JSES International 8 (2024) 111–118

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Influence of acromioclavicular joint arthritis on outcomes after reverse total shoulder

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A R T I C L E I N F O

Keywords:
Shoulder replacement
AC
RTSA
RSA
Acromion
Clavicle
Petersson classification

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Background: Although substantial motion at the acromioclavicular joint (ACJ) occurs during overhead shoulder motion, the influence of ACJ arthritis on postoperative outcomes of patients undergoing reverse total shoulder arthroplasty (rTSA) is unclear. We assessed the influence of ACJ arthritis, defined by degenerative radiographic changes, and its severity on clinical outcomes after primary rTSA.

Methods: We conducted a retrospective review of a prospectively collected shoulder arthroplasty database of patients that underwent primary rTSA with a minimum 2-year clinical follow-up. Imaging studies of included patients were evaluated to assess ACJ arthritis classified by radiographic degenerative changes of the ACJ; severity was based upon size and location of osteophytes. Both the Petersson classification and the King classification (a modified Petersson classification addressing superior osteophytes and size of the largest osteophyte) were used to evaluate the severity of degenerative ACJ radiographic changes. Severe ACJ arthritis was characterized by large osteophytes (≥2 mm). Active range of motion (ROM) in abduction, forward elevation, and external and internal rotation as well as clinical outcome scores (American Shoulder and Elbow Surgeons Shoulder, Constant, Shoulder Pain and Disability Index, simple shoulder test, University of California, Los Angeles scores) were assessed both preoperatively and at the latest follow-up; outcomes were compared based on severity of ACJ arthritis. Multivariable linear regression models were used to determine whether increasing severity of ACJ arthritis was associated with poorer outcomes.

Results: A total of 341 patients were included with a mean age of 71 ± 8 years and 55% were female. The mean follow-up was 5.1 ± 2.4 years. Preoperatively, there were no differences in outcomes based on the severity of ACJ pathology. Postoperatively, there were no differences in outcomes based upon the severity of ACJ arthritis except for greater preoperative to postoperative improvement in active internal rotation in patients with normal or grade 1 ACJ arthritis vs. grade 2 and 3 (3 ± 2 vs. 1 ± 2 and 1 ± 3, $P = .029$). Patients with ACJ arthritis and osteophytes ≥2 mm had less favorable Shoulder Pain and Disability Index scores, corresponding to greater pain (−49.3 ± 21.5 vs. −41.3 ± 26.8, $P = .015$). On multivariable linear regression, increased severity of ACJ arthritis was not independently associated with poorer postoperative ROM or outcome scores.

Conclusion: Overall, our results demonstrate that greater ACJ arthritis severity score is not associated with poorer outcome scores and has minimal effect on ROM. However, patients with the largest osteophytes (≥2 mm) did have slightly worse pain postoperatively. Radiographic presence of high-stage ACJ arthritis should not alter the decision to undergo rTSA.

Reverse total shoulder arthroplasty (rTSA) reliably reduces pain and restores function in patients with glenohumeral arthritic conditions. Surgeons continue to study the myriad of patient and radiographic factors that affect functional outcomes and complications in rTSA.[9,12,33] Postoperative range of motion is one outcome that affects both global function and patient

Institutional Review Board (IRB): University of Florida Institutional Review Board: IRB# IRB202001233.

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https://doi.org/10.1016/j.jseint.2023.08.014

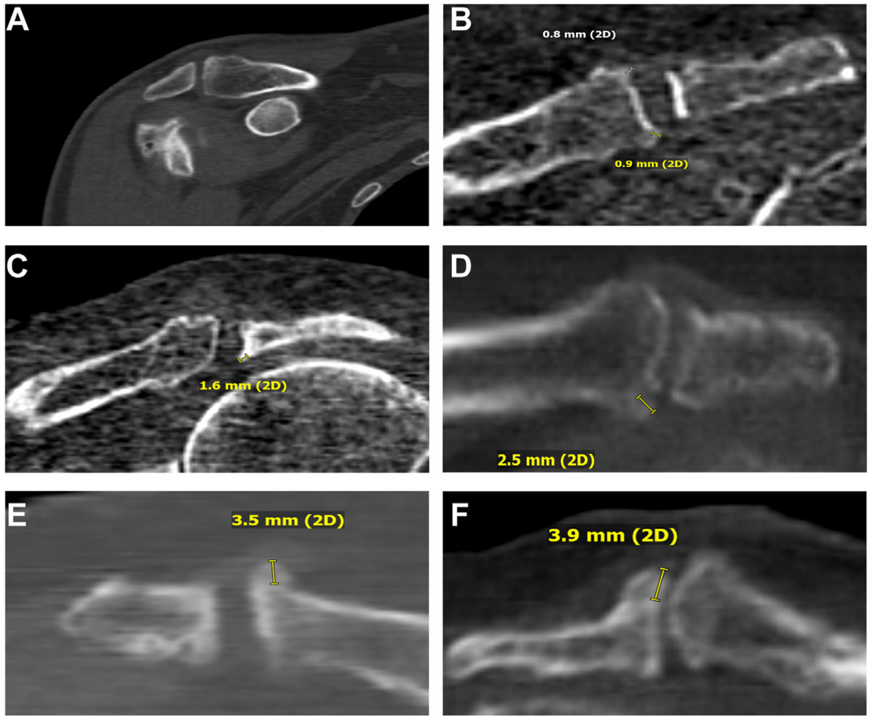

Figure 1 King classification of acromioclavicular joint arthritis based on osteophyte measurement on computed tomography. (**A**) Grade 1. (**B**) Grade 2. (**C**) Grade 3. (**D**) Grade 4. (**E**) Grade 5. (**F**) Grade 6.

