Systematic Review

Patient Outcomes as a Function of Shoulder Surgeon Volume: A Systematic Review

Kent T. Weinheimer, M.D., Dallas M. Smuin, B.S., and Aman Dhawan, M.D.

Purpose: To examine surgical complications, length of stay, surgical time, cost, revision rates, clinical outcomes, current surgical trends. and minimum number of cases in relationship to surgeon volume for shoulder arthroplasty and rotator cuff repair. **Methods:** We performed a systematic review of studies using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. All studies that met inclusion criteria from January 1990 to January 2016 were included. Inclusion criteria included Level IV evidence or greater, contained specific surgeon volume, and were written in or translated into English. Exclusion criteria included non-English manuscripts, abstracts, and review papers. A written protocol was used to extract relevant data and evaluate study results. Data extracted included volume-specific data pertaining to length of stay, operating time, complications, and cost. **Results:** A total of 10 studies were included. Seven studies evaluated arthroplasty with 88,740 shoulders, and 3 studies evaluated rotator cuff repair with 63,535 shoulders. Variation was seen in how studies defined low- versus high-volume surgeon. For arthroplasty, <5 cases per year met the criteria for a low-volume surgeon and were associated with increased length of stay, longer operating room time, increased in-hospital complications, and increased cost. Mortality was not significantly increased. In rotator cuff surgery, <12 surgeries per year met the criteria for low volume and were associated with increased length of stay, increased operating room time, and increase in reoperation rate. **Conclusions:** Our systematic review demonstrates increased surgical complications, length of stay, surgical time, and surgical cost in shoulder arthroplasty and rotator cuff repair when performed by a low-volume shoulder surgeon, which is defined by those performing <5 arthroplasties and/or <12 rotator cuff repairs per year. **Level of Evidence:** Level III, systematic review of Level II and III studies.

There is growing interest in improving value of health care by improving patient outcomes and decreasing morbidity and mortality, while decreasing cost. The correlation between increase in volume and decrease in mortality and surgical complications has been well documented in coronary artery bypass,[1] liver transplantation,[2] and oncologic surgery.[3] While it would seem intuitive that patient outcomes would improve with those providers and institutions that perform a higher volume of a given procedure or intervention, there has been conflicting literature. Khuri and associates demonstrated no association between surgical volume and 30-day mortality rate for total hip arthroplasty, abdominal aortic aneurysmectomy, carotid endarterectomy, cholecystectomy, and partial colectomy and concluded that volume should not be used as a surrogate for quality of care.[4]

In orthopaedics and specifically total hip arthroplasty, one study demonstrated a decrease in mortality with increase in volume, but this difference occurred at very low volumes when compared with nonorthopaedic procedures.[5] A systematic review of numerous different orthopaedic procedures (including shoulder surgery) studied the relationship between surgeon volume and patient outcomes. The authors of that study found an association between higher surgeon volume and lower rate of hip dislocation, but no other associations were significant.[6] A recent systematic review examined primary total knee arthroplasty and found a significant association between high-volume surgeon (>5 to >70 total knee arthroplasties per year) and decreased rates of infection, procedure time, and transfusion rate and improved patient-reported outcomes.[7] The relationship

From the Department of Orthopaedic Surgery, Penn State Hershey Medical Center, Hershey, Pennsylvania, U.S.A.

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Address correspondence to Kent T. Weinheimer, M.D., Department of Orthopaedic Surgery, Penn State Hershey Medical Center, 30 Hope Drive, Hershey, PA 17033, U.S.A. E-mail: kentwein2007@gmail.com

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between surgeon volume and outcomes specific to shoulder surgery remains undefined.

The purpose of this systematic review was to examine surgical complications, length of stay, surgical time, cost, revision rates, clinical outcomes, current surgical trends, and minimum number of cases with respect to surgeon volume for shoulder arthroplasty and rotator cuff repair. We hypothesized that there would be an inverse relationship between surgeon volume and surgical complications, length of stay, surgical time, cost, and revision rates in shoulder arthroplasty, rotator cuff repair, and shoulder stabilization.

