JSES International 5 (2021) 261–265

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Rheumatoid arthritis is associated with increased symptomatic acromial and scapular spine stress fracture after reverse total shoulder arthroplasty

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ARTICLE INFO

Keywords:
Reverse total shoulder arthroplasty
acromial stress fracture
scapular stress fracture
rheumatoid arthritis
shoulder arthroplasty
shoulder replacement

Level of Evidence: Level III, Retrospective Case-Control Design, Treatment Study

Background: The purpose of this study was to determine factors associated with early symptomatic acromial and scapular spine fractures in patients who underwent reverse total shoulder arthroplasty (RTSA).

Methods: We retrospectively evaluated all RTSAs performed by the senior author between 1/1/2013 and 6/1/2019. We evaluated patient demographics including gender, age, prevalence of comorbidities including osteoporosis, inflammatory arthritis, diabetes, and endocrine disorders such as hypothyroidism. We also evaluated preoperative and 2-week postoperative radiographs for center of rotation medialization (CORM) as distance between the center of the humeral head or glenosphere and the line of the deltoid, and distalization via the acromial-greater tuberosity distance (AGT). We evaluated inter- and intra-rater reliability via intraclass correlation coefficients.

Results: We included 335 RTSAs with a minimum of 3 months of follow-up in the analysis. Reliability was acceptable with all intraclass correlation coefficients> 0.75. Symptomatic acromial and scapular spine stress fractures were significantly more common in those with inflammatory arthritis than those without (18% vs. 5%, $P = 0.016$). The rate of fracture was highest in patients with rheumatoid arthritis (24% vs. 5.2%, $P = 0.003$). There was no statistically significant association between symptomatic fractures and preoperative CORM or AGT ($P = 0.557$, $P = 0.528$) or postoperative CORM or AGT ($P = 0.56$, $P = 0.102$). There also was no statistically significant correlation between symptomatic stress fracture and patient age, gender, BMI, smoking, osteoporosis, gout, medical comorbidity, or previous shoulder surgery.

Conclusion: In this retrospective analysis of postoperative RTSA, symptomatic acromial and scapular stress fractures were significantly more common in patients with rheumatoid arthritis and thus precautions should be taken in these patients.

Although reverse total shoulder arthroplasty (RTSA) typically has low reoperation rates[8] and very good long-term outcomes,[2,5,7,10] some patients develop complications leading to worse outcomes.[1] Acromial stress fractures after RTSA result in substantial pain and limited function, compromising the expected outcome of the procedure.[11] Given the potential morbidity of this complication, it is important to know which patients are at highest risk to adjust their postoperative rehabilitation protocol accordingly.

Rheumatoid arthritis (RA) is a systemic autoimmune disorder that is not uncommon.[4] RA can contribute to significant degeneration within the shoulder joint and the development of rotator cuff tears.[4] About 91% of patients with RA complain of significant shoulder pain.[12] Because RA results in concomitant destruction of the joint surfaces and rotator cuff, RTSA is often the preferred arthroplasty in this setting.[4] In addition, RA is known to be associated with increased risk of osteoporosis and fracture.[17] There has been little research on the efficacy of RTSA in patients with RA and the studies that have been published have had small sample sizes.[18] Young et al noted multiple complications in a small study of 16 patients with RA who underwent RTSA including acromial fracture, coracoid fracture, avulsion of the greater tuberosity, and axillary nerve neuropraxia.[18]

The Institutional Review Board of the University of Utah approved this study (00071740).

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https://doi.org/10.1016/j.jseint.2020.10.010

In a meta-analysis that included 123 patients with RA from 7 different studies, 12 of the 123 patients had a fracture after RTSA (9.7%).[4] This included four scapular spine fractures, two acromion fractures, one coracoid fracture, three glenoid fractures, one periprosthetic fracture, and one fracture of the greater tuberosity. To the best of our knowledge, there are no studies investigating the risk of stress fracture in the RA population vs. the population at large after RTSA.

The purpose of this study was to determine which factors, including demographics and radiologic measures, associate with symptomatic acromial stress fractures after RTSA. The authors hypothesized that RA would associate with post-RTSA symptomatic acromial stress fractures.

Methods

Included patients

This is a retrospective chart review study. A single surgeon (R.Z.T.) performed all procedures using the same technique and postoperative protocol (Appendix 1). The study was approved by the (University of Utah Institutional Review Board) institutional review board. All patients who underwent RTSA by a single surgeon between 1/1/2013 and 6/1/2019 were identified. Patients were excluded if they had less than 3 months of follow-up.

