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Does Preservation of Coracoacromial Ligament Reduce the Acromial Stress Pathology Following Reverse Total Shoulder Arthroplasty?

Chang Hee Baek, MD[1], Jung Gon Kim, MD[1], Dong Hyeon Lee, MD[2], and Gyu Rim Baek[3]

Abstract

Introduction: Acromial pathologies (AP), such as acromial stress reaction (ASR), acromial stress occult fracture (ASOF), and acromial stress fracture (ASF), are known as complications that deteriorate the clinical score and patient satisfaction after reverse total shoulder arthroplasty (RSA). Several factors that increase stress on the acromion have been reported as risk factors for AP, but this is also unclear. Thecoracoacromial ligament (CAL) is a structure that distributes the stress loading on such an acromion, although its importance has been mentioned, there is a lack of research. Therefore, we investigated the incidence of AP according to the preservation of the CAL and whether it is a risk factor.

Methods: The study was retrospectively conducted on patients who underwent RSA from 2016 and 2018. Patients with CAL transection was classified into group 1 and CAL preservation was classified into group 2. ASR and ASOF were identified through symptoms and ultrasound, and ASF identified through simple radiograph or computed tomography. The incidence of AP in each group was checked and compared.

Results: Of the total of 265 patients. Among 197 cases of group 1, 21 cases of ASR(10.7%), 28 cases of ASOF (14.2%),10 cases of ASF (5.1%), and 59 cases of total AP (29.4%). Among 68 cases in group 2, 2 cases (2.9%) of ASR, 6 cases of ASOF (8.8%), 1 case of ASF (1.5%), and 9 cases of total AP (13.2%). It was confirmed that ASR and ASOP were significantly decreased in the group preserving CAL. ($P = .008$)

Conclusion: In the case of preservation of CAL during surgery, it was confirmed that the incidence of ASR, ASOF was reduced. Therefore, preservation of CAL can be regarded as a modifiable risk factor that can reduce the risk of AP by distributing the stress applied to acromion after RSA surgery.

Keywords

Reverse shoulder arthroplasty, complication, acromion, coracoacromial ligament

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Introduction

The use of reverse total shoulder arthroplasty (RSA) has increased quite rapidly and its indications have been expanded.[1,2] However, with this expansion, the number of complications has also increased.[3,4] Acromial fracture is one of the complications after RSA. The incidence of acromial fracture after RSA ranges between 0.6% and 25%.[5–7] Moreover, the acromial fracture is difficult to diagnose and treat,[8] and patients with acromial fracture have been reported to have poor satisfaction and clinical outcomes, as well as increased pain and

[1]Department of Orthopaedic Surgery, Yeosu Baek Hospital, Jeollanam-do, Republic of Korea
[2]Yeosu Baek Hospital
[3]Department of Mathematics, Dongguk University, Seoul, Republic of Korea

Corresponding Author:
Chang Hee Baek, Department of Orthopaedic Surgery, Yeosu Baek Hospital, Jeollanam-do, Republic of Korea.
Email: ch100c@chol.com

instability.[9–11] the causes of acromial fracture include increased acromial stress due to increased deltoid tension and arm length after RSA.[12,13] Although studies have investigated multiple factors contributing to acromial fractures, such as osteoporosis, acromial thickness, and prosthesis type, to date no clear evidence has been established.[14–16]

The coracoacromial ligament (CAL) has been described as a structure that plays a role in impingement in rotator cuff disease. Moreover, the CAL prevents anterior and superior glenohumeral translation of humeral head in massive rotator cuff tears.[17,18] Several previous anatomical and biomechanical studies reported other functions of the CAL as follows: transmitting load onto the scapula, limiting the pulling force on the acromion exerted by the deltoid and trapezius muscles, thus distributing stress, and acting as a dynamic tensional brace within the shoulder girdle.[19–21] Anatomically, the CAL is connected to the deep deltoid fascia of the anterior and intermediate deltoid and acts as a stabilizing factor.[22–24] Thus, the CAL resection may affect deltoid integrity, indicating the relationship between the CAL and deltoid function (Figure 1). Despite these unique functions of the CAL, it is sometimes resected during surgical exposure for RSA (Figure 2),[25,26] which may increase stress for the acromion, thereby increasing the incidence of acromial fracture. However, studies investigating the importance of CAL in acromial fractures following RSA are scarce.