satisfaction.[4,10] While the majority of shoulder range of motion comes from the glenohumeral joint, a substantial portion also derives from movement of the scapula over the thorax (scapulothoracic motion), which only has one bony connection to the axial skeleton through the acromioclavicular joint (ACJ).[13,16,18] Scapulothoracic motion becomes an increasingly important source of motion in shoulders following rTSA compared to native shoulders.[34] We do know that rTSA imparts stress across the ACJ to the clavicle based on reported clavicular stress fractures after rTSA[1,23] and that reverse shoulder arthroplasty alters scapulothoracic kinematics.[17,34] Additionally, studies have shown that clavicle fractures can significantly alter scapulothoracic kinematics in the native shoulder.[22,30] Such compensatory alterations in scapulothoracic kinematics[5,31] involve the ACJ, which may affect the outcomes after rTSA.

The contribution of ACJ disorders to functional outcomes, range of motion, and complications after rTSA is seldom studied. Although significant motion occurs at the ACJ, little is known about how disorders of the ACJ affect shoulder range of motion in the native shoulder or after arthroplasty. Therefore, we aimed to characterize the relationship between preoperative radiographic degenerative changes of the ACJ and clinical outcomes after primary rTSA. We hypothesized that while ACJ degenerative changes would not prohibit a successful outcome after rTSA, patients with more severe preoperative ACJ degenerative radiographic changes would have poorer outcomes.

Materials and methods

Following the institutional review board approval, we performed a retrospective review of our institution's prospectively collected shoulder arthroplasty database of patients that underwent primary rTSA between January 2007 and October 2019. We initially identified 554 shoulders aged 18 and older that underwent primary rTSA by 1 of 4 fellowship-trained surgeons between January 2007 and October 2019. Two surgeons were shoulder/elbow fellowship trained, 1 was hand fellowship trained with a large emphasis on shoulder surgery, and one was dual fellowship trained (shoulder/elbow and sports). We excluded 28 shoulders with a preoperative diagnosis of fracture ($n = 10$), rheumatoid arthritis ($n = 3$), tumor ($n = 1$), or post-traumatic arthritis ($n = 14$). Additionally, shoulders were excluded if any documented or obvious radiographic evidence was found of prior distal clavicle excision ($n = 46$), prior Bankart procedure ($n = 2$), prior acromioplasty ($n = 3$), prior SAD/débridement ($n = 4$), acromial fractures ($n = 8$), os acromiale ($n = 47$), type III or greater ACJ separation ($n = 8$), prior shoulder instability (eg, documented prior dislocations; $n = 11$), or capsulorrhaphy arthropathy ($n = 3$). Additionally, shoulders without good radiographic views of the ACJ and no advanced imaging involving the ACJ preoperatively were excluded ($n = 9$). Patients with identified complications were excluded to isolate the influence of ACJ arthritis on postoperative outcomes ($n = 32$). Finally, 12 shoulders were excluded due to missing preoperative range of motion or outcome scores.

Surgical intervention

A standard deltopectoral approach was used for all rTSAs. The biceps tendon was routinely tenodesed to the pectoralis major when identified. No acromioplasties or distal clavicle excisions were performed. All patients underwent a rehabilitation protocol consisting of a home exercise program directed by a physical therapist. Slings were recommended for 6 weeks postoperatively, and range of motion (ROM) was limited to passive ROM only during this time. Active ROM was initiated after sling use was discontinued. Patients were advised to avoid any weight-bearing activities for 3 months after surgery; strengthening exercises were introduced thereafter.

Table I
Demographic and radiographic characteristics of included rTSAs.

Variable	Mean ± SD or % (N)
Age at surgery (y)	70.9 ± 7.7
BMI (kg/m^2)	29.9 ± 6.6
Follow-up (y)	5.1 ± 2.4
Female sex	55.1 (188)
Previous surgery on shoulder	24.6 (84)
Comorbidities	
Inflammatory arthritis	7.9 (27)
Hypertension	61.9 (211)
Heart disease	19.9 (68)
Diabetes	20.2 (69)
Tobacco use	5.0 (17)
Chronic renal failure	1.8 (6)
Chronic liver failure	0.6 (2)
CT or MRI available	90.0 (307)
ACJ arthritis grade (King Classification)	
Grade 1	1.8 (6)
Grade 2	4.7 (16)
Grade 3	13.2 (45)
Grade 4	17.9 (61)
Grade 5	23.2 (79)
Grade 6	39.3 (134)
ACJ arthritis grade (Petersson Classification)	
Normal	1.8 (6)
Grade 1	3.8 (13)
Grade 2	41.3 (141)
Grade 3	53.1 (181)
Largest osteophyte location (≥2 mm)	
None	26.7 (91)
Inferior	15.0 (51)
Superior	19.9 (68)
Both inferior and superior	38.4 (131)
Subchondral cysts present on X-ray	40.2 (137)
Size of largest osteophyte on:	
X-ray	2.3 ± 1.6
CT and/or MRI	3.1 ± 1.7
Narrowest ACJ space	
X-ray	1.4 ± 1.2
CT and/or MRI	1.0 ± 1.2
ACJ loose body or HO	22.6 (77)

ACJ, acromioclavicular joint; *BMI*, body mass index; *CT*, computed tomography; *HO*, heterotopic ossification; *MRI*, magnetic resonance imaging; *rTSA*, reverse total shoulder arthroplasty; *SD*, standard deviation.

