Impact of Accumulating Risk Factors on the Acromial and Scapular Fracture Rate after Reverse Total Shoulder Arthroplasty

Roche, C; Simovitch, R; Flurin, PH; Wright, T; Zuckerman, J; Routman, H

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Introduction: Identifying risk factors for acromial and scapular risk factors helps us understand which variables are relevant to this fracture complication; however, this data is difficult to integrate into clinical practice because the majority of rTSA patients have 1 or more risk factors. The goal of this new statistical analysis is to better facilitate pre-operative identification of patients at-risk for acromial and scapular fracture to quantify the impact of accumulating risk factors on the incidence of fracture.

Methods: We retrospectively analyzed an international multi-center database of a single platform shoulder prosthesis (Equinoxe; Exactech Inc, Gainesville, FL USA) and quantified the acromial and scapular fracture rate associated with this medialized glenoid/lateralized humerus onlay rTSA prosthesis to identify pre-operative risk factors for this fracture complication. All rTSA patients in the database were included, no patients were excluded, including those with revisions, previous infections, and fracture indications. These criteria resulted in 9,079 patients (5,494F/3,432M/153 unspecified; mean age: 71.5yrs) treated with rTSA by 40 orthopaedic surgeons between March 2007 and March 2022. All patients were evaluated at pre-determined intervals using standardized pre-operative demographic and clinical forms, as well as post-operative clinical and radiographic forms. The presence of tenderness of the acromion/scapula or radiographic diagnosis of an acromial/scapula fracture was reported as an adverse event; each identified patient was then radiographically reviewed and those with radiographic documentation of fracture had their fracture pattern classified according to Levy et al.

To identify significant risk factors for acromial and/or scapular fractures, we conducted a univariate and multivariate statistical analysis of demographic, diagnosis, comorbidity, implant data, and clinical and radiographic outcomes for fracture patients relative to the larger cohort of patients without fracture. Specifically, a univariate analysis was performed using a two-tailed, unpaired t-test for continuous variables and a Chi-Square test or Fisher's Exact test for categorical variables to identify significant risk factors for acromial and scapular fractures. Next, a multivariate logistic regression analysis was performed on the parameters identified as being significant from the univariate analysis. The multivariate analysis adjusted the effect of each individual parameter, holding all the other variables constant. Next, to better understand the commonality of these identified significant risk factors of age, gender, and diagnosis in the patient population undergoing rTSA, we quantified the prevalence of patients with zero, one, two, three, and four age, gender, or diagnosis risk factors for fracture. Finally, to better adapt our statistical results for prospective pre-operative identification of patients who are most at-risk for fracture, we stratified our dataset by multiple combinations of age, gender, and diagnosis risk factors and calculated the odds ratio for each cohort to quantify the impact of accumulating risk factors on the incidence of fracture.

Results: One hundred and thirty-eight (1.52%) of 9,079 patients were radiographically identified to have a fracture of the acromion or scapula at an average of 10.2 ± 15.1 months (range: 1 day to 83.3 months) after surgery. The average follow-up of fracture patients was 26.5 ± 23.9 months, which was not significantly different than the average follow-up of patients without fracture which was 26.2 ± 26.4 months. One hundred and two (73.9%) of 138 fractures occurred in the first year after surgery and 46 (33.3%) occurred within 3 months of surgery. Regarding fracture classification, 54 patients had a Type 1 fracture (39.1%) at an average of 9.1 ± 12.5 months after surgery, 54 patients had a Type 2 fracture (39.1%) at an average of 6.5 ± 12.1 months, and 30 patients had a Type 3 fracture (21.7%) at an average of 19.2 ± 20.9 months. At latest follow-up, which was on average 18.2 ± 19.5 months after fracture occurrence, patients with acromial and/or scapular fractures had significantly worse outcomes than patients without fractures.

