Severe acromioclavicular joint osteoarthritis is associated with acromial stress fractures after reverse shoulder arthroplasty

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A R T I C L E   I N F O

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Background: Little is known about the role of disorders of the acromioclavicular joint (ACJ) and how they relate to complications after reverse shoulder arthroplasty (RSA). The purpose of this study is to compare the severity of ACJ osteoarthritis in patients undergoing RSA with and without postoperative acromial and scapular spine fractures.

Methods: A retrospective review was performed to identify all patients who underwent primary RSA between 1/1/2007 and 10/31/2019 with a postoperative acromial or scapular spine stress fracture from a single institution. Patients who underwent RSA with a fracture were compared with an age-, sex-, and preoperative diagnosis-matched control group (1:4 controls) with a minimum 2-year follow-up. We compared demographics, medical comorbidities, and ACJ osteoarthritis between the 2 groups. Preoperative radiographs and 3-dimensional computed tomography scans were evaluated for ACJ osteoarthritis in all patients. The Petersson classification, a modified Petersson classification, location of the osteophytes, subchondral cysts, ACJ space, and size of the largest osteophyte were recorded and compared between the 2 groups.

Results: The study included 11 patients who underwent primary RSA (8 women and 3 men) with acromial (6) and scapular spine (5) fractures confirmed radiographically and 44 matched controls (average follow-up 3.1 vs. 4.3 years, P = .17). Average age at surgery was similar between study and control groups (69.6 vs. 70.0 years, P = .86). ACJ osteoarthritis with osteophytes larger than 2 mm was common and similar between the 2 groups (91% of patients with acromial fracture and 66% of controls, P = .15). There was no significant difference in the size or location of the ACJ osteophytes. The Petersson classification was similar between groups. However, the percentage of patients with subchondral ACJ cysts was higher in the fracture group (91% vs. 50%, P = .02), and the percentage of patients with large spanning or fused osteophytes was significantly higher in the fracture group (55% vs. 14%, P = .008).

Conclusion: Radiographic ACJ osteoarthritis is common in patients undergoing RSA. Severe ACJ osteoarthritis with completely spanning or fused osteophytes may predispose patients to acromial or scapular spine fractures after RSA.

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osteoarthritis may also be a risk factor for ASF or SSF, as biomechanical studies have consistently shown a significant contribution of the AC joint and scapulothoracic articulation to overall shoulder motion, especially during arm elevation.\cite{1,9} Therefore, we theorize that severe AC joint osteoarthritis causing stiffness and decreased motion through the AC joint would increase the amount of stress seen by the acromion and scapular spine during shoulder motion.

AC joint osteoarthritis is a common degenerative condition typically seen beginning in middle-aged patients.\cite{13} AC joint osteoarthritis, especially with inferior osteophytes, has been well documented to be associated with rotator cuff disease.\cite{2,7,17} Brown et al reported that 86% of patients over 50 years old with AC joint osteoarthritis had concomitant rotator cuff disease, with 57% of those patients having full-thickness tears.\cite{1} Therefore, as commonly patients who undergo RSA are also over the age of 50, AC joint arthritis should be common in this population.

There have been few reports looking at the relationship between AC joint osteoarthritis and ASFs after RSA.\cite{3} Therefore, we performed a retrospective case-control study to assess if there is an association between the extent of AC joint osteoarthritis assessed radiographically and the development of an ASF or SSF. We hypothesized that patients diagnosed with an ASF or SSF would have more severe AC joint osteoarthritis.

**Materials and methods**

Institutional review board approval was obtained before beginning this study. A retrospective review was performed of all patients who underwent primary RSA at our institution from 1/1/2007 to 10/31/2019. All patients diagnosed with a postoperative ASF or SSF were identified. These were diagnosed with either X-ray or computed tomography (CT) after the patient presented with pain and tenderness over the acromion or scapular spine. Exclusion criteria included diagnosis of an unstable preacromial os acromiale involving the AC joint articulation, preoperative ASF or SSF, revision RSAs, and patients whose primary RSA was performed for an acute fracture as these patients may have had confounding injuries of the suspensory complex that were not identified at the time of the original injury. Twelve patients with postoperative ASF or SSF were identified out of 1046 total RSAs performed during the study period. One patient was excluded from analysis because of having an arthritic preacromial os acromiale involving the AC joint, leaving 11 patients with ASF or SSF included in the fracture group.