Data collection

Demographic (Table I) and surgical information was collected on chart review including age, gender, body mass index (BMI), medical comorbidities including type I and type II diabetes, obesity, inflammatory arthritis, RA, osteoporosis, chronic kidney disease, indication for surgery, and reoperations. Osteoporosis was a self-reported diagnosis from patients, or noted on chart review. Obesity was defined as a BMI greater than 30 and our BMI range was from 16 to 53 (Table I). The indications for surgery included rotator cuff arthropathy, primary osteoarthritis, primary inflammatory arthritis, fracture sequalae including malunion and nonunion, failed arthroplasty, and chronic dislocation. In the data search, we searched for all types of inflammatory arthritis including seronegative spondyloarthropathy, gout, lupus, and RA.

On preoperative and 2-week postoperative two-dimensional imaging, the following measurements were made: (1) acromial-greater tuberosity distance (AGT) and (2) the center of rotation medialization (CORM, Figure 1). AGT was used to measure humeral distalization relative to the acromion. To determine the interobserver reliability of these measurements, two observers, blinded to each other's measurements, analyzed 50 radiographs. From these measurements, intraclass correlation coefficients were calculated. Intraclass correlation coefficients were interpreted based on prior guidelines.[3] All measurements were made using the measurement tools provided within the picture archiving systems program in our hospital system (PACS IntelliSpace 4.4, Philips, Andover, MA, USA). The senior author utilized Aequalis (Wright Medical Technology, Memphis TN, USA) components during the study period with most humeral components placed in 10-20° retroversion.

Diagnosis of symptomatic fractures

We included patients with scapular spine or acromial fractures. We only included patients with both radiographic signs of a fracture and a complaint of shoulder pain from the patient. Fractures were diagnosed radiographically via X-ray or CT or in some instances using both X-ray and CT. X-rays were taken postoperatively at two weeks, 6 weeks, 12 weeks, and one year, and additional radiographs were taken if a patient complained of sustained shoulder pain postoperatively or had difficulty regaining mobility after surgery. In a single institution study including 1,000 patients, symptomatic fractures were most commonly noted in the first three months after RTSA, [15] and thus it was felt that a minimum of 3 months of postoperative follow-up was appropriate for this complication.

Table I
Study group attributes

	Mean	SD	Range
Age (years)	69.24	9.4	34-92
BMI	29.66	6.8	16-53
PreopCORM (mm)	21.2	10.1	2-72
PreopAGT (mm)	10.1	8.7	0-63
PostopCORM (mm)	44.4	9.1	11-69
PostopAGT (mm)	39.8	10.1	8-69

AGT, acromial-greater tuberosity distance; *CORM*, center of rotation medialization. Continuous data are presented as mean±standard deviation [range] Preop and PostopCORM and AGT are measured in millimeters.

Statistical analysis

Statistical analysis was performed utilizing SPSS version 26 (IBM, Armonk, NY, USA). Levene's test was used to evaluate heteroscedasticity and the Kolmogorov-Smirnov test was used to evaluate normality. The differences between preoperative and postoperative measures were analyzed using Student's t tests and

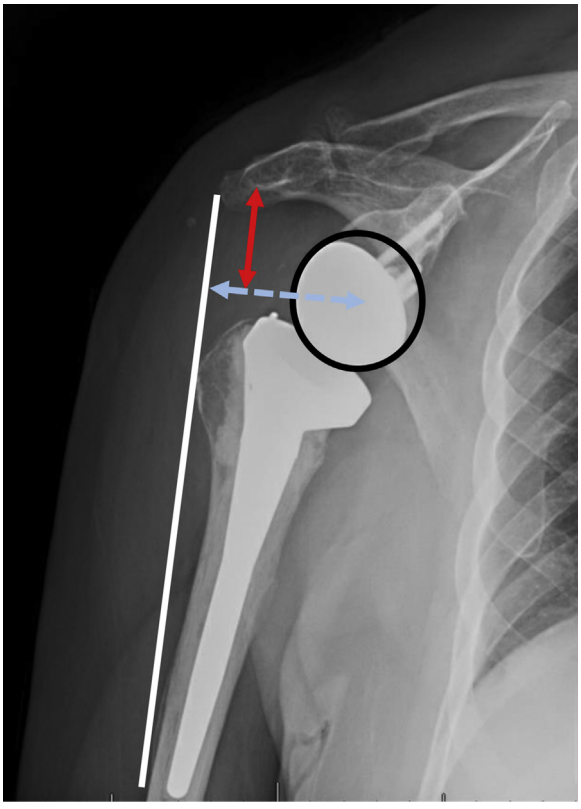

Figure 1 Radiographic measurement technique. The ▬ shows the acromial-greater tuberosity distance (AGT), which was measured as the shortest distance between the greater tuberosity and the acromion. The center of rotation medialization (▬) was measured as the distance between the ▭, which shows the line of pull of the deltoid, and the center of the best-fit circle of the glenosphere. This technique has been validated in another study.[13]