Methods

Search Strategy

A protocol was developed in adherence with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to conduct a systematic review of the literature. We used the PubMed and the Science Direct electronic databases to search the available literature. We searched for the keywords ["Outcomes" OR "Complications" OR "Risk factors"] AND ["Provider Volume" OR "Surgeon Volume" OR "Hospital Volume"] with each of the following secondary search keywords: "shoulder," "glenohumeral," "labral stabilization," "proximal humerus ORIF," "rotator cuff repair," and "shoulder arthroplasty." We included studies published from January 1, 1990, to January 1, 2016.

Duplicates were removed from the results of each of the separate searches. The titles and abstracts for all of the studies were then screened by the senior author, A.D., to ensure relevance to our study questions. The evaluators included one M.D. attending surgeon, one M.D. 4th-year resident, and one 4th-year medical student. Each relevant study's full manuscript was then reviewed by the senior author and assessed using our inclusion and exclusion criteria for appropriateness for qualitative and quantitative analysis in our study. Studies were excluded if they were primarily written in a language other than English, abstracts only, case reports, technique papers, or review papers or were written in non-peer-reviewed publications. Studies were included only if they were Level IV evidence or better. Studies were included if they had specific data comparing shoulder surgical outcomes in relation specifically with surgeon volume for shoulder arthroplasty, including hemiarthroplasty (HA), total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RSA), and rotator cuff repair, including arthroscopic and open procedures. One study on proximal humerus fractures discussed surgeon volume in relation to HA so this was included in the arthroplasty group. Surgeon volume was reported by the individual studies as number of cases per year. Each study reported on criteria for low-, medium-, and high-volume surgeons. This was not controlled and was left up to the individual studies. Some studies reported dividing the groups into thirds, and some arbitrarily provided cutoffs. This led to difficulty with a meta-analysis due to heterogeneity among the data. The flowchart diagram describing the search strategy is included in Figure 1. After removal of duplicates and application of inclusion/exclusion criteria to the abstracts by 2 screeners, A.D. and K.W., a total of 23 complete articles were included in our initial review process. Additional review of the references in each article was performed to ensure no articles were missed. These articles were then examined and were finally included if they met the inclusion and exclusion criteria.

Ten articles ultimately met the inclusion and exclusion criteria and were included in this systematic review. Results were divided into the following 2 categories: arthroplasty and rotator cuff repair. Shoulder stabilization was initially included in the review but was later excluded as only one study was found that met the inclusion criteria. The results are included in Tables 1 and 2, respectively.

Statistics

A quantitative analysis was applied to 2 studies involving arthroplasty. No comprehensive quantitative synthesis could be performed on the remaining arthroplasty, rotator cuff repair, and shoulder stabilization studies due to study heterogeneity of data (diverse reporting methods and definitions of high- vs low-surgeon volume). Raw data were extracted and tabulated in a standardized form for calculations of risk ratios (RRs). Data were reported as RR and 95% confidence intervals (95% CI). A fixed-effects model was used to calculate summary RRs and 95% CIs to evaluate the rate of complication between surgeons who perform <5 arthroplasty procedures per year and those who perform more than 5. Heterogeneity between studies in the fixed-effects model was investigated using the Q-statistic with a *P*-value of <.05 considered significant.[8] Analysis of the Q-statistic was found to be insignificant. DerSimonian and Laird random-effects model was also analyzed, and the results were replicated.[9] All analyses were performed using R Core team (ver. 3.1.3) statistical software[10] and the rmeta package.[11]

To evaluate the quantitative methodological quality of the studies included, the Newcastle-Ottawa Quality Assessment Scale (NOQAS) was used.[12] Two independent evaluators, K.W. and D.M.S., interrogated the studies and assigned each study with its respective NOQAS score. The average between these 2 scores was then taken to give a final score and included in Tables 1 and 2 for the respective studies.

