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Prior nonarthroplasty shoulder surgery and modifiable risk factors negatively affect patient outcomes after shoulder arthroplasty

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Background: Total shoulder arthroplasty frequently is performed in patients with a history of shoulder surgery. The purpose of this study was to evaluate clinical outcomes after primary shoulder arthroplasty in patients with a history of nonarthroplasty shoulder surgery, and whether certain modifiable risk factors (MRFs) were negatively associated with final outcome measures. The secondary purpose was to determine if costs or complications were higher in patients with prior shoulder surgery.

Methods: We conducted a retrospective cohort study of all patients who underwent primary shoulder arthroplasty from January 2015 to December 2019 by one surgeon at one institution. Patients who received hemiarthroplasty were excluded. Univariate analysis was performed to assess the influence of prior shoulder surgery on costs, complications, and patient-reported outcome measures. Multivariable analysis was performed to determine if MRF negatively affected results, defined as anemia, malnutrition, obesity, uncontrolled diabetes, tobacco use, and opioid use.

Results: 512 patients met inclusion criteria; 139 patients had at least one prior shoulder surgery. Patients with history of prior shoulder surgery were younger (65.2 ± 9.3 years vs. 70.7 ± 9.1 years, $P < .001$), more likely to be male (52.2% vs. 47.8%, $P = .016$), more likely to have smoking history (20.1% vs. 10.5%, $P = .002$), and borderline more likely to use preoperative opioids (47.5% vs. 38.9%, $P = .078$) while reporting significantly higher pain scores at final follow-up (visual analog scale for pain 1.7 ± 2.4 vs. 1.1 ± 1.9, $P = .001$) and lower patient-reported outcome measure ($P \leq .017$ for all). The final American Shoulder and Elbow Surgeons score (ASES) score was independently negatively impacted by a history of prior surgery ($\beta = -4.25$ (−7.92, −0.56), $P = .024$) and other nonmodifiable factors including prosthesis type of reverse arthroplasty ($\beta = -6.31$, confidence interval [CI] −10.02, −2.60, $P = .001$), cardiac disease ($\beta = -3.59$, CI −7.12, −.0.07, $P = .046$), and any complication ($\beta = 0.28$, CI 0.19, 0.36, $P < .001$). The final ASES score was negatively impacted by MRF including opioid use ($\beta = -4.08$, CI: −7.32, −0.84, $P < .001$) and smoking status ($\beta = -7.59$, CI: −12.69, −2.49, $P < .001$). Males had slightly higher final ASES scores ($\beta = 3.79$, CI 0.46, 7.11, $P = .026$). Patients with prior surgery were more likely to have an intraoperative stress fracture [odds ratio [OR] 4.6 (1.1, 19.5), $P = .038$] and borderline more likely to have neurologic complication [OR 1.7 (1.0, 3.0), $P = .062$] or any complication [OR 1.5 (1.0, 2.3), $P = .075$].

Conclusion: Patients with prior shoulder surgery were younger, more likely to be male, and more likely to have a history of tobacco use and opioid use. These patients experienced worse subjective clinical outcomes and were more likely to experience a complication.

Total shoulder arthroplasty (TSA) cases including anatomic total shoulder arthroplasty (ATSA) and reverse total shoulder arthroplasty (RTSA) more than doubled between 2011 and 2017, with the number of RTSA almost tripling in that same period.[27] Whereas revision arthroplasty has been extensively investigated, less is understood about the effect of prior nonarthroplasty surgery on complications and outcomes after shoulder arthroplasty.

This study was conducted with the protocol approved by the SSM St. Louis Institutional Review Board.

This study was performed at SSM Health Orthopedics, St. Louis, MO, USA.