Radiographic assessment

Available imaging studies including X-Ray (XR), computed tomography (CT), and magnetic resonance imaging (MRI) taken within 6 months before their procedure were retrieved for assessment of ACJ pathology. Available imaging was reviewed for ACJ subluxation, arthritis, size of the largest osteophyte, location of osteophytes over 2 mm (superior, inferior, or both), coracoclavicular ligament ossification, prior surgery, osteolysis, subchondral cysts, narrowest width of the ACJ, heterotopic ossification of the ACJ, and os acromiale. When available, size of the largest osteophyte was measured using both CT, MRI, and XR. Measurements obtained from CT and MRI studies were preferentially used except for the assessment of osteolysis and subchondral cysts, which were evaluated on XR only. If neither CT nor MRI were available, XR measurements were utilized for all measurements. All measurements were performed using Visage 7 imaging software.

Acromioclavicular joint (ACJ) arthritis was assessed by a single reviewer (B.S.S), a medical student, using both the Petersson Classification of ACJ degenerative joint disease (DJD)[27] and a new ACJ arthritis classification system that is founded on and expanded from the Petersson system, the King Classification of ACJ DJD. The Petersson system was used as a comparator for assessing the utility of the new King classification proposed herein. A fellowship-trained shoulder surgeon was consulted on ambiguous imaging findings and measurements to reduce bias from a single reviewer and ensure accuracy.

There are 3 grades of osteoarthritis in the Petersson classification system. Grade I shows superficial degenerative signs including mild to moderate joint space narrowing with no osteophytes and some blister formation and fragmentation. Grade II shows deep degeneration, including ulceration, significant joint space narrowing and osteophytes ≤2 mm, regardless of location. Grade III shows full cartilage degeneration of more than 50% of the joint surface and inferior osteophytes >2 mm.[32] The King classification system is a modified Petersson system that takes superior osteophytes into account in the grade of ACJ DJD and more specifically defines the cutoff at each level of ACJ DJD based on size and joint space. The King classification system is broken down into 6 grades of ACJ DJD (Fig. 1) with the goal of expanding on the previous classification system to evaluate if any outcome differences exist based on the grade of ACJ arthritis and improving objectivity. Grade 1 shows no ACJ arthritis or capsular distention on advanced imaging. Grade 2 shows mild joint space narrowing with or without small osteophytes (less than 1 mm). Grade 3 shows obvious joint space narrowing with or without moderate-sized osteophytes (1 mm to <2 mm). Grade 4 shows large osteophytes or large heterotopic ossifications/loose bodies from 2 mm to ≤3 mm. Grade 5 shows large osteophytes or large heterotopic ossifications/loose bodies >3 mm, but that are not spanning the ACJ. Grade 6 includes large articulating or spanning osteophytes, irregular joint borders on both sides of the ACJ, or complete fusion/arthrosis of the ACJ.

Clinical outcomes

Range of motion (ROM) and outcome scores were assessed preoperatively and at follow-up visits. The following outcome scores were utilized: the Shoulder Pain and Disability Index (SPADI), the Simple Shoulder Test (SST), the American Shoulder and Elbow Surgeons Shoulder score, the University of California, Los Angeles score, and the normalized Constant Score. Active forward elevation (FE), abduction, and external rotation (ER) were measured using a hand-held goniometer at time of follow-up. Active internal rotation (IR) was assessed based on the vertebral segment level that could be reached by the thumb and was scored as follows: not capable of IR, 0; hip, 1; buttocks, 2; sacrum, 3; L5-L4, 4; L3-L1, 5; T12-T8, 6; and T7 or higher, 7.[8]

Statistical analysis

Demographics and radiographic characteristics of included patients were summarized descriptively. Range of motion (ROM) and outcome scores were compared based on ACJ arthritis grades at preoperative and latest postoperative follow-up after rTSA. Additionally, improvement preoperatively to postoperatively was also compared. Acromioclavicular joint (ACJ) arthritis grades were also grouped to test the broader influence of osteophyte size and location. Continuous measures were analyzed using a 2-tailed unpaired Welch's *t*-test. Count data were analyzed using Fisher's Exact test. Spearman correlations were used to evaluate whether increasing severity of ACJ arthritis is correlated with worse postoperative ROM and outcome scores. Correlation coefficients were classified according to convention: <0.10, negligible; 0.10-0.39, weak; 0.40-0.69, moderate; and ≥0.70, strong.[11] Multivariable linear regression models were used to determine whether increasing severity of ACJ arthritis was independently associated with poorer postoperative ROM and outcome scores. Estimates of the influence of ACJ arthritis grade were adjusted for age, body mass index (BMI), sex, hypertension, diabetes mellitus, tobacco use, previous surgery, and the preoperative value of the ROM or outcome score being assessed.