A univariate and multivariate analysis was performed to identify risk factors for acromial and scapular fractures. As presented in Table 1, patients with acromial and/or scapular fractures were more likely older (73.2 vs. 71.5 years, p=0.010), female (79.6% vs. 61.3%, p<0.001), more likely to have a RA diagnosis (5.9% vs. 2.6%, p=0.026), more likely to have a CTA diagnosis (43.0% vs. 32.0%, p=0.009), and less likely to have a diabetes diagnosis (7.5% vs. 15.2%, p=0.010) as compared to patients without fracture. A few implant differences were also observed, as presented in Figure 1, patients with acromial and/or scapular fractures had significantly more glenoid baseplate screws (3.8 vs 3.7 screws, p=0.005) and a significantly smaller diameter glenosphere (38.6 vs 39.5mm, p<0.001) as compared to patients without fracture. All but age, which trended significant (p=0.054), were confirmed by the multivariate analysis as being a significant risk factors for fractures. To illustrate the commonality of these age, gender, and diagnosis risk factors in the rTSA patient population, we identified that only 15.0% of patients in our study had no age, gender, or diagnosis risk factors for acromial and/or scapular fractures. Specifically, 61.6% of patients in our study were female, 48.3% were 73 years or older at the time of surgery, 32.2% had CTA diagnosis, and 2.6% had RA diagnosis. Considering these distributions, 37.1% of rTSA patients in our study had 1 risk factor, 36.7% had 2 risk factors, 11.0% had 3 risk factors, and 0.2% had 4 risk factors. Interestingly, 9 of 138 patients with acromial and/or scapular fractures exhibited 0 risk factors. For these age, gender, and diagnosis risk factors, we stratified multiple combinations of age, gender, and diagnosis cohorts and calculated odds ratio associated with fracture risk to quantify the impact of accumulating risk factors on the fracture incidence. As described in Figure 2, several combinations of risk factors were observed with acromial and/or scapular fracture odds ratios >1.5. Age by itself failed to adequately identify patients at-risk for fracture, as none of the six, 5-year age bins yielded a cohort with a fracture rate >2% or a odds ratio >1.4. Gender by itself provided better fracture risk resolution, as female patients were demonstrated to have an odds ratio of 2.48, however, acromial and/or scapular fractures in this cohort were still rare as only 1.98% of female patients experienced a fracture. In combination, age and gender provided slightly better fracture risk resolution by identifying 2 cohorts (females >75 and females > 80) with fracture rates >2.25% and odds ratios >1.5. The inclusion of diagnosis provided better fracture risk resolution, as 2 diagnoses (RA and CTA) were associated with fracture rates >2% and odds ratios >1.5. The combination of age and diagnosis identified 2 cohorts with elevated fracture risk: 1) females with CTA (2.75% fracture rate and odds ratio = 2.25) and 2) females with RA (4.3% fracture rate and odds ratio = 3.0). The combination of age, gender, and diagnosis identified numerous cohorts with the most pronounced risk of acromial and/or scapular fractures, where the patients with the greatest fracture risk were identified to be female with RA diagnosis who are >70 years (7.7% fracture rate and odds ratio = 5.6), >75 years (10.4% fracture rate and odds ratio = 7.8), and >80 years (13.3% fracture rate and odds ratio = 10.1).

Discussion: This 9,079 rTSA multi-center study demonstrated that 1.52% of patients experienced acromial and/or scapular fractures with one specific medialized glenoid/lateralized humerus onlay rTSA prosthesis at an average of 10.2 months after surgery. The multivariate analysis identified numerous risk factors for fracture but also demonstrated that only 15% of rTSA patients had no fracture risk factors; additionally, 37.1% have 1 risk factor, 36.7% have 2 risk factors, 11.0% have 3 risk factors, and 0.2% have 4 risk factors. Given this commonality, we demonstrated the benefit of stratifying multiple combinations of age, gender, and diagnosis to quantify the impact of accumulating risk factors on fracture incidence and identified that the patients with the most pronounced fracture risk were females with RA diagnosis who are >70 years, >75 years, and >80 years at the time of surgery. Patients considering rTSA with these age, gender, and diagnosis characteristics should be made fully aware of this elevated complication risk.

Significance: This rTSA clinical study used a multivariate analysis to identify risk factors for acromial and scapular fractures after rTSA and demonstrated the majority of patients undergoing rTSA have at least 1 risk factor for fracture. Additionally, this study quantified the impact of accumulating age, gender, and diagnosis risk factors on fracture incidence and identified that the patients with the most pronounced fracture risk.

Figure 1. Results of a Multivariate Analysis Comparison of rTSA Patient Demographics, Diagnosis, and Comorbidities and also Implant data Between Patients with and without Acromial or Scapular Fractures