The purpose of this study was to analyze the incidence of acromial pathology according to whether CAL, which distributes acromial stress, was transected or preserved and assessed CAL as a potential risk factor for acromial stress fracture. We hypothesized that the incidence of acromial pathology would be lower in patients whose CAL was preserved.

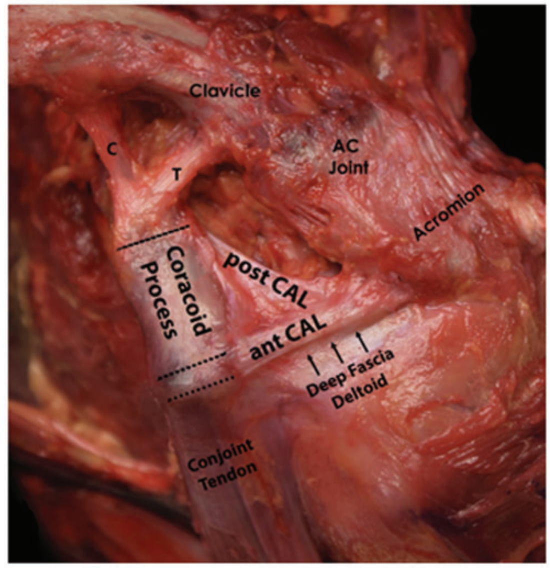

Figure 1. Dissected left shoulder displaying the conoid (C) and trapezoid (T) coracoclavicular ligament and coracoacromial ligament (CAL) bundles. The deep fascia of the deltoid attached to the most anterior aspect of the anterior CAL. Reprinted from Chahla et al.,[24] Copyright (2018), with permission from Elsevier.

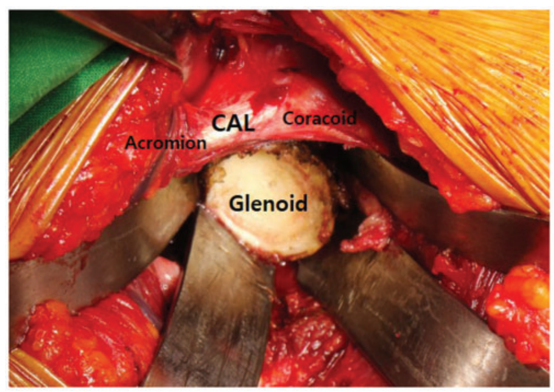

Figure 2. Exposure of the glenoid without release of coracoacromial ligament (CAL) via deltopectoral approach in right shoulder. Intact CAL is seen.

Methods

This study included patients who underwent RSA at a single center between January 2016 and December 2018. All medical records were retrospectively reviewed, and the demographic, clinical, and radiologic characteristics of the enrolled patients were obtained. During the study period, one senior experienced shoulder surgeon performed a total of 340 RSAs at a single center for various indications, including rotator cuff disease with concomitant glenohumeral arthritis, previously failed arthroplasty, and post-traumatic disease. The implants used for the surgery were Depuy: Delta III (Warsaw, IN), DJO: Altivate (Vista, CA), and Exactech: Equinoxe (Gainesville, FL), and the deltopectoral approach was applied to all patients. Based on surgical records and radiographs of all patients, those who had previously undergone shoulder arthroscopic surgery before RSA were excluded. The rationale for this exclusion is that rotator interval release and CAL partial resection are performed during the rotator cuff repair procedure in our institution. In addition, subacromial decompression is a routine procedure of arthroscopic surgery, and it is expected that the connective structure between the CAL and deltoid fascia is violated during this procedure. Postoperative trauma history, osacromiale, revision after arthroplasty, and follow-up loss were also excluded.