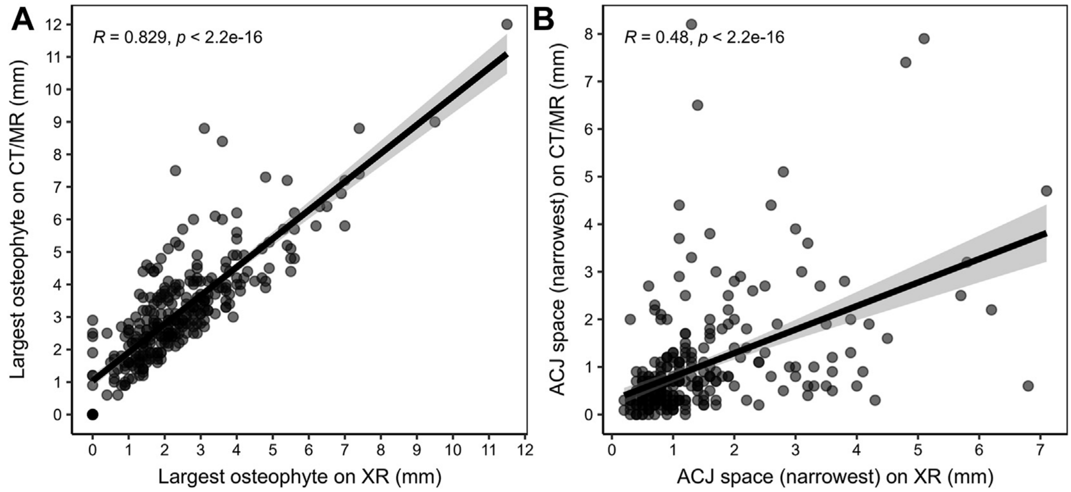

Figure 2 Correlation between measurements of (**A**) largest osteophyte and (**B**) acromioclavicular joint space on X-Ray vs. computed tomography and/or magnetic resonance imaging. *ACJ*, acromioclavicular joint; *XR*, x-ray.

Table II
Comparison of range of motion and outcome scores at preoperative and latest postoperative follow-up based on the King classification of ACJ arthritis.

Outcome measure	Grade 1 (n = 6)	Grade 2 (n = 16)	Grade 3 (n = 45)	Grade 4 (n = 61)	Grade 5 (n = 79)	Grade 6 (n = 134)	*P*
Preoperative							
SPADI score	66.5 ± 2.9	69.4 ± 12.3	66.3 ± 14.7	70.4 ± 14.7	67.1 ± 13.7	66.9 ± 16.1	.674
SST score	3.5 ± 2.5	3.3 ± 2.8	3.9 ± 2.6	3.7 ± 2.2	4.0 ± 2.6	4.1 ± 2.6	.859
ASES score	35.0 ± 8.1	36.0 ± 11.5	38.8 ± 16.0	36.2 ± 15.4	37.6 ± 14.5	38.2 ± 16.7	.920
UCLA score	14.5 ± 1.9	12.7 ± 3.1	14.4 ± 3.8	13.5 ± 3.7	13.9 ± 4.1	13.7 ± 3.8	.672
Constant Score	35.0 ± 6.2	38.2 ± 13.2	41.5 ± 15.9	37.3 ± 15.0	40.8 ± 14.9	39.9 ± 15.1	.540
Active ER (°)	23 ± 22	20 ± 18	26 ± 21	16 ± 23	23 ± 20	17 ± 21	.131
Active FE (°)	93 ± 23	84 ± 31	82 ± 31	77 ± 31	87 ± 33	82 ± 32	.511
Active IR score	3 ± 1	3 ± 2	4 ± 2	3 ± 2	3 ± 2	3 ± 2	.059
Active Abduction (°)	89 ± 23	84 ± 30	77 ± 32	75 ± 30	84 ± 34	79 ± 31	.586
Postoperative							
SPADI score	12.7 ± 11.5	18.5 ± 19.6	17.9 ± 17.6	29.4 ± 26.1	24.9 ± 21.9	25.0 ± 21.3	**.031**
SST score	10.5 ± 2.3	9.2 ± 2.8	9.7 ± 2.7	8.4 ± 3.6	9.1 ± 2.8	9.2 ± 3.0	.343
ASES score	85.6 ± 16.1	83.1 ± 16.0	81.7 ± 18.7	71.7 ± 24.7	76.9 ± 19.5	77.1 ± 20.0	.161
UCLA score	32.7 ± 2.5	31.2 ± 4.8	29.1 ± 6.2	28.9 ± 6.0	29.2 ± 5.0	28.9 ± 5.3	.282
Constant Score	87.1 ± 6.3	78.5 ± 18.6	71.9 ± 18.5	75.1 ± 17.5	73.3 ± 15.3	72.8 ± 17.0	.059
Active ER (°)	45 ± 5	32 ± 24	32 ± 19	36 ± 17	29 ± 21	31 ± 21	**.009**
Active FE (°)	140 ± 15	128 ± 33	124 ± 29	127 ± 26	126 ± 23	125 ± 24	.749
Active IR score	5 ± 2	5 ± 1	4 ± 2	5 ± 2	5 ± 2	4 ± 2	.461
Active Abduction (°)	122 ± 10	124 ± 37	116 ± 30	116 ± 28	114 ± 27	117 ± 27	.895
Improvement							
SPADI score	−51.2 ± 14.0	−50.2 ± 19.4	−48.8 ± 23.1	−39.3 ± 30.2	−43.0 ± 24.0	−41.2 ± 27.0	.296
SST score	6.5 ± 4.1	5.7 ± 3.8	6.0 ± 3.8	4.5 ± 3.9	5.1 ± 3.7	5.0 ± 4.0	.592
ASES score	46.7 ± 21.6	47.4 ± 17.2	43.2 ± 26.0	33.6 ± 29.3	39.3 ± 23.6	38.4 ± 26.7	.325
UCLA score	16.5 ± 2.1	18.5 ± 6.0	14.0 ± 9.0	14.4 ± 7.5	15.6 ± 6.2	15.1 ± 6.7	.579
Constant Score	53.6 ± 12.7	38.7 ± 18.3	29.2 ± 27.4	36.3 ± 22.4	32.8 ± 21.7	32.2 ± 22.6	.375
Active ER (°)	17 ± 38	12 ± 18	5 ± 32	22 ± 28	6 ± 30	14 ± 28	.196
Active FE (°)	43 ± 4	47 ± 48	43 ± 48	52 ± 39	40 ± 39	42 ± 38	.707
Active IR score	3 ± 2	2 ± 1	0 ± 3	2 ± 3	1 ± 3	1 ± 3	.068
Active Abduction (°)	26 ± 27	44 ± 47	40 ± 48	42 ± 38	33 ± 42	36 ± 39	.861