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Several authors have noted that patients undergoing shoulder arthroplasty after previous ipsilateral shoulder surgery may demonstrate increased complications and inferior outcomes. Previous shoulder surgery has been identified as a risk for intraoperative[1] and postoperative complications after shoulder arthroplasty.[8,15] Prior surgery increases the risk of prosthetic joint infection (PJI) in those patients who had surgery within 2 years of arthroplasty,[19,29] with the highest risk within 90 days.[14] Jensen et al found that prior rotator cuff repair increased the risk of revision for PJI.[12] Prior nonarthroplasty surgery has also impacted postoperative clinical outcomes[8,20,22] and postoperative range of motion.[17]

There has been increased interest in identifying factors that can negatively impact results after shoulder arthroplasty. In addition to a history of prior ipsilateral shoulder surgery, other factors including age, male gender, smoking status, and comorbidities have been implicated in complications and revisions after TSA.[5,6,13] Modifiable risk factors (MRFs) represent a subset of medical comorbidities that can be positively impacted prior to surgery. Several factors previously identified to increase health-care utilization after arthroplasty include anemia, malnutrition, obesity, uncontrolled diabetes, preoperative opioid use, and tobacco use.[3,9,21] Opioid use has been associated with inferior outcomes after ATSA[26] and risk of revision.[25] Smoking, diabetes, and malnutrition are associated with increased risk of surgical complications and revisions.[2,7,11,13,15]

The primary aim of this study was to evaluate clinical results in patients with a history of ipsilateral shoulder surgery prior to TSA. Secondary aims were (1) to determine if a history of prior surgery impacted health-care utilization or complication risk after TSA and (2) to identify whether MRF independently impacted outcomes in patients with a history of ipsilateral shoulder surgery.

Patients and methods

Study population

This study was approved by our institutional review board. We performed a retrospective review of all patients who underwent elective primary TSA, both ATSA and RTSA, at one institution by one surgeon from January 2015 through December 2019. Revision arthroplasty patients and those who received hemiarthroplasty were excluded. Patient characteristics including age, sex, body mass index (BMI), ethnicity, comorbidities, and general health status as measured by the American Society of Anesthesiologists score were recorded. Type of arthroplasty performed, ATSA vs. RTSA also was noted. Each procedure was treated as an independent observation.

Surgical technique and postoperative protocol

All patients received a preoperative interscalene block and underwent general anesthesia. The implants were placed via a standard deltopectoral approach. Humeral components were placed in an estimated 30 degrees of retroversion. All components were press fit with the exception of the peripheral pegs of the anatomic glenoid component, and all patients had the subscapularis repaired, regardless of tissue quality. The rehabilitation protocol was the same for all patients. A sling was used for 3 weeks; passive range of motion exercises were started on day 1; patients were allowed to use the affected arm for activities of daily living and light activity, with a one-pound restriction. The use of tranexamic acid (TXA) was adopted during the study period, and TXA use was recorded for each patient.

Exposure of interest

The exposure of interest was a history of prior ipsilateral nonarthroplasty shoulder surgery in patients undergoing primary shoulder arthroplasty. This was confirmed via patient history and the presence of ipsilateral shoulder scars, and included both open and arthroscopic procedures.

Outcomes of interest

Patient-reported outcome measures (PROMs) including visual analog scale for pain, (VAS); American Shoulder and Elbow Surgeons score, (ASES); Simple Shoulder Test, (SST); and Single Assessment Numeric Evaluation, (SANE) were compared between groups. The minimal clinically important difference (MCID) was defined for ASES (13.6 ± 2.3), SST (1.5 ± 0.3), and VAS (1.6 ± 0.3) by Simovitch et al.[23] MCID for the SANE score was defined by Gowd et al as 13.4.[10] Substantial clinical benefit (SCB) was defined for VAS (3.2 ± 0.3), ASES (31.5 ± 2.0), and SST (3.4 ± 0.3).[24] SCB for the SANE score was defined as a final score of 80.4.[4]

Transfusion rates as well as other medical and surgical complications were also recorded. Assessed complications included transfusion, prosthetic joint infection or surgical site infection, medical complications including DVT, PE, MI or stroke, neurologic complications, fracture complications (differentiated into intraoperative, postoperative, and acromial stress fracture and acromial pain), and reoperation (differentiated into revision arthroplasty and ipsilateral surgery nonrevision), as well as any other complications not otherwise specified. This category included rashes and superficial wound issues including stitch abscess that did not require surgery or meet the criteria of surgical site infection.