Patients in the fracture group were compared with an age (within 3 years), sex-, and preoperative diagnosis-matched control group (1:4 controls). Control patients were selected as the first 4 patients chronologically who underwent surgery beginning in January of the same year as the fracture group subject who met the match criteria. All patients included in this study had their surgeries performed by 1 of 4 board-certified and shoulder and elbow fellowship-trained orthopedic surgeons at a single academic institution.

Demographic information, past medical history, and surgery information for both groups were obtained from medical records. Preoperative radiographs and CT scans were evaluated by study investigators to characterize the extent of AC joint osteoarthritis. Radiographic variables collected included the following: acromial erosion (defined as any amount of acromial acetalubarization seen on preoperative imaging), AC joint subchondral cysts, distal clavicular osteolysis, size of the largest osteophyte, narrowest AC joint width, AC joint subluxation, Petersson classification of AC joint degeneration,\cite{16} location of large osteophytes, coracoclavicular ligament ossification, and evidence of prior AC joint surgery. The Petersson classification of AC joint degeneration was developed in 1983 and consists of 3 grades: grade I (superficial degenerative signs with blister formation and some fragmentation), grade II (deep degeneration with cartilage fragmentation, blister formation, and penetrating ulceration of the joint surface in irregularly shaped areas), and grade III (full-thickness cartilage degeneration denuding the subchondral bone of more than 50% of the joint surface, with osteophytes on the inferior joint margins >2 mm). As the Petersson classification was originally developed based on gross anatomic assessment of cadavers, a modified Petersson classification was developed by study investigators and utilized in this study to allow for more differentiation between grades for the severity of AC joint osteoarthritis (6 grades rather than 3, see Table I).

A standard deltopectoral approach was used for all RSAs included in our study. All implants used a medial glenoid/lateral humeral design (Exactech Equinox Shoulder System, Gainesville, FL, USA). There were no notable differences in surgical technique or initial rehabilitation protocol used between the cases and control cohorts.

Continuous data were summarized with means and compared with exact independent t-test. Categorical data were summarized with counts and percentages and analyzed with one-tailed Fisher's exact test and chi-square Testing. Univariate analysis was performed given the low number of study patients precluding multivariate analysis. Statistical significance was set at $P < .05$.

**Results**

Fifty-five (11 in the fracture group and 44 in the control group) primary RSAs were included in final analysis, consisting of 15 men (27%) and 40 women (73%). The average age of all patients was 69.9 years old (range 53-79 years), with a mean follow-up time of 4.0 years (range 0.5-9.7 years). The 11 patients with postoperative fracture consisted of 6 ASFs and 5 SSFs, and the fractures occurred at an average of 2.0 years (range 0.3-6.9 years) after surgery. There were no statistical differences between the fracture group and the control group in regard to patient body mass index, laterality of procedure, past medical history, tobacco use, previous shoulder surgery, or length of follow-up ($P > .05$; Table I).

All but 1 patient (54/55, 98%) in this study were found to have some level of radiographic evidence of AC joint osteoarthritis preoperatively. The fracture cohort was found to have a significantly greater proportion of patients with AC joint subchondral cysts seen on XR (91% vs. 50%; $P = .01$) and large spanning or fused AC joint osteophytes (55% vs. 14%; $P = .02$) than the control cohort (Fig. 1). However, the mean size of the largest osteophyte (3.5 mm vs. 3.2 mm; $P = .73$) and the narrowest acromioclavicular joint (ACJ) width (1.4 mm vs. 1.2 mm; $P = .72$) measured by CT scan were similar between the fracture and control groups. The fracture cohort was also found to have significantly more acromial erosion than the control group (91% vs. 50%; $P = .01$). Of the 6 patients with fracture who were found to have the highest level of AC joint disease with large spanning or fused AC joint osteophytes, 3 (50%) were diagnosed with an ASF, and 3 (50%) were diagnosed with an SSF. There were no statistical differences between the fracture and control groups for any other radiographic parameters, including presence of pre-os acromiale ($P = .60$), presence of distal clavicle osteolysis ($P = .51$), AC joint subluxation ($P = .36$), Petersson classification ($P = .56$), location (superior, inferior, or both) of large osteophytes ($P = .67$), coracoclavicular ligament ossification ($P = .64$), or evidence of prior distal clavicle excision surgery for AC joint osteoarthritis ($P = .26$) (Table II).
Radiographic evidence of AC joint osteoarthritis in patients undergoing RSA is very common and rarely symptomatic. In patients undergoing primary RSA, severe AC joint osteoarthritis was associated with postoperative ASF and SSF compared with the control cohort. Specifically, patients with subchondral cysts and large spanning or fused AC joint osteophytes were at significantly increased risk of developing a postoperative ASF or SSF. These findings suggest a possible association between severe AC joint osteoarthritis and postoperative complications in RSA.