ACJ, acromioclavicular joint; *ASES*, American Shoulder and Elbow Surgeons; *ER*, external rotation; *FE*, forward elevation; *IR*, internal rotation; *SPADI*, shoulder pain and disability index; *SST*, simple shoulder test; *UCLA*, University of California, Los Angeles.
Values represent mean ± standard deviation unless otherwise noted. Bold indicates statistical significance.

Regression estimates and *P* values were reported only for the predictor of interest (ie, arthritis grade) for brevity. All statistical analyses were performed using the R software (version 4.2.0; R Core Team, Vienna, Austria) with a defined $\alpha = 0.05$.

Results

Patient cohort

We included 341 rTSAs. The mean age at surgery was 70 ± 8 years, 55% were female, and the mean follow-up was 5.1 ± 2.4 years (Table I). Twenty-five percent of patients had previous surgery on their shoulder. The mean BMI was 29.9 ± 6.6 kg/m^2.

Radiographic outcomes

Almost all included patients (90%) had advanced imaging (CT or MRI) available for analysis (Table I). We found a strong correlation between osteophyte size on CT and/or MRI and XR ($R = 0.829$, $P < .001$) and a moderate correlation between narrowest ACJ space on CT and/or MRI and XR ($R = 0.48$, $P < .001$) (Fig. 2). Based on the Petersson classification, 2% of shoulders had no ACJ arthritis, 4% had

Table III
Comparison of range of motion and outcome scores at preoperative and latest postoperative follow-up based on King grade of ACJ arthritis 1-3 vs. 4-6.

Outcome measure	Grade 1-3 (n = 67)	Grade 4-6 (n = 274)	*P* value
Preoperative			
SPADI score	67.1 ± 13.6	67.7 ± 15.1	.767
SST score	3.7 ± 2.6	4.0 ± 2.5	.474
ASES score	37.9 ± 14.5	37.6 ± 15.8	.881
UCLA score	13.9 ± 3.6	13.7 ± 3.9	.692
Constant Score	40.2 ± 14.8	39.6 ± 15.0	.771
Active ER (°)	24 ± 20	19 ± 21	**.049**
Active FE (°)	84 ± 31	82 ± 32	.776
Active IR score	4 ± 2	3 ± 2	.197
Active Abduction (°)	80 ± 31	79 ± 32	.857
Postoperative			
SPADI score	17.6 ± 17.5	26.0 ± 22.6	**.001**
SST score	9.7 ± 2.7	9.0 ± 3.1	.086
ASES score	82.4 ± 17.7	75.8 ± 21.0	**.011**
UCLA score	29.9 ± 5.7	29.0 ± 5.4	.368
Constant Score	74.6 ± 18.2	73.5 ± 16.5	.701
Active ER (°)	33 ± 20	31 ± 20	.659
Active FE (°)	126 ± 29	126 ± 24	.944
Active IR score	4 ± 2	5 ± 2	.422
Active Abduction (°)	119 ± 30	116 ± 27	.528
Improvement			
SPADI score	−49.3 ± 21.5	−41.3 ± 26.8	**.015**
SST score	5.9 ± 3.7	4.9 ± 3.9	.068
ASES score	44.5 ± 23.6	37.6 ± 26.4	.052
UCLA score	15.4 ± 8.1	15.1 ± 6.7	.816
Constant Score	33.0 ± 25.1	33.3 ± 22.2	.951
Active ER (°)	8 ± 29	13 ± 29	.237
Active FE (°)	44 ± 47	43 ± 39	.952
Active IR score	1 ± 3	1 ± 3	.123
Active Abduction (°)	40 ± 46	36 ± 40	.630

ACJ, acromioclavicular joint; *ASES*, American Shoulder and Elbow Surgeons; *ER*, external rotation; *FE*, forward elevation; *IR*, internal rotation; *SPADI*, shoulder pain and disability index; *SST*, simple shoulder test; *UCLA*, University of California, Los Angeles.
Values represent mean ± standard deviation unless otherwise noted. Bold indicates statistical significance.