Costs were evaluated between the cohorts, including surgery-related 90-day charges after shoulder arthroplasty, length of stay (LOS), emergency department (ED) visits, and hospital readmission within 90 days from surgery. Other factors examined were ED charges and readmission charges, operative time, and intraoperative estimated blood loss. Charges were determined using Chargemaster, which is software within the EMR that applies a standardized list of charges for a given procedure, product, or service. The Chargemaster price represents the estimated cost for labor, facility use, technology costs, and including the cost of covering underinsured/uninsured care. This does not directly correlate with the payment received by the institution but is a standardized list of charges.

Covariates

Patient characteristics including age, sex, race, and patient comorbidities including MRFs were evaluated, as well as baseline laboratory studies including baseline hemoglobin (Hg) and hematocrit. Recorded patient comorbidities included pulmonary disease, cardiac disease, hypertension, diabetes mellitus (DM), peptic ulcer disease, liver disease, history of DVT or PE, and anxiety/depression. Anticoagulant use was also evaluated, and for the purposes of this study included the use of antiplatelet medications (aspirin, clopidogrel, apixaban, rivaroxaban, and warfarin).

The presence of MRF between cohorts of patients with and without prior surgery was evaluated as possible predictors and confounders. MRFs were defined as the following: anemia (World Health Organization definition, Hg < 13 g/dL for males and Hg < 12 g/dL for females), severe anemia (Hg < 10 g/dL for all), malnutrition (albumin <3.4 g/dL), obesity (BMI >40 kg/m^2), uncontrolled DM (random glucose >180 mg/dL or hemoglobin A1C >8%), tobacco use (International Classification of Diseases 10 code indicating patient is a smoker) and opioid use (opioid prescription within 90 days of

surgery). Missing data were not imputed, and only patients with data for the variable in question were analyzed.

Statistical methods

Clinical characteristics, baseline demographics, complications, and costs were described according to prior surgery status using counts and frequencies (%) for categorical variables and mean with standard deviation for numeric variables. We tested for differences in numeric variables by prior surgery status using t-tests or Wilcoxon Rank Sum tests, as appropriate for data distribution. Skewness and kurtosis were evaluated visually using histograms and box plots, and Wilcoxon Rank sum tests were used for data without a normal distribution. Tests of normality were not utilized for this cohort due to limited sensitivity. Categorical variables were assessed using Pearson's chi-square or Fisher's exact test.

Multivariable linear regression was used to compare final ASES score between the prior surgery group and patients without prior surgery, after adjusting for confounders including baseline ASES score. A confounder was defined as any variable which, when added to the model, altered the relationship between prior surgery and PROMs by >15%. We evaluated the following variables for inclusion in the model: age, sex, left or right side, cardiac disease, anticoagulant use and procedure type; we also evaluated MRFs for inclusion defined as tobacco use, opioid use, uncontrolled DM, severe anemia, and malnutrition. Only variables that were statistically significantly ($P < .05$) associated with prior surgery or were confounders were included in the final model. We built separate models for adjusted and unadjusted final ASES and present both results. The ASES model was adjusted for predictors and confounders including sex, age, procedure type, smoking status, preoperative opioid use, cardiac disease, and complications, as well as baseline ASES score. We present βs and 95% confidence intervals (CIs), which is interpreted as the change in the outcome for each unit change in the independent variable. No adjustments were made for multiple comparisons.

Model appropriateness and fit were assessed using a specification link test for single-equation models, the Hosmer-Lemeshow goodness-of-fit test, and inspection of residuals, outliers, and leverage. A P value of <.05 was considered statistically significant and all CIs were 95%. All statistical analysis was performed using Stata 17.0 (StataCorp, College Station, TX, USA).