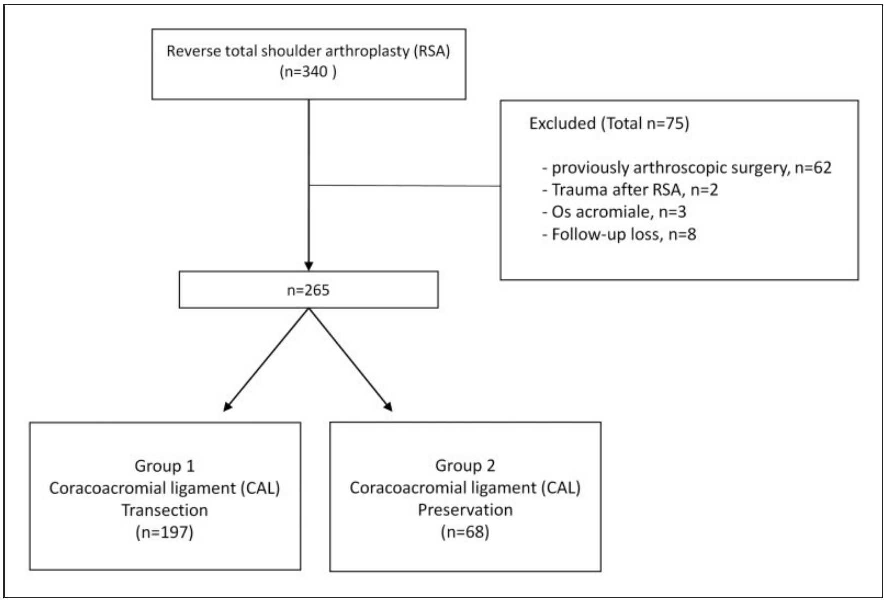

Figure 3. Flowchart of the study groups according to inclusion and exclusion criteria.

After applying the exclusion criteria, 265 patients remained. Patients who underwent surgery before November 2017, that is, before we began preserving the CAL during surgical exposure due to the proficiency in surgical technique and awareness of functional anatomy between the CAL and deltoid muscle,[18,23] were placed in Group 1 (n = 197). The other patients who underwent surgery after November 2017 (i.e., with CAL preservation) were placed in Group 2 (n = 68) (Figure 3). Data on factors that may cause an acromial stress fracture, such as sex, acromioclavicular joint (ACJ) arthritis confirmed by clinical symptoms and MRI,[27] osteoporosis, implant design, and acromion thickness, were extracted from medical and surgical records and analyzed. Subsequently, the incidence of acromial pathology was assessed in each group. The protocol for this study was approved by the institutional review board, and informed consent and permission to enroll in the RSA clinical database were obtained from all patients.

Radiological Evaluation

Follow-up was performed at 3 weeks, 6 weeks, 3 months, 6 months, and 12 months after surgery, respectively. At the follow-up date, plain radiographs (anteroposterior, axillary lateral, scapular-Y, and Grashey views) were used to detect acromial stress fractures. When no fracture line was found on plain radiographs in patients who were highly suspected of having acromial fractures and with a tender point along the acromion, additional ultrasonography (Affiniti 70g; Philips, Bothell, WA, and HD15; Philips, Bothell, WA) to evaluate acromial pathology was performed by one skilled radiologist who was not involved in this study.

We defined "acromial pathology" based on previous studies[8,28–30] as follows: (1) acromial stress reaction (ASR), i.e., tenderness at the acromial area without radiographically confirmed fracture, without ultrasonographically confirmed cortical discontinuity and with periosteal thickening and surrounding soft-tissue edema;[28,31,32] (2) acromial stress occult fracture (ASOF), i.e., tenderness at the acromial area without radiographically confirmed fracture but with ultrasonographically confirmed cortical discontinuity[28,32] on the tender point suspected of having fracture(Figure 4); and (3) acromial stress fracture (ASF), i.e., tenderness at the acromion with fracture confirmed by plain radiography. The location of the acromial pathologies was classified according to Levy's classification.[11]

Statistical Analyses

The SPSS software package (version 21.0, IBM, Armonk, NY, USA) was used for statistical analysis. The Mann-Whitney U test was used for non-parametric continuous variables and independent Student's *t*-test was used for parametric continuous variables. $P < 0.05$ was considered to indicate statistical significance.