### Table I
Demographic data.

| Variable                        | Control group (N = 44) | Study group (N = 11) | P value |
|---------------------------------|------------------------|----------------------|---------|
| Age (SD)                        | 70.0 (6.0)             | 69.6 (6.6)           | .86     |
| Gender (%)                      |                        |                      |         |
| Males                           | 12 (27.3)              | 3 (27.3)             | .658    |
| Females                         | 32 (72.7)              | 8 (72.7)             |         |
| BMI (SD)                        | 31.7 (7.6)             | 29.9 (12.5)          | .544    |
| Laterality (%)                  |                        |                      | .312    |
| Left                            | 14 (31.8)              | 2 (18.2)             |         |
| Right                           | 30 (68.2)              | 9 (81.8)             |         |
| Hypertension (%)                | 25 (56.8)              | 7 (63.6)             | .478    |
| Diabetes (%)                    | 10 (22.7)              | 1 (9.1)              | .292    |
| Inflammatory arthritis (%)      | 0 (0)                  | 1 (9.1)              | .200    |
| Current tobacco use (%)         | 3 (6.8)                | 2 (18.2)             | .259    |
| Previous shoulder surgery (%)   | 18 (40.9)              | 3 (27.3)             | .319    |
| Preoperative diagnosis (%)      |                        |                      | 1.000   |
| Rotator cuff arthropathy        | 36 (81.8)              | 9 (81.8)             |         |
| Massive rotator cuff tear       | 4 (9.1)                | 1 (9.1)              |         |
| Osteoarthritis                  | 4 (9.1)                | 1 (9.1)              |         |
| Follow-up in years (SD)         | 4.3 (2.7)              | 3.1 (2.3)            | .174    |

SD, standard deviation; BMI, body mass index.

### Table II
Radiographic data.

| Variable                        | Control group (N = 44) | Study group (N = 11) | P value |
|---------------------------------|------------------------|----------------------|---------|
| Os acromiale (%)                | 3 (6.8)                | 1 (9.1)              | .602    |
| Acromial erosion (%)            | 22 (50)                | 10 (90.9)            | .013    |
| Subchondral cysts (%)           | 22 (50)                | 10 (90.9)            | .013    |
| Osteolysis (%)                  | 3 (6.8)                | 0 (0)                | .505    |
| Largest osteophyte in mm (SD)   | 3.2 (2.3)              | 3.5 (1.5)            | .728    |
| Narrowest AC joint width in mm (SD)| 1.2 (0.7) | 1.4 (1.3)            | .724    |
| ACJ subluxation (%)             |                        |                      | .363    |
| Stable (also mild or questionable subluxation) | 43 (97.7) | 10 (90.9) | .018    |
| Obvious subluxation but <100% subluxation (type II separation) | 1 (2.3) | 1 (9.1) |         |
| At least 100% subluxation (type III, IV, V, VI separation) | 0 (0) | 0 (0) |         |
| Modified Petersson classification (%) |                      |                      |         |
| Grade I                         | 10 (22.7)              | 1 (9.1)              | .545    |
| Grade II                        | 9 (20.5)               | 2 (18.2)             |         |
| Grade III                       | 25 (56.8)              | 8 (72.7)             | .668    |
| Large osteophytes (%)           |                        |                      | .637    |
| None or not large osteophytes   | 14 (31.8)              | 2 (18.2)             | .668    |
| Superior osteophytes            | 14 (31.8)              | 3 (27.3)             |         |
| Both inferior and superior osteophytes | 12 (27.3) | 5 (45.5) |         |
| CA ligament ossification (%)    | 42 (95.5)              | 11 (100)             | .261    |

SD, standard deviation; AC, acromioclavicular; ACJ, acromioclavicular joint; HO, heterotopic ossification; CA, coracoacromial.

### Discussion
Radiographic evidence of AC joint osteoarthritis in patients undergoing RSA is very common and rarely symptomatic. In patients undergoing primary RSA, severe AC joint osteoarthritis was associated with postoperative ASF and SSF compared with the control cohort. Specifically, patients with subchondral cysts and large spanning or fused AC joint osteophytes were at significantly increased risk of developing a postoperative ASF or SSF. These findings suggest a possible association between severe AC joint...
ostearthitis, resulting in loss of motion through the joint and potential transferring strain through the scapula, and sustaining a postoperative ASF or SSF after RSA.