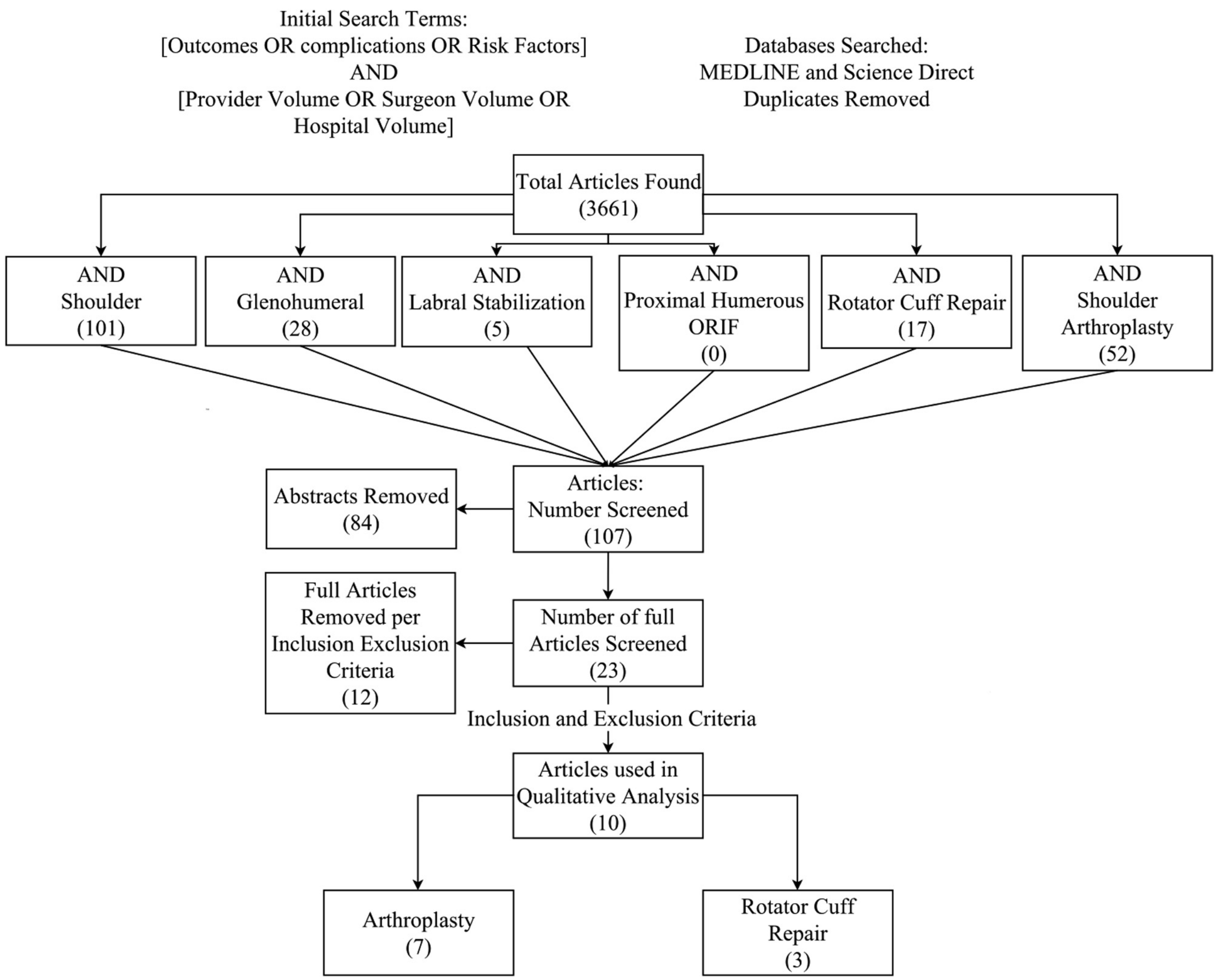

Fig 1. Search strategy and results.

Results

Arthroplasty

Seven studies (6 retrospective analyses and one epidemiologic study) were reviewed that discussed surgeon volume related to shoulder arthroplasty (Table 1). A meta-analysis was unable to be performed due to study heterogeneity, specifically in data-reporting methods and definitions of high versus low surgeon volume.