Mann-Whitney U tests as appropriate based on data normality. For categorical variables, a chi-squared and Fisher's exact test were performed based on cell populations.[9] Statistical significance was set at a *P*-value of less than 0.05 level and all tests were two-tailed.

Funding

The institution of one or more of the authors (PNC, RZT) has received funding from the National Institute of Arthritis and Musculoskeletal and Skin Diseases of the National Institutes of Health (R01 AR067196). The content is solely the responsibility of the authors and does not necessarily represent the officials views of the National Institutes of Health.

Results

Study cohort

During the 7-year period in question, the senior author performed 394 RTSAs, of which 30 were lost to follow-up before 3 months, providing a follow-up rate of 92%. For patients who received bilateral RTSAs (29 patients), we only included one shoulder. This left us with 335 patients for inclusion. Mean follow-up was 2 years [3-80 months]. This cohort had an average age of 69 and mostly women (63%) (Table I). About 22% of patients were undergoing a revision RTSA.

Many participants had medical comorbidities: 65 of 335 (19%) had osteoporosis, 33 of 335 (10%) had inflammatory arthritis, and 90 of 335 (27%) had type II diabetes. In our patient population, ten of the patients with inflammatory arthritis had gout and 25 patients had RA. There were three patients who had both gout and RA. Glenohumeral osteoarthritis was the most common indication for surgery (32%) and the second most common etiology was rotator cuff tear arthropathy, accounting for 29% of patients. Failed arthroplasty/revision was the indication for surgery in 21% of patients. The mean time to fracture was 419 days. Approximately half (10/22) occurred within the first three months after surgery.

Radiographic measures

Inter- and intra-rater reliability was excellent for all radiographic measures (Table II). The average PreopCORM was 21±10 and PreopAGT was 10±9 and the average change in CORM and AGT was 23±12 and 29.5±12, respectively. There was no significant association between radiographic measures and fracture rates (Table III).

Complications and associations with outcomes

Seven percent of patients had a postoperative acromial or scapular spine stress fractures (22/335). Nine of which were scapular spine fractures. There were no statistically significant differences between the fracture and nonfracture groups in age, gender, BMI, osteoporosis, diabetes, chronic kidney disease, use of upper extremity assist device, or current smoking (Table IV). There were significantly more acromial stress fractures in the group with inflammatory arthritis than the group without (18% vs. 5%, $P = 0.016$) (Figure 2). When examining RA specifically, the fracture rate was 24%, as compared with 5% among those without RA ($P = 0.003$).

Table II
Reliability statistics for each radiographic measure

Radiographic measures	ICCs	95% CI
PreopCORM	0.926	0.874 to 0.958
PreopAGT	0.819	0.701 to 0.893
PostopCORM	0.844	0.741 to 0.908
PostopAGT	0.872	0.785 to 0.925

ICC, intraclass correlation coefficient; *CI*, confidence interval; *AGT*, acromial-greater tuberosity distance; CORM, center of rotation medialization.

Table III
Difference in radiographic measures in patients with and without fractures

Radiographic measures	Mean difference	Mann-Whitney *P* value
PreopCORMedialization	1.21	.577
PreopAGT	2.24	.528
PostopCORMedialization	1.12	.560
PostopAGT	3.21	.102
ChangeCORMMedialization	−0.24	.589
ChangeAGT	1.02	.639

AGT, acromial-greater tuberosity distance; *CORM*, center of rotation medialization.

Discussion

In this analysis of 335 RTSAs, the rate of symptomatic acromial stress fractures and scapular spine fractures was significantly higher in patients with RA than those without (24% vs. 5%, $P = 0.003$). There was no statistically significant association with other patient demographics including age, gender, or other medical conditions such as diabetes or radiographic measures. Overall, these analyses suggest that patients with RA are at higher risk for acromial and scapular spine stress fractures and prevention of this complication should be focused on this patient group.