Grade 1, 41% had Grade 2, and 53% had Grade 3. When using the King classification, stratification was more spread out (Grade 1: 2%, Grade 2: 5%, Grade 3: 13%, Grade 4: 18%, Grade 5: 23%, Grade 6: 39%). When present, large osteophytes (≥2 mm) were most frequently found both superior and inferior to the ACJ (38%) compared to superior only (20%) or inferior only (15%); 27% of patients had no large osteophytes (≥2 mm). The mean narrowest ACJ space on XR was 1.4 ± 1.2 mm and 1.0 ± 1.2 mm on CT and/or MRI. Other pathologic findings identified included subchondral cysts identified on XR (40%) and ACJ loose body or heterotopic ossification (23%).

Influence of ACJ arthritis on clinical outcomes

When comparing ROM and outcome scores based on the King classification, only the postoperative SPADI and ER scores differed between ACJ grades (*P* = .031 and *P* = .009, respectively) (Table II). However, no differences remained on post hoc pairwise analysis. When grouped by osteophyte size, patients with osteophytes ≥2 mm (Grade 4-6) had poorer preoperative ER than those <2 mm (19 ± 21° vs. 24 ± 20°, *P* = .049), a less favorable postoperative SPADI (26.0 ± 22.6 vs. 17.6 ± 17.5, *P* = .001), and a poorer postoperative American Shoulder and Elbow Surgeons Shoulder score (75.8 ± 21.0 vs. 82.4 ± 17.7, *P* = .011) (Table III). When compared based on the Petersson classification, patients with normal or Grade 1 ACJ arthritis had more favorable preoperative to postoperative improvement in the IR score compared to patients with Grade 2 or Grade 3 ACJ arthritis (3 ± 2 vs. 1 ± 2 and 1 ± 3, respectively; *P* = .029) (Table IV).

Table IV
Comparison of range of motion and outcome scores at preoperative and latest postoperative follow-up based on the Petersson classification.

Outcome measure	Normal or grade 1 (n = 19)	Grade 2 (n = 141)	Grade 3 (n = 181)	*P*
Preoperative				
SPADI score	67.6 ± 10.0	66.7 ± 14.9	68.3 ± 15.2	.682
SST score	3.4 ± 2.5	3.8 ± 2.6	4.1 ± 2.5	.425
ASES score	37.2 ± 11.3	37.6 ± 16.5	37.7 ± 15.2	.982
UCLA score	13.8 ± 2.4	13.9 ± 3.7	13.6 ± 4.0	.795
Constant Score	36.9 ± 12.1	40.0 ± 14.5	39.7 ± 15.6	.636
Active ER (°)	17 ± 19	22 ± 19	18 ± 22	.120
Active FE (°)	86 ± 33	83 ± 31	82 ± 32	.904
Active IR score	3 ± 2	3 ± 2	3 ± 2	.326
Active Abduction (°)	84 ± 26	80 ± 31	79 ± 32	.694
Postoperative				
SPADI score	17.0 ± 15.4	23.9 ± 21.5	25.4 ± 22.8	.130
SST score	9.6 ± 2.7	9.0 ± 3.1	9.2 ± 3.0	.596
ASES score	82.7 ± 14.1	77.3 ± 21.1	76.4 ± 20.7	.241
UCLA score	30.6 ± 4.4	29.2 ± 5.2	29.0 ± 5.7	.471
Constant Score	81.8 ± 13.6	73.1 ± 16.3	73.3 ± 17.4	.110
Active ER (°)	33 ± 24	34 ± 18	30 ± 21	.266
Active FE (°)	134 ± 29	125 ± 25	126 ± 25	.547
Active IR score	5 ± 2	4 ± 2	5 ± 2	.206
Active Abduction (°)	126 ± 28	117 ± 27	114 ± 28	.341
Improvement				
SPADI score	−48.5 ± 13.8	−42.6 ± 25.8	−42.6 ± 27.1	.303
SST score	5.9 ± 2.9	5.1 ± 3.8	5.1 ± 4.0	.604
ASES score	44.5 ± 12.8	39.4 ± 25.8	38.1 ± 27.1	.264
UCLA score	16.2 ± 5.0	14.9 ± 6.9	15.3 ± 7.3	.725
Constant Score	43.6 ± 16.3	31.8 ± 22.3	33.2 ± 23.5	.094
Active ER (°)	19 ± 25	11 ± 26	12 ± 31	.603
Active FE (°)	52 ± 44	43 ± 41	43 ± 40	.781
Active IR score	3 ± 2	1 ± 2	1 ± 3	**.029**
Active Abduction (°)	42 ± 32	39 ± 42	35 ± 41	.660

ACJ, acromioclavicular joint; *ASES*, American Shoulder and Elbow Surgeons; *ER*, external rotation; *FE*, forward elevation; *IR*, internal rotation; *SPADI*, shoulder pain and disability index; *SST*, simple shoulder test; *UCLA*, University of California, Los Angeles.
Values represent mean ± standard deviation unless otherwise noted. Bold indicates statistical significance.