Surgical Trends. Day et al. compared the use of RSA with TSA and HA. Among 31,002 total patients, TSA was performed in 42% of the population, RSA in 37%, and HA in 21%. Fifty-one percent of all arthroplasties were performed by lower volume surgeons (defined as <10 per year).[13]

Jain et al. (2005) found that a high-volume surgeon was more likely to perform a TSA compared with an HA (odds ratio [OR], 1.59; 95% CI, 1.23-2.07) with high volume >5 cases per year versus low volume <2.[14] Hammond et al. found that the percentage of TSA compared with HA increased with surgeon volume: 26.5% TSA with low-volume (1-5 per year) compared with 63.6% TSA with high-volume (>30 per year).[15] Hasan et al. studied the frequency distribution of shoulder arthroplasty compared with hip and knee arthroplasty between surgeons and reported that of the 1,300 surgeons included in the study, 90% performed at least one hip replacement per year, 62% performed at least one knee replacement, and only 30% performed at least one shoulder replacement. Of the 30% performing shoulder replacement, 78% performed only one or 2 in that year.[16]

Complications. Mortality following shoulder arthroplasty was reported in 2 of the studies. Jain et al. (2004) reported an increase in mortality by an OR of 4.4 (0.6-31.2) if performed by a low-volume surgeon (0.36% mortality with <2 cases per year) compared with a high-volume surgeon (0.08% mortality

Table 1. Arthroplasty

Author	Number of Shoulders	Study Design	Level of Evidence	NOQAS	Study Population	Procedure(s)	Outcomes Measured	Results	Provider Cutoff
Day et al. (2015)[13]	31,002	Epidemiology, database analysis	Epidemiology study	8.5	N, 31,002 (37% RSA, 42% TSA, 21% HA); M/F: RSA, 64% F; TSA, 51% F; HA, 62% F; mean age, 74.6 ± 6.3	TSA, RSA, HA	Demographics of TSA, RSA, and HA; gender, age, LOS, payment	TSA used 42% of the time with RSA and HA at 37% and 21%, respectively; 51% of all arthroplasties done by lower volume surgeons (<10). Very low and low-volume surgeons do 57% of RSA, 65% of TSA, and 97% of HA.	Very low (1-5), low (6-10), moderate (11-20), high (>20)
Hammond et al. (2003)[15]	1,868	Retrospective prognostic Study	II	8	N, 1,868; M/F, 31.8% M, 68.2% F; mean age, 68.1	TSA, HA	Risk of in hospital complication, LOS, total hospital chargers, compared low vs high	OR Complication 0.60 (0.4-0.9); LOS, 0.30 (0.20-0.60); charges, 0.80 (0.5-1.3); high volume cost $1,000 less, but not significant.	Low 1-5, medium 6-30, high >30
Hasan et al. (2003)[16]	1,175	Retrospective Study	III	9	N, 27,874; M/F, not noted; mean age, not noted	TSA, TKA, THA	Which procedure is performed most frequently by high-, medium-, and low- volume surgeons?	TSA: 44% performed by low-volume surgeon vs 2.9% THA and 2.2% TKA. Low-volume and high-volume shoulder surgeons significant difference compared with hip and knee surgeons; 70% of orthopaedic surgeons did not do TSA; those that did 78% did only 1 or 2 per year.	1-2, 3-10, 11-20, 21-30, 31-40, 41-50, >50. Also divided as >10 and 1-2

(continued)

Table 1. Continued

Author	Number of Shoulders	Study Design	Level of Evidence	NOQAS	Study Population	Procedure(s)	Outcomes Measured	Results	Provider Cutoff
Jain et al. (2004)[17]	30,046	Retrospective study	III	9	N, 30,875; M/F: TSA, 38.8% M; 61.2% F; HA, 29.9% M; 70.1% F; mean age: TSA, 68.3 ± 11.8; HA, 68.4 ± 13.7	TSA, HA	In-hospital mortality, LOS, disposition of patient, in-hospital postop complications.	Adjusted ORs: mortality, 4.4 (0.6-31.2); complications, 1.4 (0.6-3.0); LOS: 17 hours earlier (*P* < .001)	Low <2, medium ≥2-<4, high ≥4.
Jain et al. (2005)[14]	13,741	Retrospective study	III	9	N, 13,741; 8,743 TSA, 4,998 HA; M/F: 43.1% M, 56.9% F; mean age: 69.2 ± 10.7	TSA, HA	Was TSA or HA chosen for OA in low vs high provider volume?	OR high volume: 2.01 (1.68-2.40) more likely for TSA.	Low <2, medium ≥2-≥4, high 5+
Singh et al. (2014)[19]	1,176	Retrospective treatment study	III	9	N, 1,176; M/F: TSA, 49.1% M, 50.9% F; HA, 50.9% M, 49.1% F; RSA: 42% M, 58% F. Mean age: TSA, : 69.1 ± 8.93; HA, 65.9 ± 11.84; RSA, 74.9 ± 7.67	TSA, HA, RSA	Length of stay, blood loss, operative time	Operative time decreased: correlation coefficients: −0.52 (*P* < .0001), −0.37 (*P* < .001), and −0.39 (*P* < .001) for TSA, HA, and RSA, respectively.	Low <8, medium ≥8-<17.5, high ≥17.5.
Jain et al. (2013)[18]	9,732	8	III	9	N, 25,731 (15,999 ORIF, 9,067 HA, 665 TSA); M/F: 26.6% M, 73.4% F; mean age: HA, 65.9 ± 11.84; RSA, 74.9 ± 7.67	Proximal humerus ORIF, TSA, HA	Mortality, LOS, complications	LOS decreased 40%, 3.4 vs 5.5 days, *P* < .01; mortality, 0.6% vs 0.2% (*P* > .05); hospital cost decreased $90, *P* < .01	Low <5, medium 5-14, high 15

