr>
<tr>
<td>Operative time (minutes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical volume</td>
<td>-0.52 (&lt;.0001)</td>
<td>-0.37 (&lt;.0001)</td>
<td>-0.39 (&lt;.0001)</td>
</tr>
<tr>
<td>Hospital volume</td>
<td>-0.26 (&lt;.0001)</td>
<td>-0.20 (.002)</td>
<td>-0.28 (&lt;.0001)</td>
</tr>
</tbody>
</table>

Reported as correlation coefficient \((P\text{ value})\).

**Total shoulder arthroplasty**

TSA had the highest annual volume per surgeon. The most common indications were osteoarthritis and rheumatoid arthritis. The tertial cutoffs were fewer than 5 cases per year for low-volume practitioners, between 6 and 15 cases a year for the medium-volume group, and more than 15 cases annually for higher volume surgeons.

After adjustment for covariates, estimated blood loss, operative time, and length of stay all decreased consistently with increasing surgeon volume. Blood loss averaged 264.6 mL for low-volume surgeons, 228.2 mL for medium-volume surgeons, and 201.3 mL for high-volume surgeons \((r = -0.3; P < .0001)\). Operative time averaged 163.4 minutes for low-volume surgeons, 147.8 minutes for medium-volume surgeons, and only 114.4 minutes for high-volume surgeons \((r = -0.52; P < .0001)\). Finally, length of stay averaged 1.8 days for low-volume practitioners, 1.9 days for medium-volume surgeons, and 1.7 days for high-volume surgeons \((r = -0.25; P < .0001)\). The results are summarized in Tables III and IV.

There was no statistically significant correlation between length of stay and institutional volume \((r = 0.02; P = .64)\). However, blood loss and operative time were inversely correlated with hospital volume \((r = -0.14, P < .0001\) and \(r = -0.26, P < .0001\), respectively). The results are presented in Tables III and V.

**Reverse total shoulder arthroplasty**

The most common indication for RSA was rotator cuff tear arthropathy. Low-volume surgeons performed 4 or fewer cases per year; medium volume was considered 5 to 8 cases a year; and higher volume practitioners performed 9 or more procedures annually.

After adjustment for covariates, length of stay averaged 2.3 \((±1.1)\) days for low-volume surgeons, 2.6 days \((±1.1)\) for the medium-volume group, and 1.9 days \((±1.1)\) for high-volume surgeons \((R = -0.14; P = .08)\).

Blood loss marginally decreased in proportion to surgeon volume. Blood loss averaged 263.6 mL \((±156.7)\) for low-volume surgeons, 283.9 mL \((±188.9)\) for medium-volume surgeons, and 215.7 mL \((±150.1)\) for high-volume surgeons \((r = -0.22; P = .08)\). Operative time averaged 147.9 minutes \((±48.4)\) for low-volume surgeons, 129.5 minutes \((±35.6)\) for medium-volume surgeons, and only 115.5 minutes \((±53.3)\) for high-volume surgeons \((r = -0.39; P < .0001)\). The results are summarized in Tables III and IV.

There was no statistically significant correlation between length of stay and institutional volume \((r = 0.13; P = .09)\). However, blood loss and operative time were inversely
correlated with hospital volume ($r = -0.22, P < .01$ and $r = -0.28, P < .0001$, respectively) in a statistically significant manner. The results are presented in Tables III and V.

### Discussion

Many studies demonstrate an inverse relationship between surgeon or hospital volume and mortality rates, functional status, and complications from a variety of procedures, including aneurysm repair, cataract surgery, coronary artery bypass graft, thyroidectomy, carotid endarterectomy, and lung cancer resection.

Several studies in the orthopaedic literature have examined the relationship between provider and institutional volume and objective outcomes such as mortality, readmission, infection, dislocation, pulmonary embolism, and revision rates by validated outcome instruments and patient satisfaction. These reports have consistently demonstrated improved patient outcomes with primary and revision hip and knee arthroplasty, scoliosis fusion, hip fracture fixation, and primary TSA.
A 2007 study by Meredith and Katz examined the use of procedure volume as a quality measure for total joint replacement. They found that operative volume was a valid, reliable, accessible, and actionable measure of quality. They recommended regionalization policies to improve quality but more research to ensure access to care for vulnerable populations.

The goal of this study was to evaluate the effect of surgeon and institutional volume on shoulder arthroplasty perioperative quality metrics. After adjustment for age, sex, and body mass index, there was a direct correlation between surgeon volume and positive perioperative metrics for all parameters tested with the exception of length of stay for RSA, which was not statistically different between groups.