When the relationship between ACJ arthritis (per the King classification, the Petersson classification, or based on the size of the largest osteophyte) and clinical outcomes was assessed on a continuous basis, all bivariate assessments demonstrated either negligible or weak correlations (*R* < 0.30 for all); the only statistically significant correlation identified was a negligible correlation between osteophyte size and the postoperative SPADI score (*R* = 0.093, *P* = .039) (Table V). Furthermore, neither ACJ arthritis classification based on the King classification nor the Petersson classification was independently associated with postoperative ROM or outcome scores when controlling for age, BMI, sex, hypertension, diabetes mellitus, tobacco use, and previous surgery on multivariable linear regression (Table VI).

Discussion

Overall, our results demonstrate that increasing ACJ arthritis severity alone is not associated with poorer outcomes scores and has a minimal effect on ROM following primary rTSA, so the decision to undergo rTSA should not depend on preoperative radiographic degenerative changes of the ACJ. However, patients with severe arthritis (osteophytes ≥2 mm) may have slightly more pain postoperatively. Postoperative pain seen in patients with large osteophytes may be due to increased impingement or may be a surrogate for painful ACJ arthritis. This theory is further

Table V
Correlation between ACJ arthritis grade and range of motion and outcome scores at preoperative and latest postoperative follow-up, divided into 3 different cohorts based on King classification, Petersson classification, and largest osteophyte size.

Outcome measure	King		Petersson		Largest osteophyte size	
	R	P	R	P	R	P
Preoperative						
SPADI score	−0.044	.566	0.035	.488	0.032	.570
SST score	0.067	.211	0.076	.204	0.025	.753
ASES score	0.026	.663	0.024	.851	−0.007	.833
UCLA score	−0.006	.995	−0.025	.543	−0.002	.957
Constant Score	0.023	.684	0.013	.682	0.010	.984
Active ER (°)	−0.080	.148	−0.099	.225	−0.054	.441
Active FE (°)	−0.010	.951	−0.033	.609	0.001	.869
Active IR score	−0.023	.760	−0.033	.871	−0.007	.856
Active Abduction (°)	−0.004	.858	−0.034	.477	0.002	.815
Postoperative						
SPADI score	0.088	.089	0.056	.138	0.093	**.039**
SST score	−0.021	.611	0.011	.921	−0.019	.578
ASES score	−0.070	.256	−0.054	.262	−0.083	.096
UCLA score	−0.087	.285	−0.024	.306	−0.033	.548
Constant Score	−0.086	.275	−0.033	.236	−0.020	.849
Active ER (°)	−0.096	.204	−0.128	.129	−0.052	.582
Active FE (°)	−0.051	.639	−0.004	.602	−0.031	.817
Active IR score	−0.016	.862	0.017	.762	0.059	.293
Active Abduction (°)	−0.037	.615	−0.088	.165	−0.096	.226
Improvement						
SPADI score	0.089	.099	0.016	.560	0.059	.198
SST score	−0.055	.250	−0.009	.509	−0.019	.465
ASES score	−0.048	.274	−0.018	.374	−0.050	.229
UCLA score	−0.033	.735	0.018	.970	−0.045	.550
Constant Score	−0.056	.436	−0.020	.441	−0.018	.864
Active ER (°)	0.019	.837	0.013	.776	0.010	.881
Active FE (°)	−0.069	.412	−0.019	.730	−0.054	.437
Active IR score	−0.012	.894	0.018	.797	0.043	.381
Active Abduction (°)	−0.044	.485	−0.065	.474	−0.088	.194

ACJ, acromioclavicular joint; *ASES*, American Shoulder and Elbow Surgeons; *ER*, external rotation; *FE*, forward elevation; *IR*, internal rotation; *SPADI*, shoulder pain and disability index; *SST*, simple shoulder test; *UCLA*, University of California, Los Angeles.
Values represent *R* and *P* per the spearman correlation test.

substantiated by limitations in IR in patients with large osteophytes (Table IV). Worse postoperative pain in patients with large osteophytes in the ACJ may simply be due to arthritis, which may be correlated with pain.[2,28] Worse arthritis may also limit scapulothoracic motion, which is known to contribute substantially to IR after rTSA.[34]

The Petersson classification of ACJ arthritis addresses both the size and location of osteophytes. In contrast, the King Classification of ACJ DJD system removes the restriction of osteophyte location when assigning ACJ DJD to the highest grade of degeneration and adds more objectivity by further stratifying by the size of the osteophytes. Osteophytes ≥2 mm were assigned to their appropriate grade of degeneration regardless of location. Additionally, expanding the prior classification was performed in this study to evaluate if there is a difference regarding ACJ osteophyte size affecting rTSA outcomes. We found that the presence of osteophytes ≥2 mm has a significant impact on the SPADI score and postoperative pain of the patient (Table III). Our results suggest that using the Petersson method may underestimate the clinically relevant characteristics of ACJ pathology and thus may misrepresent the postoperative pain a patient may experience based on this study.