HA, hemiarthroplasty; LOS, length of stay; M/F, male/female; N, number of patients; NOQAS, Newcastle-Ottawa Quality Assessment Scale; OR, odds ratio; ORIF, open reduction internal fixation; RSA, reverse total shoulder arthroplasty; THA, total hip arthroplasty; TKA, total knee arthroplasty; TSA, total shoulder arthroplasty.

Table 2. Rotator Cuff Repair

Author	Number of Shoulders	Study Design	Level of Evidence	NOQAS	Study Population	Procedure(s)	Outcomes Measured	Results	Provider Cutoff
Green et al. (2003)[21]	1,077	Retrospective prognostic study	II	9	N, 1,077; M/F: 59% M, 41% F; mean age, >60 years (49%)	Rotator cuff repair (open and arthroscopic)	Extended stay (<24 hours), 30-day readmission, operating room time	Risk ratio: extended stay, 2.15 (0.95-4.83), $P = .064$; readmission 2.11 (0.78-5.71), $P = .1410$. Regression coefficients: operative time, −0.87 (−1.22, −0.53), $P < .0001$	<12/yr
Jain et al. (2005)[22]	9,973	Retrospective study	III	9	N, 9,973; M/F: 62% M, 38% F; mean age, 56 ± 12.4	Rotator cuff repair (open and arthroscopic)	Extended length of hospital stay, operating room time	Adjusted OR: LOS extended, 2.3 (1.2-4.4); operating room time, 112 min (low) vs 102 min (high), $P = <.001$	Low, <15; intermediate, 15-29; high, 30+
Sherman et al. (2008)[20]	52,485	Retrospective study	III	9	N, 52,485; M/F: 56.6% M, 43.4% F; mean age, 56 ± 13.5	Rotator cuff repair (open and arthroscopic)	Reoperation, 90-day readmission	Reoperation: OR, 1.25 (1.08-1.44); $P < .01$. Readmission: OR, 0.91 (0.83-1.00); $P = .14$	Low, <6/yr; medium, ≥6 to <12; high, ≥12 to <24; very high ≥24

LOS, length of stay; M/F, male/female; N, number of patients; NOQAS, Newcastle-Ottawa Quality Assessment Scale; OR, odds ratio.

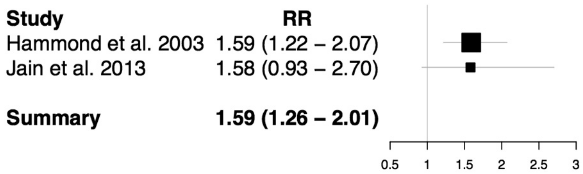

Fig 2. Subgroup analysis and quantitative synthesis of 2 studies comparing postoperative complications between low and high surgeon volume. (RR, risk ratio.)

with >4 cases per year).[17] Although results were not statistically significant, Jain et al. found a trend toward increased mortality following an HA for a proximal humerus fracture if performed by a low-volume surgeon (<5 per year) compared with a high-volume surgeon (>15 per year).[18]