We calculated the effect size we would be able to detect with the available 512 patients. Assuming a two-sided alpha level of 0.05, 80% power, and a probability of any complication among the prior surgery group of 0.28, we would be able to detect an odds ratio (OR) of 1.37 or greater. We also calculated the effect size (β) we could detect with 512 patients based on a multivariable linear regression model with 4 control variables ($R^2 = 0.2$) and 1 exposure of interest. Assuming 80% power and a two-sided α of 0.05, we would be able to detect an effect size of $\beta = 0.18$. Power was calculated using G*Power 3.1 (Heinrich Heine Universität, Düsseldorf, Germany).

Results

A total of 512 patients met study inclusion criteria; 373 had no history of prior surgery; 139 patients had at least one prior ipsilateral shoulder surgery. The types of prior surgery included rotator cuff repair, both open and arthroscopic (n = 131), shoulder arthroscopy without cuff repair (n = 41), and other open procedures including open stabilization or acromioclavicular joint reconstruction (n = 10). Thirty-four patients had more than one ipsilateral prior shoulder surgery and 58 patients had bilateral procedures.

Clinical characteristics

The demographic and clinical characteristics of the populations are summarized in Table I. We found that those in the group with prior surgery were more than 5 years younger than those who had a previous surgery (65.2 ± 9.3 vs. 70.7 ± 9.1, respectively, $P < .001$). Sex was different between groups, with a higher proportion of males in the prior surgery group compared to those who did not have a prior surgery (52.2% vs. 40.3%, respectively, $P = .016$). Additionally, those who had a prior surgery were more likely to have surgery on the right shoulder compared to those with no prior surgery (64.0% vs. 49.1%, $P = .003$). Patients with prior surgery were more likely to receive RTSA than those in the no prior surgery group (82.7% vs. 72.4%, $P = .016$). No difference was found between groups for all other baseline characteristics, including BMI, race, American Society of Anesthesiologists classification, estimated blood loss, TXA use, and anticoagulant use (Table I, $P > .05$ for all).

Modifiable risk factors

Regarding MRFs, patients with prior surgery were more likely to smoke or have a history of smoking (51.8% vs. 36.5%, $P = .002$) and were borderline more likely to use preoperative opioids (47.5% vs. 38.9%, $P = .078$) (Table I). Patients with prior surgery had similar rates of uncontrolled DM (3.0% vs. 4.6%, $P = .615$), obesity (8.6% vs. 11.8%, $P = .308$), anemia (23.4% vs. 24.7%, $P = .765$), severe anemia with Hg < 10 (0.7% vs. 2.7%, $P = .303$), and malnutrition (14.3% vs. 16.7%, $P = .514$).

Complication risk

Patients with prior surgery were more likely to sustain an intraoperative fracture. [OR 4.6 (1.1, 19.5) $P = .038$], and were borderline more likely to have a neurologic complication [OR 1.7 (1.0, 3.0) $P = .062$] as well as any complication [OR 1.5 (1.0, 2.3), $P = .075$], (Table II). Only 2 patients had PJI, all in the no-prior-surgery group; thus, comparative analysis could not be performed for this variable.

Health-care utilization

Patients with prior surgery had similar operative time (55.8 ± 13.5 vs. 57.1 ± 18.6 minutes, $P = .426$), no difference in 90-day charges ($35,899 ± $4959 vs. $36,160 ± $5918.50, $P = .671$), ED visit charges ($135.10 ± 562.00 vs. $224.70 ± 1539.80, $P = .505$) or readmission charges ($296.30 ± 2471.00 vs. $1447.10 ± 8486.20, $P = .120$, Table III). Patients with prior surgery had similar rates of readmission (3.6% vs. 6.4%, $P = .284$) and ED visits (7.2% vs. 5.4%, $P = .286$). Last, LOS was statistically significantly less in patients with prior surgery compared to those who did not have a previous surgery, though this difference is small and likely not clinically significant (2.2 ± 1.1 vs. 2.4 ± 1.1 days, respectively, $P = .016$).