Association between symptomatic acromial stress fractures and radiographic implant position

The two major considerations for implant placement are medialization and distalization. Our study showed significant variability in both measures with an average medialization of 44 mm with a standard deviation of 9 mm and an average of 40 mm for distalization with a standard deviation of 10 mm. However, within our study, there was no association between Preop or PostopCORM or distal position and symptomatic acromial stress fractures. These results suggest that implant position within these ranges may not be as significant of a predictor of this complication as RA. Outside the ranges of distalization and lateralization defined in the present study, we may see increased risk for fracture. A prior study of 1082

Table IV
Demographics of patients with and without symptomatic stress fracture

	Fracture w/ comorbidity (%)	Fracture without/ comorbidity (%)	Significance (*P* value)
Revision	4.0	7.3	.31
Sex (F)	8.5	3.2	.06
Previous surgery	4.5	8.3	.17
Fragmentation	6.9	6.5	.94
Os Acromiale	6.6	6.9	.25
Osteoporosis	10.8	5.6	.13
Inflammatory arthritis	**18.2**	5.3	**.005**
Rheumatoid arthritis	**24.0**	5.5	**0**
Gout	10.0	6.4	.66
Diabetes	3.3	7.8	.15
Endocrine Disorders	6.8	6.5	.94
CKD	6.3	6.6	.92
UpperExtrem	6.1	7.1	.71
Current smoker	6.3	6.6	.96

Fracture w/comorbidity, fracture rate with medical comorbidity; *Fracture without/comorbidity*, fracture rate without medical comorbidity; *CKD*, chronic kidney disease; *UpperExtrem*, upper extremity assist device.

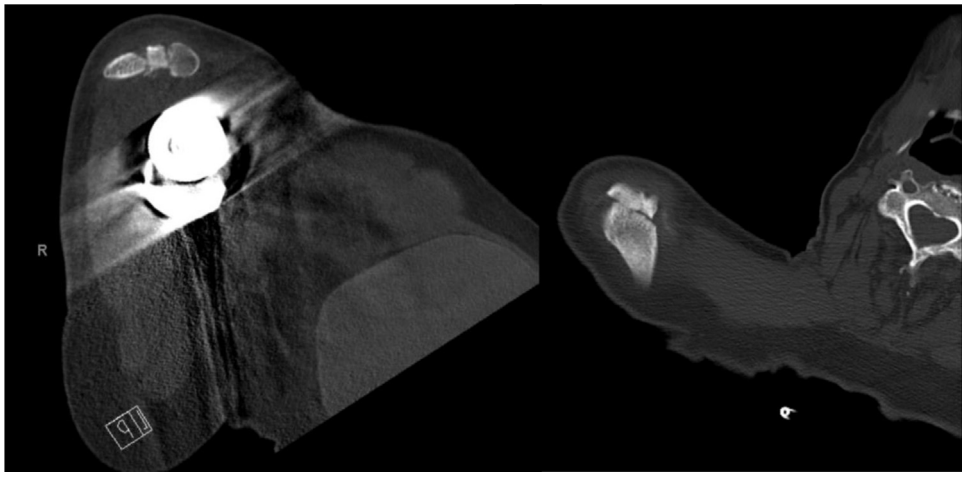

Figure 2 Acromial fracture after reverse total shoulder arthroplasty demonstrated in sagittal and axial CT scans.

patients that included radiographic measures also noticed no statistically difference in AGT distance in between patients with and without postoperative complications but did find that a smaller lateral offset of the greater tuberosity (48 vs 52 mm) and greater arm lengthening (25 vs. 18 mm) were associated with an increased risk of fracture ($P = 0.026$, $P = 0.004$).[15] It may be that the larger sample size used in this study would be necessary to detect this difference. Another study of 125 patients by Dubrow et al showed no difference in arm lengthening and rate of acromial fracture and this study may be similarly underpowered.[6] In a study by Zmistowski et al that included 1170 patients, they also showed that female gender and increased PreopCORM were risk factors for an acromial stress reaction, but this result was not statistically significant for stress fractures—again suggesting that the effect is so small that it requires a very large sample size to detect.[19] A small biomechanical study of 10 patients showed that acromial fracture was associated with increased glenosphere lateralization (17.2% increased risk, $P = 0.001$).[16] A different biomechanical study showed that there was a potential 19.7% increase in scapular strain in patients with coracoacromial ligament resection thus putting the shoulder at increased risk of fracture.[14] Overall these results suggest that while implant position may play a role in acromial stress fracture risk, the overall effect size is likely very small. Finally, we only made two-dimensional measurements. It is possible that with three-dimensional measurements of the entire scapula and humerus both preoperatively and postoperatively, a difference would be found. Based on clinical experience the senior author continues to decrease intraoperative tension through reduced humeral length and reduced glenosphere lateralization in patients at risk for acromial fractures.