Hammond et al. addressed hospital complications following orthopaedic surgery and found that the risk of complications decreased by 40% for a high-volume surgeon (>30 per year) compared with a low-volume surgeon (<5 per year).[15] Jain et al. also reported an increase in postoperative complications (wound infection, nonhealing wound, pulmonary embolism, thrombophlebitis, or other unspecified complications) in lower volume surgeons; however, results were not statistically significant.[17]

Subgroup analysis and quantitative synthesis were performed with the 2 previously mentioned studies to evaluate data regarding postoperative complications between low surgeon volume (<5 shoulder arthroplasty procedures per year) and high surgeon volume (>5). An RR of 1.59 (95% CI, 1.26-2.01) was calculated and demonstrated that patients who underwent shoulder replacement by a low-volume surgeon had 59% increase in risk of complications, as shown in Figure 2.

Length of Stay. Four studies reported a decrease in length of stay with a higher volume surgeon. Hammond et al. found that length of stay is decreased by 1.4 days for a high-volume surgeon (>30 per year) versus a low-volume surgeon (1-5 per year),[15] and Jain et al. (2013) reported a similarly decreased length of stay by 40% (3.4 vs 5.5 days).[18] Singh et al. divided TSA, HA, and RSA and reported decreased length of stay for TSA and HA with correlation coefficients of −0.25 ($P < .001$) and −0.13 ($P = .03$), respectively, and a nonsignificant decrease in RSA with a correlation coefficient of −0.14 ($P = .08$).[19] Jain et al. (2004) reported a shorter hospital stay by 17 hours if the procedure was performed by a surgeon who did >5 arthroplasties per year compared with a surgeon who performed <2 per year ($P < .001$).[17]

Surgical Time. Operating room time was discussed in one of the 7 studies. Singh et al. reported a decrease in operative time for TSA, HA, and RSA; correlation coefficients were −0.52 ($P < .0001$), −0.37 ($P < .001$), and −0.39 ($P < .0001$), respectively.[19] These results correspond to a 30-minute decrease in operative time for high-volume compared with low-volume surgeons for HA and RSA and a 50-minute decrease for TSA.

Hospital Cost. Hospital cost was discussed in 2 studies comparing high- with low-volume surgeons. Jain et al. (2013) reported the cost per procedure was reduced by $90 for each additional arthroplasty performed by a surgeon.[18] Hammond et al. reported a decrease in cost of $1,000, but the data were not statistically significant after adjustment of multiple variables (OR, 0.80; 95% CI, 0.5-1.3).[15]

Rotator Cuff Repair

Three studies were included in our review of the literature regarding rotator cuff surgery with surgeon volume.

Reoperation Rates. Sherman et al. was the only study that looked into reoperation rates based on surgical volume.[20] These authors found a statistically significant increase in reoperation rates when comparing surgeon volume of <6 rotator cuff repairs per year compared with surgeon volume of >24 repairs per year.

Length of Stay. Two of the studies looked at length of hospital stay. Green et al. looked at extended stay, (defined as >24 hours) and found a trend (not statistically significant) toward extended stay when the surgeon volume was <12 procedures per year.[21] Jain et al. found a statistically significant increase in extended length of stay when comparing high volume (>30 per year) and low volume (<15 per year).[22]

Readmission Rates. Green et al. looked into 30-day readmission rates but found differences in readmissions to not be statistically significant based on surgical volume.[21] Sherman et al. also looked into 90-day readmission rates and also found that surgeon volume was not independently associated with readmission rates.[20]

Surgical Time. Two of the studies looked at operating room time based on surgical volume. Green et al. reported that operative time decreased with increase in surgeon volume. For each additional 10 rotator cuff procedures performed, operative time decreased by an average of 8.7 minutes ($P < .0001$).[21] Jain et al. (2005) reported a significantly shorter time for high-volume surgeons (112 ± 4 minutes compared with 102 ± 4 minutes, $P < .001$) when the surgeon performed >30 procedures compared with <15 per year.[22]

Discussion

In this study we confirmed our hypothesis that higher surgical volume correlated with decreased surgical complications, shorter length of stay, and improved surgical outcomes for shoulder arthroplasty and rotator cuff repair. Based on our qualitative review of the available data, the number of caseloads required to decrease complications and improve patient-reported outcomes for shoulder arthroplasty and rotator cuff repair was 5 or more and 12 or more, respectfully.