Clinical outcomes

Follow-up was similar in both groups, 28.8 ± 21.1 months in patients with a history of prior surgery and 30.3 ± 23.7 months in patients without prior surgery ($P = .524$) (Table IV). Patients who had prior surgery had significantly higher VAS at final follow-up (1.7 ± 2.4 vs. 1.1 ± 1.9, $P = .001$), lower final ASES scores (75.1 ± 21.5 vs. 81.9 ± 18.6, $P < .001$), lower final SST (8.1 ± 3.0 vs. 8.9 ± 2.8, $P = .013$), and lower final SANE scores (78.1 ± 21.6 vs. 83.3 ± 20.1, $P = .018$), despite similar baseline scores for all measures ($P > .05$ for

Table I
Demographics and clinical characteristics of the study population.

Variable	No prior surgery		Prior surgery		*P* value*
	N	Mean ± SD or count (%)	n	Mean ± SD or count (%)	
Demographics					
Age	373	70.7 ± 9.1	139	65.2 ± 9.3	<.001
BMI	373	31.7 ± 6.8	139	31.4 ± 6.3	.551
Sex†	372		138		.016
Female		222 (59.7)		66 (47.8)	
Male		150 (40.3)		72 (52.2)	
Race	373		139		.408
White		327 (87.7)		118 (84.9)	
Black		46 (12.3)		21 (15.1)	
Clinical characteristics					
Number of prior surgeries	373	–	139	1.3 ± 0.6	NA
Side	373		139		.003
Right		183 (49.1)		89 (64.0)	
Left		190 (50.9)		50 (36.0)	
ASA classification	373		139		.540
1		3 (0.8)		0 (0)	
2		155 (41.6)		53 (38.1)	
3		210 (56.3)		85 (61.2)	
4		5 (1.3)		1 (0.7)	
Procedure type	373		139		.016
ATSA		103 (27.6)		24 (17.3)	
RTSA		270 (72.4)		115 (82.7)	
Estimated blood loss (ml)	373	158.6 ± 108.6	139	144.4 ± 80.8	.162
TXA use	373	118 (31.6)	139	41 (29.5)	.642
Anticoagulant use†	373	31 (8.3)	139	8 (5.8)	.332
Modifiable risk factors					
Smoking status	373		139		.002
Never		237 (63.5)		67 (48.2)	
Former		97 (26.0)		44 (31.7)	
Current		39 (10.5)		28 (20.1)	
Preoperative opioid use	373	145 (38.9)	139	66 (47.5)	.078
Uncontrolled DM	369	17 (4.6)	135	4 (3.0)	.615
Obesity	373	44 (11.8)	139	12 (8.6)	.308
Severe anemia‡	373	10 (2.7)	139	1 (0.7)	.303
Malnutrition	365	61 (16.7)	133	19 (14.3)	.514

BMI, body mass index; *ASA*, American Society of Anesthesiologists; *TXA*, tranexamic acid; *DM*, diabetes mellitus; *ATSA*, anatomic total shoulder arthroplasty or hemiarthroplasty; *RTSA*, reverse total shoulder arthroplasty; *SD*, standard deviation.

**P* values were obtained using t-tests or Wilcoxon Rank Sum test, dependent upon distribution. Categorical variables were analyzed using Pearson's chi-square or Fisher's Exact test, dependent upon the expected counts.

†Anticoagulant use is defined as patients who were taking anticoagulation medication preoperatively (including aspirin, clopidogrel, apixaban, rivaroxaban, and warfarin).

‡Severe anemia was defined as Hg < 10.

Table II
Univariate associations between history of prior surgery and surgical complications (n = 518).