Results

There were no differences in patient demographics between the two groups (Table 1). In terms of

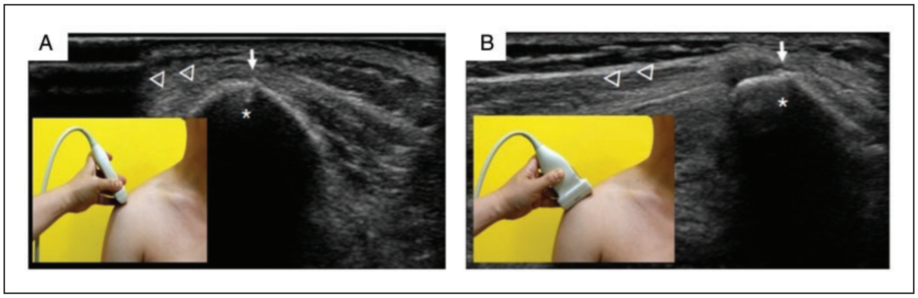

Figure 4. Acromial stress occult fracture site. A, Longitudinal ultrasonography. B, Transverse ultrasonography. The fracture was diagnosed based on a radiographic finding of cortical discontinuity and periosteal thickening.

Table 1. Demographics Between Two Groups.

	Group 1 (CAL Transection) n = 197	Group 2 (CAL Preservation) n = 68	Pvalue
Age (year)	73.53 ± 6.0	73.1 ± 6.3	0.606
Female (%)	83.2	80.9	0.657
Indication (%)			0.025*
- CTA	63.0	82.4	
- MRCT	6.8	4.8	
- OA	29.2	11.4	
- Proximal humerus Fx.	1.0	1.4	
Implant design (%)			0.341
- Delta III (MG/MH)	40.1	35.7	
- DJO (LG/MH)	34.2	34.2	
- Exactech (LG/LH)	25.7	30.1	
BMI	23.3 ± 3.3 (16–36)	24.0 ± 3.4 (17–35)	0.143
Osteoporosis (%)	55.3	60.3	0.476
ACJ arthritis (%)	89.4	83.8	0.145
Acromial thickness (mm)	7.89 ± 0.76 (5–14)	7.94 ± 0.85 (6–12)	0.571
Smoking (%)	2.1	5.9	0.125
DM (%)	27.6	10.0	0.005*
HTN (%)	63.0	70.0	0.324
Arm dominance (%)	72.1	66.2	0.357
Mean follow-up period (months)	17.6 ± 6.4	12.1 ± 5.6	0.031*

*Significant P value (<0.05).
CTA: cuff tear arthropathy, MRCT: massive rotator cuff tear, OA: glenohumeral osteoarthritis, MG: medial glenoid, LG: lateral glenoid, MH: medial humerus, LH: lateral humerus, AP: acromial pathology.

preoperative diagnosis, cuff tear arthropathy accounted for 63.0% of the patients in Group 1, followed by glenohumeral osteoarthritis (29.2%) and proximal humerus fracture (1.0%); in Group 2; such diagnoses were found in 82.4%, 11.4%, and 1.4% of the patients, respectively. The distribution of implant design did not differ significantly between groups. The groups also did not differ significantly in known risk factors for acromial stress fracture such as osteoporosis, acromial thickness, and ACJ arthritis.

In Group 1 (n = 197), acromial pathologies were confirmed in a total of 59 patients (29.4%) (ASR, n = 21, 10.7%; ASOF, n = 28, 14.2%; and ASF, n = 10, 5.1%). In Group 2 (n = 68), 9 patients (13.2%) had acromial pathology (ASR, n = 2, 2.9%; ASOF, n = 6, 8.8%; and ASF, n = 1, 1.5%) (Table 2). The diagnosis times of acromial pathologies after RSA were 8.4 ± 8.2, 4.9 ± 5.6, and 4.5 ± 8.7, respectively, in Group 1, and 70 ± 5.6, 2.0 ± 1.1, and 2.0, respectively, in Group 2. There were no significant differences between the two groups (Table 2). The locations of the acromial pathologies were identified as 67.2%, 22.4%, and 10.3%, respectively, in type I, II, and III in Group 1, and 66.7%, 22.2%, and 11.1% in Group 2, respectively. No significant differences were found between the two groups. In all patients with confirmed acromial pathology, immobilization with

Table 2. Acromial Pathology Incidence Rate and Time From Surgery to Acromial Pathology Following RSA.