rTSA Patient Demographics	**Patients w/o Fx**	**Fx Patients**	**P Value (bivariate)**	**P Value (Multivariate)**
Shoulder Number	8941	138		
Average Age at Surgery (yrs)	71.5 ± 8.2	73.2 ± 7.6	**0.010**	0.054
Gender (female=1)	5385 (61.3%)	109 (79.6%)	**< 0.001**	**< 0.001**
BMI	29.1 ± 6.0	28.5 ± 6.5	0.341	-
No Comorbidities	27.8%	31.3%	0.382	-
OA Diagnosis	46.2%	48.9%	0.543	-
RA Diagnosis	2.6%	5.9%	**0.026**	**0.016**
RCT Diagnosis	31.3%	34.1%	0.456	-
CTA Diagnosis	32.0%	43.0%	**0.009**	**0.012**
Diabetes Diagnosis	15.2%	7.5%	**0.010**	**0.032**
Previous Shoulder Surgery	32.1%	38.7%	0.117	-
Hypertension	55.1%	55.2%	1	-
Heart Disease	15.8%	15.7%	1	-
Previous Injections	36.0%	40.1%	0.325	-
Tobacco Usage	7.2%	8.2%	0.615	-
Chronic Renal Failure	2.0%	2.2%	0.750	-
Glenoid retroversion	7.8 ± 9.4	7.4 ± 8.4	0.770	-
Walch glenoid type (A1 vs other)	50.8%	50%	1	-
Preop Beta angle	81.2 ± 9.1	80.0 ± 10.6	0.594	-
Preop subluxation	55.8 ± 19.9	52.7 ± 21.3	0.539	-
SIRVCLASS (No=0)	36.7%	28.6%	0.379	-
rTSA Patient Implant Data	**Patients w/o Fx**	**Fx Patients**	**P Value (bivariate)**	**P Value (Multivariate)**
% Cemented Humeral Stem	15.0%	10.1%	0.118	-
Humeral Stem Size (mm)	10.6 ± 2.5	10.8 ± 2.4	0.245	-
Humeral Liner Constraint %	5.0%	4.4%	1	-
Humeral Liner Offset (mm)	0.5 ± 1.0	0.5 ± 1.0	0.526	-
Humeral Tray Offset (mm)	0.5 ± 1.8	0.5 ± 2.0	0.893	-
Combined Tray+Liner Offset (mm)	1.1 ± 2.2	1.0 ± 2.4	0.844	-
Glenosphere Diameter	39.5 ± 2.4	38.6 ± 2.0	**< 0.001**	**< 0.001**
Expanded Glenosphere Usage	8.3%	7.0%	0.747	-
Augmented Baseplate Usage	33.4%	37.3%	0.357	-
Number of Baseplate Screws	3.7 ± 0.9	3.8 ± 0.7	**0.005**	**0.025**
Subscapularis Repair	40.3%	45.5%	0.249	-

Figure 2. Comparison of Odds Ratios Associated with rTSA Patients of Accumulating Age, Gender, & Diagnosis Risk Factors for Acromial or Scapular Fractures, red text denotes cohorts with odds ratios >1.5

Risk Factor	Variables	# of Fx Patients	# of Patients w/o Fx	Fx Rate	Odds Ratio
All Patients	NA	138	8941	1.52%	1.00
Male Patients	Gender	28	3403	0.82%	0.41
Female Patients	Gender	109	5385	1.98%	2.48
<60yr Patients	Age	6	678	0.88%	0.55
60-65yr Patients	Age	13	881	1.45%	0.95
65-70yr Patients	Age	17	1703	0.99%	0.60
70-75yr Patients	Age	36	2229	1.59%	1.06
75-80yr Patients	Age	37	1900	1.91%	1.36
>80yr Patients	Age	28	1391	1.97%	1.38
RA	Diagnosis	8	226	3.42%	2.37
OA	Diagnosis	24	2120	1.12%	0.68
RCT	Diagnosis	10	910	1.09%	0.69
CTA	Diagnosis	58	2792	2.04%	1.60
RCT+OA	Diagnosis	23	1262	1.79%	1.22
Primary	Indication	121	7490	1.59%	1.38
Revision	Indication	15	970	1.52%	1.00
Humeral Fracture	Indication	2	478	0.42%	0.26
Male, >70	Gender + Age	21	1919	1.08%	0.66
Male, >75	Gender + Age	11	1075	1.01%	0.63
Male, >80	Gender + Age	6	441	1.34%	0.88
Female, >70	Gender + Age	80	3605	2.17%	2.04
Female, >75	Gender + Age	54	2220	2.37%	1.95
Female, >80	Gender + Age	22	954	2.25%	1.59
CTA, M	Diagnosis + Gender	12	1167	1.02%	0.63
CTA, F	Diagnosis + Gender	46	1625	2.75%	2.25
RA, F	Diagnosis + Gender	8	178	4.30%	3.03
RA, F, >70	Diagnosis + Gender + Age	7	84	7.69%	5.63
RA, F, >75	Diagnosis + Gender + Age	5	43	10.42%	7.78
RA, F, >80	Diagnosis + Gender + Age	2	13	13.33%	10.1
CTA, F, >70	Diagnosis + Gender + Age	34	1151	2.87%	2.21
CTA, F, >75	Diagnosis + Gender + Age	19	722	2.56%	1.82
CTA, F, >80	Diagnosis + Gender + Age	5	296	1.66%	1.10
CTA, M, >70	Diagnosis + Gender + Age	11	704	1.54%	1.01
CTA, M, >75	Diagnosis + Gender + Age	6	421	1.41%	0.92
CTA, M, >80	Diagnosis + Gender + Age	4	152	2.56%	1.73