Outcome variable	No prior surgery (referent, n = 373) vs. Prior surgery (n = 139)	
	OR (95% CI)	*P* value*
Transfusion	0.7 (0.1, 6.0)	.720
Instability, cuff dysfunction	2.1 (0.7, 6.0)	.189
DVT/PE, MI or stroke	0.7 (0.1, 3.2)	.610
Neurologic complications	1.7 (1.0, 3.0)	.062
Intraoperative fracture	**4.6 (1.1, 19.5)**	**.038**
Acromial stress fracture/pain	1.0 (0.4, 2.4)	.979
Revision	1.7 (0.7, 4.6)	.260
Other complication†	0.7 (0.1, 6.0)	.720
Same side reoperation	0.9 (0.1, 8.7)	.923
Any complication†	1.5 (1.0, 2.3)	.075

DVT, deep vein thrombosis; *PE*, pulmonary embolism; *MI*, myocardial infarction; *CI*, confidence interval; *OR*, odds rartio.
Bold text indicates statistical significance.

**P* values were obtained using univariate logistic regression.

†Other complications included rashes and superficial wound concerns.

‡Any complication was defined as having any one of the surgical complications listed except transfusion.

all). Objective data including active forward elevation (AFE) and forward flexion strength testing (FF) showed similar gains between groups ($P = .335$ and $P = .670$, respectively).

Multivariable model

A multivariable model was created to evaluate the independent effects of predictors on the relationship between final ASES scores and a history of prior surgery (Table V). Having a history of prior surgery decreased the final ASES score by 4.25 points compared to those who did not have prior surgery (CI: −7.93, −0.57, $P = .024$). Male patients had higher final ASES scores ($\beta = 3.79$, CI: 0.46, 7.12, $P < .026$) compared to females. Having RTSA also lowered ASES scores at final follow-up when compared to ATSA ($\beta = -6.31$, CI: −10.02, −2.60, $P = .001$).

Patient factors (including MRFs) also independently impacted final ASES scores, including preoperative opioid use ($\beta = -4.08$, CI: −7.32, −0.84, $P = .014$), and preoperative current smoking status ($\beta = -7.59$, CI: −12.69, −2.49, $P = .004$). Experiencing a complication reduced final ASES scores independent of a history of prior surgery ($\beta = -8.75$, CI −12.36, −5.14, $P < .001$). Cardiac disease also independently predicted reduction in final ASES score and may be a marker for medical comorbidities ($\beta = -3.59$, CI: −7.12, −0.07, $P = .046$). Obesity, malnutrition, anemia, number of prior surgeries, and uncontrolled DM did not influence final ASES scores in the multivariable model either as a predictor or a confounder and therefore were not included in the final model.

Table III
Univariate associations between history of prior surgery and health-care utilization.

Variable	No prior surgery		Prior surgery		*P* value*
	N	Mean ± SD or count (%)	n	Mean ± SD or count (%)	
Charges					
Operative time (min)	373	57.1 ± 18.6	139	55.8 ± 13.5	.426
Encounter costs, dollars	324	36,160.0 ± 5918.5	117	35899.8 ± 4959.0	.671
Total ED costs	371	224.7 ± 1539.8	138	135.1 ± 562.0	.505
Total revisit charges, dollars	366	1447.1 ± 8486.2	136	296.3 ± 2471.0	.120
Nonsurgical complications					
Readmission	373	24 (6.4)	139	5 (3.6)	.284
ED visit	373	20 (5.4)	139	10 (7.2)	.432
Length of stay	373	2.4 ± 1.1	139	2.2 ± 1.1	.016

ED, emergency department; *SD*, standard deviation.
**P* values were obtained using t-tests or Wilcoxon Rank Sum test, dependent upon distribution. Categorical variables were analyzed using Pearson's chi-square or Fisher's Exact test, dependent upon the expected counts.

Table IV
Univariate associations between outcome measures and history of prior surgery.