Evaluation of hospital and surgical costs has been an important element of recent efforts to improve the value of health care. We found an association between higher surgical volume and decreased cost in 2 of the studies on arthroplasty. One showed a decrease of $90 for each additional arthroplasty performed per year, and another reported a decrease of $1,000 but was not statistically significant due to multiple variables.

The association between higher case volume and lower complication rates has been described in many disciplines of surgery and medicine.[1-4] Understanding this relationship in orthopaedic surgery will be important as discussions of regionalization and improvement in quality and outcomes become more prevalent.[23]

We found several strong associations between surgeon volume and outcomes specific to shoulder surgery. There was a high correlation between shorter length of stay and higher surgeon volume throughout the procedures included in this study. All of the 4 studies with volume and length-of-stay data on shoulder arthroplasty demonstrated shorter length of stay with statistical significance. One of the 2 studies on rotator cuff repair showed a statistically significant decrease in length of stay, while a second found a trend but no statistical significance. Operating room time was also decreased for both shoulder arthroplasty and rotator cuff surgery. Both studies on rotator cuff repair and the only study on arthroplasty showed a statistically significant decrease in operative times.

A trend toward a decrease in mortality with higher surgeon volume was reported in 2 shoulder arthroplasty studies, although this trend should be interpreted with caution. The rate of mortality after shoulder arthroplasty is extremely low, and therefore numbers needed to find an association were not high enough to show a statistically significant result.

In-hospital complications following arthroplasty procedures were shown to be significantly decreased in one of the 2 articles. One study on arthroplasty showed a trend toward decreased cost but did not reach statistical significance. The only study on shoulder stabilization demonstrated no difference in revision surgery or postoperative dislocation based on surgeon volume. This was the only study in the review that showed no difference.

In our review, the literature revealed substantial variability in reporting on the caseload required to define a high-volume surgeon and also varied between procedures. For arthroplasty, most studies define a low-volume surgeon as one who performs <2-8 cases per year, with almost all studies demonstrating worse outcomes with surgeons who perform 5 or fewer arthroplasties per year. For rotator cuff repair, case volume was higher for all surgeons when compared with arthroplasty. A low-volume surgeon ranged from <6-15 cases per year, and a high-volume surgeon logged >12-30 cases per year. Almost all studies defined 12 or fewer rotator cuff repairs as low volume. For shoulder stabilization, only one study was included and defined a low-volume surgeon as <11 cases and a high-volume surgeon as >37 cases.

Limitations

The body of literature involved in this review has some inherent limitations. No Level I studies met inclusion criteria, and most of the study designs were retrospective reviews. All studies included in this review were from the United States. We were able to extrapolate trends in surgical volume by procedure, but these numbers should be interpreted with caution due to individual study heterogeneity in reporting methods and definitions of high versus low surgeon volume. In arthroplasty studies alone, the number of cases ranged from <2 to <8 procedures per year to define a low-volume surgeon and >4 to >30 procedures per year to define a high-volume surgeon. Rotator cuff criteria for high versus low volume ranged as well and were overall higher than for arthroplasty. The heterogeneity of the result reporting and the differences in defining surgeon volume allowed only limited quantitative synthesis. Other factors could also play a role in the surgical outcomes that are not included by examining surgeon volume. For instance, there was no control for open versus arthroscopic rotator cuff repair and no report on the size or type of tear. Hospital volume and conditions and other medical specialties could have an influential impact on the surgical outcomes. Also, many of the included studies are over 10 years old, and there may have been changes over time that influence the applicability of this study. Currently rotator cuff repair is an outpatient procedure with length of stay of <24 hours for almost all patients and surgeons independent of surgical volume. Demonstrating a difference in our review is likely not applicable today since these findings were from older studies. Finally, reporting on the exact extent of in-hospital complications was limited by the studies.

Conclusions

Our systematic review demonstrates increased surgical complications, length of stay, surgical time, and surgical cost in shoulder arthroplasty and rotator cuff repair when performed by a low-volume shoulder surgeon. Low volume for a shoulder surgeon is defined as those performing <5 arthroplasties and/or <12 rotator cuff repairs per year.

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