Osteophyte size has been previously correlated with increased pain in joints such as the native hip[7] and decreased function in shoulders when humeral head osteophytes are present.[15] In patients undergoing total ankle replacement, osteophytes may cause painful impingement and necessitate secondary procedures to reduce pain.[24] Similarly, our study suggests that large osteophytes at the ACJ may result in greater pain postoperatively after undergoing rTSA (Table III). When classifying osteophytes under the Petersson classification, the change in score is not significant between different grades, which may be because large osteophytes superior to the ACJ are classified as less severe than those found inferiorly (Grade II rather than Grade III). Our results suggest that future investigations evaluating methods of addressing ACJ arthritis when large osteophytes are present may have the potential to improve patient outcomes.

Table VI
Multivariable linear regression performed to determine whether increased severity of King ACJ pathology independently influences postoperative range of motion and outcome scores.

Outcome measure	King			Petersson		
	Estimate	Std. Error	P	Estimate	Std. Error	P
SPADI score	1.46	1.00	.146	1.92	2.06	.353
SST score	−0.04	0.14	.787	0.11	0.28	.699
ASES score	−0.94	0.95	.325	−1.47	1.95	.450
UCLA score	−0.10	0.31	.750	−0.20	0.63	.753
Constant Score	−0.49	0.94	.605	−1.26	1.89	.507
Active ER (°)	−1.55	1.03	.136	−3.48	2.03	.088
Active FE (°)	−0.52	1.34	.698	−1.13	2.66	.673
Active IR score	−0.02	0.09	.801	−0.02	0.18	.918
Active Abduction (°)	−1.05	1.46	.472	−4.90	2.86	.088

ER, external rotation; *FE*, forward elevation; *IR*, internal rotation; *ASES*, American Shoulder and Elbow surgeons; *SPADI*, shoulder pain and disability index; *SST*, simple shoulder test; *UCLA*, University of California, Los Angeles; *BMI*, body mass index; *ACJ*, acromioclavicular joint; *Std*, standard.
Estimates derived from multivariable linear regression models adjusted for age, BMI, sex, hypertension, diabetes mellitus, tobacco use, previous surgery, and the preoperative outcome measure.

Previous studies have been conducted on evaluating the risk of acromial stress fractures with ACJ pathology.[6,32,35] Patients undergoing rTSA with osteophytes spanning the ACJ (Grade 6) may have a predisposition to acromial stress fractures, which is a rare but potentially catastrophic complication of rTSA.[32] While recent work has begun to provide some insight into the risk factors of acromial stress fractures after rTSA, the exact etiology is multifactorial and surgical considerations to prevent their occurrence remain largely unknown.[3,14,19,20,25,29] In the present study, we excluded patients with postoperative acromial stress fractures due to their influence on outcomes of rTSA.

Given the retrospective nature of our study, it has inherent limitations. However, patient outcome data were collected prospectively, helping to mitigate some of the limitations. Measurement errors are possible given the resolution and quality of the imaging studies, which can vary between patients and lead to errors in measurement and classification of arthritis. However, our institution has undertaken efforts to standardize imaging procedures to maximize image quality. Additionally, having one primary imaging reviewer may introduce bias to the data. To mitigate this bias, a fellowship-trained shoulder surgeon provided secondary review on any unclear or ambiguous imaging. We utilized advanced imaging (CT and/or MRI) when available, which was the case for 90% of patients. While 10% of ACJs were characterized based on radiographs alone, we demonstrated a strong and moderate correlation between radiographs and advanced imaging for the size of measured osteophytes and ACJ narrowing, respectively (Fig. 2). Inevitably, there were some patients that had to be excluded due to poor quality imaging (typically lack of a good view of the ACJ), which possibly introduced selection bias. Given the inclusion and exclusion criteria used in this study, we also cannot comment on the relationship between ACJ arthritis and complications after rTSA, as postoperative complications were excluded to remove confounding influences on outcomes from our analysis. It should also be noted that pain at the ACJ was not part of this study as we only looked at radiographic degenerative changes of the ACJ. Pain may also affect the biomechanics across the ACJ and may alter the functional outcomes of patients. Lastly, we did not assess the effect of prior surgery on the outcomes in this cohort and, given that 25% of our patients had prior surgery, this could affect the outcomes of this study.[21,26]

Conclusion

Overall, we found that greater ACJ arthritis severity alone is not associated with poorer outcome scores and has minimal effect on ROM. However, patients with large osteophytes ($\geq$ 2 mm) had slightly worse pain postoperatively. Our findings confirm that patients with degenerative changes of the ACJ can safely undergo rTSA and expect similar outcomes to patients without ACJ arthritis.

Disclaimers:

Funding: No Funding was disclosed by the authors.
Conflicts of interest: Mr. Hao has a consultancy agreement with LinkBio Corp. Dr. King is a paid consultant for Exactech, Inc. and LinkBio Corp. Dr. Wright is a paid consultant and receives royalties from Exactech, Inc. Dr. Schoch receives royalties from Exactech, Responsive Arthroscopy, and Innomed. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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