Variable	No prior surgery		Prior surgery		*P* value*
	n	Mean ± SD	n	Mean ± SD	
Follow-up, months	357	30.3 ± 23.7	132	28.8 ± 21.1	.524
Preoperative values					
VAS	340	5.9 ± 2.6	132	6.1 ± 2.5	.563
ASES	340	38.8 ± 19.5	130	36.4 ± 18.0	.210
SST	353	3.7 ± 2.7	136	4.0 ± 2.7	.316
SANE	249	40.6 ± 22.8	101	40.9 ± 22.1	.915
Active elevation	352	107.8 ± 39.2	137	114.2 ± 40.1	.109
Strength†	344	4.1 ± 1.0	136	4.0 ± 0.9	.191
Postoperative values					
VAS	348	1.0 ± 1.9	126	1.7 ± 2.4	.001
ASES	347	81.9 ± 18.6	124	75.1 ± 21.5	<.001
SST	348	8.9 ± 2.8	126	8.1 ± 3.0	.013
SANE	353	83.3 ± 20.1	122	78.1 ± 21.6	.018
Active elevation	250	138.1 ± 26.2	88	138.2 ± 24.8	.990
Strength†	247	4.7 ± 0.6	84	4.7 ± 0.6	.977
Difference post-pre					
VAS	320	−4.9 ± 2.7	119	−4.4 ± 2.9	.070
ASES	319	43.8 ± 20.5	116	38.7 ± 22.7	.025
SST	353	5.2 ± 3.3	123	4.1 ± 3.2	.003
SANE	234	43.2 ± 26.0	92	39.8 ± 28.7	.304
Active elevation	239	32.1 ± 37.4	87	27.6 ± 38.1	.335
Strength†	230	0.7 ± 1.1	82	0.7 ± 1.0	.670

VAS, visual analog scale for pain; *ASES*, American Shoulder and Elbow Surgeon score, *SST*, Simple Shoulder Test; *SANE*, Single Assessment Numeric Evaluation; *SD*, standard deviation.
The minimal clinically important difference (MCID) was defined for ASES (13.6 ± 2.3), SST (1.5 ± 0.3), VAS (1.6 ± 0.3) and 13.4 for SANE., Substantial clinical benefit (SCB) was defined for VAS (3.2 ± 0.3), ASES (31.5 ± 2.0), and SST (3.4 ± 0.3). SCB, for the SANE, score was defined as a final score of 80.4 or higher.
**P* values were obtained using t-tests.
†Measured strength in forward flexion on a 1-5 grading scale.

Discussion

Patients with a history of ipsilateral shoulder surgery had worse postoperative arthroplasty outcomes compared with outcomes for patients with no history of prior surgery, including higher VAS and lower patient reported outcomes (ASES, SST, and SANE), despite being similar at baseline. This was true despite similar objective gains in AFE and strength testing. These patients were also more likely to have a postoperative complication, specifically intraoperative fracture. These findings are similar to those of Frank et al and Wright-Chisem et al, who found that clinical results and complication risk were negatively impacted by a history of prior surgery.[8,29] A recent study by Marigi et al confirmed that patient factors (specifically prior surgery and smoking) increased complication risk more substantially than implant design choice.[15]

Despite these findings, patients with prior surgery did achieve SCB as defined by Simovitch et al for VAS, ASES, and SST.[24] The only exception was the SANE score, for which SCB was defined as a score of 80.4[4]; only patients without a history of prior surgery achieved this threshold. This finding is similar to a few case-control studies evaluating patients with prior instability surgery[17] or prior rotator cuff repair[16] in which similar improvements in scores were found between groups.

To our knowledge, no studies have previously quantified the impact of prior surgery on health-care utilization. Our results indicate that prior surgery does not significantly impact cost drivers, with the exception of a shorter LOS. This finding may be confounded by the fact that prior surgery patients were younger and male. Matsen et al found that female sex and advanced age were among several factors associated with longer LOS and these patients were over-represented in the cohort without prior surgery.[18] Further studies will be needed to confirm our findings that prior surgery patients do not incur increased charges, LOS, readmissions, or ED visits.

Few studies have examined the impact of MRFs on PROMs after shoulder arthroplasty. In this cohort, smoking and opioid use contributed to lower ASES scores at final follow-up. This confirms results by Thompson et al who found preoperative opioid use reduced ASES and increased VAS at final follow-up after ATSA.[26] Our results also confirm those by White et al who found that smoking status resulted in lower postoperative PROMs,[28] though their findings did not reach clinical significance. None of these factors independently reached the MCID for the ASES; however, these factors may have a cumulative effect and are worthy of further investigation.