Hospital volume also showed a statistically significant positive correlation with perioperative metrics in all parameters with the exception of length of stay with TSA and blood loss with HA. Interestingly, although the correlation coefficients with hospital volume were statistically significant, they were less strong than the correlation coefficients between provider volume and metrics of interest. The finding that provider volume has more impact than hospital volume supports the findings published by Hammond and McFarland in 2003 but expands the results to RSA. The Hammond study included HA for fractures, which is now a known risk factor for poor outcome. In addition, there was no validation of individual patient data because of the use of a database without individual electronic records.

Surgical distribution

Splitting data into tertials to streamline data analysis is standard in studies analyzing the effects of surgical volume on quality. The categorical volumes in this study are higher than the volumes in previous studies. For example, the minimum volume for a high-volume surgeon in the 2004 Jain study was 5 cases per year, and the average high-volume surgeon in the 2003 Hammond study performed 7.5 cases annually. This is in contrast to the higher volume group in the present study, which averaged 30 shoulder arthroplasty cases per annum.

One explanation for the increase in surgical volumes in our study is that the Jain and Hammond studies were published almost a decade ago, before the advent of the RSA, and at a time when most surgeons performed only 1 or 2 procedures annually. In the past decade, the use of shoulder arthroplasty has increased dramatically. The case volumes in this study mirror that increase.

Correlation between volume and perioperative metrics

The Pearson correlation coefficients ($r$) between study groups demonstrated a significant statistical correlation between higher surgeon volumes and shorter operative times with coefficients between $-0.37$ and $-0.52$, inclusive. In our study group, this translated to a statistically significant difference of more than 30 minutes of operative time between low- and high-volume practitioners for HA and RSA and a 50-minute difference for TSA. This increase in surgical time is of interest as there is literature confirming increased infection rates during longer hip and knee arthroplasty cases. A study showed that instrument trays become contaminated in a time-dependent manner such that at 1 hour, 22% of open trays were contaminated. A procedure that takes, on average, 50 minutes longer is likely to be adding risk to the patient in terms of infection, anesthesia exposure, and potentially nerve damage if the arm is kept in external rotation for prolonged periods during glenoid exposure.

This study provides shoulder arthroplasty–specific data relating volume to quality in the perioperative setting. Our data suggest that with shoulder arthroplasty procedures, provider experience with surgical approaches, instrumentation, and potential complications is more important than hospital-based variables such as nursing, physical therapy, medical consultant, and administrative familiarity with the treatment of shoulder arthroplasty patients. The fact that these are technically demanding procedures with variables that an experienced surgeon can control may explain the moderate to strong correlation coefficients ($r$) between provider volume and improved perioperative metrics.

There are several limitations to this institutional registry–based study. First, we were limited to the data in the registry and thus were unable to assess validated outcome instruments. We relied on ICD-9 codes, which may not be consistently documented, although diagnoses were audited by registry research personnel. Third, blood loss is an estimate based on methods such as weighing lap sponges or figures agreed on by the operating surgeon and anesthesiologist that can be subjective in nature. In terms of the HA data, it is possible that more experienced surgeons performed TSA or RSA instead for similar diagnoses, skewing the surgeon cohort toward more low-volume individuals. Finally, because no consensus volume thresholds have been set for shoulder arthroplasty, we broke down volume into tertials for statistical comparison.

We did not determine an acceptable minimal threshold in terms of numbers of cases per year to optimize results. Furthermore, there is other information that would be useful in making decisions about the ideal distribution of cases to optimize outcomes, such as patient satisfaction, cost data, and maximizing access in rural communities and for vulnerable minority and uninsured populations. Furthermore, there are outliers in each group, and we cannot prospectively determine if a low-volume hospital may be effective or which high-volume surgeons will have poor outcomes. It is apparent that completing a case 40 to 50 minutes faster cuts down on operating room costs and anesthesia exposure and would allow more cases to be done in the same amount of time; however, with the current data, we cannot exclude individual surgeons from performing
particular procedures. The data do support a centers of excellence model where certain centers and practitioners focus on providing higher volume, more efficient care.

This study does have some noteworthy findings. We examined several perioperative parameters that have not been analyzed for TSA, such as estimated blood loss and operative time. Most of the previous literature examines government databases containing readmission and mortality data. In addition, this is the first study to our knowledge to examine the relationship between annual surgical volume and RSA. Given the significant learning curve for RSA, it is possible that higher volume surgeons will bypass the early portion of the learning curve quickly, whereas surgeons who perform only 1 or 2 cases a year may not.

**Conclusion**

This study demonstrates that on average, high-volume surgeons and hospitals performed shoulder HA, TSA, and RSA with less blood loss, lower surgical time, and shorter length of stay compared with lower volume practitioners and hospitals.

**Disclaimer**

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**References**