	Group 1 (CAL Transection)	Group 2 (CAL Preservation)	*P-value*
Case, n	197	68	
Total acromial pathology, n (%)	59 (29.4)	9 (13.2)	0.008*
- ASR	21 (10.7)	2 (2.9)	0.029*
- ASOF	28 (14.2)	6 (8.8)	0.044*
- ASF	10 (5.1)	1 (1.5)	0.142
Time from surgery to AP, month	6.1 ± 7.2	3.1 ± 3.1	0.225
- ASR	8.4 ± 8.2	7.0 ± 5.6	0.808
- ASOF	4.9 ± 5.6	2.0 ± 1.1	0.214
- ASF	4.5 ± 8.7	2.0	0.790

*Significant P-value (<0.05).
CAL: coracoacromial ligament, ASR: acromial stress reaction, ASOF: acromial stress occult fracture, ASF: acromial stress fracture.

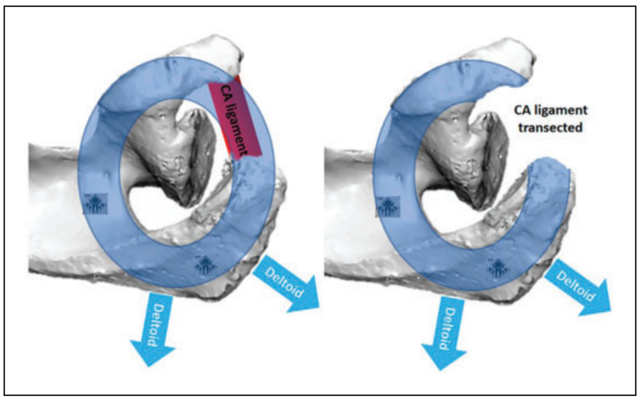

Figure 5. Scapular ring concept. The broad and robust coracoacromial ligament (CAL) completes the "scapular ring" by working to distribute the forces exerted on the scapula. The stiff CAL counteracts the bending of the acromion to create more of a shared load and dissipate the large hoop stresses imparted by a mechanically advantaged deltoid following RSA. Reprinted from Taylor et al.[33] Copyright (2020), with permission from Wolters Kluwer Health, Inc.

an abduction brace was provided for 6 weeks until the symptoms subsided. None of the patients had nonunion or malunion at the final follow-up.

Discussion

Our study assessed the frequency of acromial pathology by performing a radiologic evaluation according to the presence and absence of the CAL, which is considered to be a cause and potential risk factor for acromial stress fracture. As presented in the Results section, we confirmed that acromial pathology occurred more frequently in the CAL transection group.

Previous biomechanical and anatomical studies demonstrated that the CAL decreases the pulling force loaded on the acromion by the deltoid and trapezius muscles, thus decreasing acromial stress; through this mechanism, the CAL could act as a tensional brace within the shoulder girdle.[19–21] Recently, Taylor et al.[33] reported the concept of "scapular ring," in which the CAL acts as a component of the coracoacromial arch and plays a counterbalancing role to distribute the force exerted on the acromion and scapula by the deltoid following RSA. Strain patterns on the acromion and scapular spine after RSA may change depending on the presence of the CAL (Figure 5). Moreover, in a three-dimensional finite element model study, Filardi[34] reported in their three-dimensional finite element model study that the percentage reported that the percentage difference in stress during elevation and external rotation was the highest in the CAL among the shoulder structures, thereby suggesting that the CAL plays a crucial role in load transfer during stress distribution within the shoulder girdle. These findings further indicate that the CAL may act as a tensional brace that protects the acromion.

Anatomically, the CAL is connected to the deltoid fascia inferiorly (Figure 1). According to previous studies,[22–24] CAL injuries interrupt the connection with the deltoid, thereby increasing the loading force on the acromion. This observation may be associated with the lower incidence of acromial pathology in the group with preserved CAL in our study. Nevertheless, anatomic and biomechanical data on the amount of stress these structures could biomechanically distribute are lacking; thus, additional research is necessary. The function and role of the CAL still need to be fully elucidated. Despite its unique functions, the CAL is often transected during surgical exposure for RSA by either the deltopectoral or anterosuperior approach. Studies investigating the importance of the CAL in acromial fracture complications following RSA are scarce.