Limitations of this study include the retrospective nature of data collection, which resulted in incomplete or missing data for MRFs, thereby limiting the population available for analysis and potentially introducing selection bias. While we cannot be certain that the data was missing-at-random, the amount of missing data was quite small and likely did not substantively impact the results. The study population was a convenience sample from one surgeon at one institution and may not be generalizable to other populations. Each surgery was treated as an independent event; we did not consider correlations within the same individual. Surgical history was obtained via the patient, and most patients had previous cuff repair. The cohort was too small and homogenous with regard to type of prior surgery, limiting ability to perform independent analysis of how the type of prior surgery impacted results. Additionally, costs were imputed based on charges, which do not reflect dollar amounts billed or collected. However, this is part of a standard accounting system utilized by our institution and allowed for unbiased assessment of costs.

Table V
Multivariable linear regression model to evaluate association of prior surgery with final ASES score.

Variable	n	Unadjusted β^{*} (95% CI)	*P* value	n	Adjusted $\beta^{*,\dagger}$ (95% CI)	*P* value
Final American Shoulder and Elbow Surgeons score (ASES)						
Prior surgery	476			439		
No	350	Referent		321	Referent	
Yes	126	−6.76 (−10.74, −2.78)	.001	118	−4.25 (−7.93, −0.57)	**.024**
Sex				439		
Female	–	–	–	244	Referent	
Male				193	3.79 (0.46, 7.12)	**.026**
Age	–			439	0.16 (−0.03, 0.35)	.093
Procedure type				439		
ATSA	–	–	–	116	Referent	
RTSA				323	−6.31 (−10.02, −2.60)	**.001**
Preoperative opioid use				439		
No	–	–	–	259	Referent	
Yes				180	−4.08 (−7.32, −0.84)	**.014**
Smoking status				439		
Never	–	–	–	265	Referent	
Former				122	1.76 (−1.81, 5.34)	.333
Current				52	−7.59 (−12.69, −2.49)	**.004**
Cardiac disease[‡]				439		
No	–	–	–	303	Referent	
Yes				136	−3.59 (−7.12, −0.07)	**.046**
Any complication[§]	–	–	–	439	Referent	**<.001**
					−8.75 (−12.36, −5.14)	
Preoperative ASES	–	–	–	439	0.28 (0.19, 0.36)	**<.001**

ASES, American Shoulder and Elbow Surgeons; *ATSA*, anatomic total shoulder arthroplasty; *RTSA*, reverse total shoulder arthroplasty; *CI*, confidence interval. Factors that significantly impacted final ASES score are identified in bold. Preoperative ASES score was highly correlated with final score and was included in the adjusted model to correct this correlation.

[*] β (slope) is interpreted as the change in the ASES for a one-unit change in the independent variable (eg, prior surgery).

[†] ASES, model is adjusted for all presented variables including the preoperative ASES. All variables included in the model were either statistically significant predictors or confounders.

[‡] Cardiac disease was defined as indicating a cardiac history on patient intake forms.

[§] Any complication was defined as having any one of the surgical complications listed previously except transfusion.

Strengths of this study include the cohort design, which allowed for assessment of variables present before, during, and after surgery. Evaluation, management, and data collection was performed by a single physician practice, reducing the likelihood of variability in surgical decision-making treatment. To our knowledge, this is the first study to examine the independent effects of multiple MRFs on outcomes after shoulder arthroplasty in patients with a history of prior nonarthroplasty surgery.

Conclusion

Patients with and without prior surgery had significant improvement after TSA, with both cohorts achieving MCID and similar health-care utilization in terms of charges, ED visits, and readmission rates. However, the magnitude of improvement was lower for patients with prior surgery. MRFs, specifically preoperative opioid use and preoperative smoking, independently negatively impacted final ASES scores, suggesting there may be a role for ameliorating MRFs prior to shoulder arthroplasty, regardless of prior nonarthroplasty surgery status.

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