The AC joint and scapulothoracic articulation play a large role in overall shoulder range of motion. During arm elevation, scapulothoracic motion consists of scapular internal rotation, upward rotation, and posterior tilting relative to the clavicle, and the AC joint contributes to each of these motions. In an in vivo biomechanical study, Ludewig et al found that the AC joint is almost solely responsible for scapulothoracic posterior tilting, providing an average of 19 degrees of the total 21 degrees of scapulothoracic motion during arm elevation. Given these data, it can be inferred that a stiff AC joint might limit the amount that the scapulothoracic articulation contributes to overall shoulder motion, thereby requiring more motion at the glenohumeral articulation for shoulder function and resulting in increased stress at the acromion and scapular spine. Our findings support this theory, as the fracture group was found to be significantly more likely to have large spanning or fused osteophytes with complete AC joint ankylosis (54.5% vs. 13.6%, \( P = 0.018 \)) than the control group. Of note, however, our results showed no difference between other radiographic measures of AC joint osteoarthritis (largest osteophyte size, location of osteophytes, narrowest AC joint width) between fracture and control groups, suggesting that the increased risk of ASF or SSF may not occur until the AC joint develops markedly severe stiffness or ankylosis.

Our results contrast with a previous study by Dubrow et al in 2014 that also reported on the prevalence of AC joint osteoarthritis in 125 patients who underwent RSA and who developed an ASF (\( N = 14, 11.2\% \)) vs. those who did not (\( N = 111, 88.8\% \)). They reported no significant difference in the prevalence of AC joint osteoarthritis between the fracture group (11/14; 77.3%) and no fracture group (71/111; 64.1%) (\( P = 0.23 \)). However, that study did not attempt to grade the severity of the AC joint osteoarthritis. We also found similar rates of AC joint osteoarthritis between fracture and nonfracture cohorts; however, severe disease with bony ankylosis was significantly more common in the fracture group (54.5% vs. 13.6%; \( P = 0.02 \)). Together, these studies support that AC joint osteoarthritis is common in patients who undergo RSA and suggest that AC joint osteoarthritis may not be a contributing factor to an ASF or SSF until it is severe enough to lead to significant loss of AC joint motion.

Interestingly, approximately 1 in 5 control patients in our study had radiographic evidence of a prior distal clavicle excision or coplanning procedure, whereas no fracture patients had any previous AC joint surgeries. Although this difference was not statistically significant, distal clavicle excision could possibly represent a protective factor to developing an ASF or SSF postoperatively, although our control group was just a small sample of all patients undergoing RSA at our institution. In patients undergoing RSA who have large spanning or fused AC joint osteophytes, consideration of a distal clavicle excision at the time of RSA may be warranted. Doing this could possibly reduce the likelihood of sustaining an ASF or SSF by improving motion through the AC joint and scapulothoracic articulation postoperatively.

We recognize that this study has several limitations. First, our data show that, in addition to severe AC joint osteoarthritis, acromial erosion from a high-riding humeral head was also significantly correlated with postoperative ASF or SSF, and this may be a confounding variable. Unfortunately, as 10 of 11 patients with fracture were found to have acromial erosion, multivariate analysis could not be performed to account for the unique contributions of acromial erosion compared with AC joint osteoarthritis on the risk of having a postoperative fracture. Future studies will be needed to assess this. However, it should be noted that acromial erosion typically affects the anterolateral acromion, but 5 of 10 patients with acromial erosion had fractures of the scapular spine in a portion of the bone that was not affected by erosion, so we feel that the erosion is likely a correlated rather than a causative factor. In addition, the case-control study design also has inherent limitations, and although we attempted to match patients to controls of similar age, sex, and preoperative diagnosis (known risk factors for ASF or SSF after RSA), there may be other confounding variables that we did not account for. Finally, because of the rarity of ASF and SSF after RSA, our study represents only a small cohort of patients, which limits the conclusions that can be drawn from the data.

Conclusions

This study found that while radiographic evidence of AC joint osteoarthritis is present in most patients undergoing RSA, severe AC joint osteoarthritis with large spanning AC joint osteophytes may predispose patients to sustaining an ASF or SSF after RSA. Patients with severe AC joint osteoarthritis with large spanning or fused osteophytes should be counseled preoperatively on their potentially increased risk of developing an ASF or SSF postoperatively. Future studies with larger sample sizes would be helpful to further characterize the association between AC joint osteoarthritis.
ankylosis and sustaining an ASF or SSF after RSA and to investigate if distal clavicle resection at the time of surgery may be protective.

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