In our study, the incidence of acromial pathology was 29.4% in Group 1 (transected CAL), and 13.2% in Group 2 (preserved CAL); these values were higher than the frequency of acromial or scapular spine fractures reported in previous studies.[5–7] most of which utilized tenderness and plain radiography only to confirm ASF. However, a complete evaluation of ASF following RSA using such methods is difficult, particularly in the case of non-displaced fractures.[6,8,11,32] Hence, ASF may be underestimated and neglected. The varying frequencies of ASF reported in previous studies support this argument. Thus, when there is a strong suspicion of ASF, plain radiography and additional imaging modalities, such as computed tomography, magnetic resonance imaging, and bone scintigraphy, are recommended for a definitive diagnosis.[8,11,35–37]

Our study confirmed acromial pathology with ultrasonography, which is a valuable tool in detecting non-displaced fractures, occult cortical fractures, and periosteal reactions that cannot be confirmed by plain radiography.[28,29,32,36,38] Thus, the acromial pathology incidence was higher in our study than in previous reports. Moreover, according to previous studies, the causes of acromial fracture include osteoporosis, ACJ arthritis, acromion morphology and thickness, diabetes, nutritional status, and bone quality.[6,7,39] In addition, modifiable risk factors such as arm lengthening, lateralization, plane of elevation, screw position, and base plate position resulting from prosthesis design have been discussed.[7,12,14,40,41] However, clear evidence is lacking, and further investigation is warranted. Additionally, we investigated the influence of the CAL on ASF and evaluated whether there were significant changes in the incidence of acromial pathology according to the presence or absence of the CAL. We also assessed whether CAL preservation versus transection during surgery could serve as a modifiable risk factor that could decrease the incidence of acromial pathology following RSA. Results revealed that there was no significant difference in the incidence of ASF, but significant differences were confirmed between ASR and ASOF. The progression from ASR to ASOF or ASF, or from ASOF to ASF, was not confirmed, which is thought to be due to the recommendation for all patients to prohibit activities of daily living and to wear an immobilizing abduction brace consistently after confirmation of the acromial pathology. In the presence of these ASRs and ASOFs, there have been difficulties in early postoperative rehabilitation and a decrease in postoperative satisfaction at the outpatient follow-up. Therefore, it is believed that reducing their incidence through the preservation of the CAL will help increase the promotion of rehabilitation and satisfaction after surgery.

Our study has some limitations. First, because of the retrospective study design, various factors may have influenced the results, such as differences in the number of cases, indications for RSA, and medical comorbidities between the groups, thereby raising the possibility of selection bias. In particular, there was a difference in the indications for RSA between the two groups. In cases of glenohumeral osteoarthritis and cuff tear arthropathy, since the difference in the remaining cuff after RSA could be a factor that affects deltoid tension, it is thought that this may have affected the results. Second, there was a significant difference in the follow-up period between the two groups. Although there was a difference, the time points at which acromial pathology was found after surgery in both groups did not significantly differ by 6.1 ± 7.2 in Group 1 and 3.1 ± 3.1 months in Group 2 ($p = 0.225$). However, the follow-up duration was relatively short, and additional long-term follow-up studies are needed. Third, although there was no significant difference in the type of prosthesis design between the two groups, it is considered a limitation that changes in biomechanics according to various prostheses could not be reflected in this study, and this may have affected the results. Finally, the clinical scores for each acromial pathology were not described.

However, our study has the following strengths. To our knowledge, this is the first clinical study to assess whether the presence or absence of the CAL influences the incidence of acromial pathology following RSA. Furthermore, we used ultrasonography, which has a higher sensitivity and specificity compared to plain radiography, in diagnosing acromial pathology.

Conclusion

We confirmed that the incidence of acromial pathology decreased when the CAL was preserved during RSA. Our results indicate that CAL preservation versus transection could be a modifiable risk factor that decreases the incidence of acromial pathology.

Authors' Note

Research was performed at Yeosu Baek Hostpital.

Ethical Approval

The protocol of this study was approved by Ministry of Health and Welfare institutional review board (IRB approval No. P01-202010-21-021).

Declaration of Conflicting Interests

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ORCID iD

Chang Hee Baek https://orcid.org/0000-0002-3169-7141

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