Association between demographics and stress fractures

Within our study, most patient factors were not significantly associated with symptomatic acromial stress fractures. This conclusion is contrary to prior studies showing that gender, age, and a history of osteoporosis may associate with symptomatic acromial stress fractures. Only a few studies have focused on patient demographics and risk of postoperative fractures and there has been significant variability in the results. A large meta-analysis that included 1082 patients showed that there was a statistically significant association with osteoporosis and the risk of acromial stress fracture (46% vs. 12%, $P = .027$).[15] Within our study, osteoporosis was via self-report and it is possible that a study measuring bone density directly may have found a difference. However, this study also showed a much lower rater of acromial stress fracture (1.11%)[15] than other studies, such as those performed by Dubrow and Zmistowski that demonstrated 11.2% and 4.2%, respectively.[6,19] In a large meta-analysis that included 813 patients, 6.9% (61/813) of patients had an acromial stress fracture.[11] This is very similar to our rate of 6.6%. Another large meta-analysis including 1170 patients showed that there was 4.2% chance of fracture.[19] In our study, the higher risk of acromial stress fracture in female participants approached statistical significance ($P = 0.06$). These suggest that with a larger sample size female gender may associate with increased risk.

There has been limited research on the efficacy of RTSA in patients with RA.[18] Young et al noted multiple complications in a small study of 16 patients with RA who underwent RTSA including acromial fracture, coracoid fracture, avulsion of the greater tuberosity, and axillary nerve neuropraxia.[18] In a meta-analysis that included 123 patients with RA from 7 different studies, 12 of the 123 patients had a fracture after RTSA (9.7%); four of which were scapular spine fractures and two acromial fractures.[4] In our study, we noted a 24% fracture rate in patients with RA, suggesting that preventative measures should be taken in this patient population. Multiple authors have adjusted their postoperative protocol for patients with RA. In an effort to minimize tension, the senior author plans to limit arm lengthening and use the smallest most medialized sphere possible to reduce deltoid loads. He also intends to avoid strengthening all together in patients with RA to reduce risk of fracture. One of the other authors has opted to delay strengthening until 3 months and increase time in sling.

Limitations

This study has several limitations. This study was a relatively small study that only included 335 patients and was only performed at a single institution by a single surgeon thus may not be generalizable. Although our study may be underpowered to find a statistically significant difference, it is unlikely that with more than 300 patients, we are underpowered to find a clinically significant difference. The data collection for this study was retrospective. There was not a set protocol for when to have preoperative or postoperative radiographs and we did not include follow-up final radiographs, which prevented us from evaluating for long-term complications such as loosening or scapular notching. Between postoperative radiographs, there were differences in arm abduction, which could affect measurements, but CORM does minimize the effects of this by measuring the shortest distance from the

center of rotation to the line of the pull of the deltoid. In addition, we only included patients with short-term follow-up to increase our sample size and thus acromial fractures that occur after 3 months might be missed, which based on the findings of our study may not be an appropriate cutoff in future studies as over half of our fractures occurred after 3 months (12/22). Self-report may not be as accurate in delineating which patients have osteoporosis as a DEXA scan.

Conclusion

In this retrospective analysis of postoperative RTSA, symptomatic acromial and scapular stress fractures were significantly more common in patients with RA and thus precautions should be taken in these patients.

Disclaimer

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Peter Chalmers: This author is a paid consultant for DePuy and A Johnson & Johnson Company. He also receives IP royalties and is a paid presenter or speaker for A Johnson & Johnson; receives publishing royalties from Journal of Shoulder and Elbow Surgery.

Robert Tashjian: This author is a paid consultant for Cayenne Medical and Mitek; has stock in Conextions, INTRAFUSE, and KATOR; receives intellectual property royalties from IMASCAP, Shoulder Innovations, and Zimmer; receives publishing royalties from JBJS; and serves on the editorial board for the Journal of Orthopaedic Trauma.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jseint.2020.10.010.

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