



## Fibrosis in the rotator interval associated with articular vs. bursal side partial-thickness rotator cuff tears

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**Background:** The pathogenesis of articular- and bursal-sided partial-thickness rotator cuff tears (PTRCTs) is considered to be different, and associated lesions with PTRCTs need to be examined.

**Methods:** The current study consisted of 76 shoulders of 73 patients (27 men, 46 women, 64.0 ± 8.3 years old) who underwent mini-open repair after conversion to full-thickness tears for either articular side (group A; n = 56) or bursal side (group B; n = 20) PTRCT with at least a 2-year follow-up. Clinical outcomes and their images were compared between the groups. Plain radiographs were used with the arm passively elevated in maximum elevation to assess restriction of glenohumeral motion.

**Results:** The retear rate was not significantly different between the groups. Both groups showed significant improvement in functional scores at the final follow-up. Patients in group A showed a higher incidence of preoperative fibrosis in the rotator interval (69.6% vs. 35.0%, respectively;  $P = .006$ ) and a lower incidence of an acromial spur (7.1% vs. 35.0%, respectively;  $P = .008$ ) compared with group B. Plain radiographs with arm elevation showed restriction of glenohumeral movement in 49 of 76 shoulders (64.5%) preoperatively, including 36 of the 46 shoulders with fibrosis and 13 of the other 30 shoulders.

**Conclusion:** Both articular- and bursal-sided PTRCTs showed significant functional improvements after surgery. The articular-sided tears had a lower incidence of an acromial spur, but had a higher incidence of fibrosis in the rotator interval, which led to a limitation in glenohumeral motion.

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Partial-thickness rotator cuff tear (PTRCT) is a common type of shoulder disorder.<sup>5,16</sup> Several authors<sup>10,13,14</sup> compared clinical outcomes after surgical repair of bursal- and articular-sided PTRCTs. Their results were not consistent. One of them reported a higher failure rate in bursal-sided tears,<sup>14</sup> whereas the others did not observe a difference in outcomes. The bursal-sided tears had a higher incidence of impingement sign caused by a protruded spur under the surface of the acromion.<sup>14,20</sup> Further features other than the acromial spur need to be examined to understand the difference in pathogenesis between articular- and bursal-sided PTRCTs.

Patients with PTRCTs reportedly suffer from more pain than those with complete tears.<sup>5</sup> Stiffness can contribute to pain before and after surgery.<sup>1,2</sup> In fact, clinical features of adhesive capsulitis and PTRCTs may overlap each other, and severe shoulder stiffness is sometimes associated with PTRCTs.<sup>25</sup> Thickening of the coracohumeral ligament (CHL) and fibrosis in the rotator interval (RI)

are reportedly the main findings of adhesive capsulitis.<sup>21</sup> The findings have been demonstrated on noncontrast magnetic resonance imaging (MRI).<sup>3</sup> It is possible that the changes accompany PTRCTs as well. However, to our knowledge, there has been no study to evaluate MRI findings associated with PTRCTs, including changes in the CHL and the RI. Our hypothesis was that associated lesions on MRI would be different between articular- and bursal-sided PTRCTs, although both would have good functional outcomes postoperatively.

### Materials and methods

A series of 102 consecutive shoulders (97 patients) with high-grade PTRCTs that had failed nonoperative treatment for at least 3 months underwent mini-open repair from 2012 to 2017 at our institute. All operations were supervised by the third author (KN). We used the following exclusion criteria: (1) a combined subscapularis (SC) tear, (2) combined acromioclavicular joint arthritis requiring concomitant distal clavicle resection, (3) neurological involvement, (4) previous surgery on the affected shoulder, (5) advanced arthritic changes of the glenohumeral joint, and (6) revision surgery. Fifteen patients who were followed for less than 2

This study was approved by our hospital institutional review board (no. J124).

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years after surgery were also excluded from the study. The remaining 76 shoulders (group A, articular side, 56 shoulders; group B, bursal side, 20 shoulders) of 73 patients were included in this study. Demographics of the groups are listed in Table I. There was no difference between the groups.

### Clinical assessment

All patients were assessed preoperatively and at the final follow-up (a minimum of 2 years) with the American Shoulder and Elbow Surgeons (ASES) score, the University of California, Los Angeles (UCLA) Shoulder Rating Scale, and the Japanese Orthopaedic Association (JOA) score. Active range of motion (ROM) was assessed by senior physical therapists (none of the present authors) with large goniometers before surgery and at the final follow-up.

### Radiographic assessment

MRI was performed with an open-type scanner (APERTO Eterna; Hitachi, Tokyo, Japan) before surgery and approximately 6 months after surgery. The following MRI protocol was used in all patients: coronal oblique T1-weighted fast spin echo (987/15 [repetition time, milliseconds/echo time, milliseconds]); coronal oblique T2-weighted fast spin echo (3500/98 [repetition time, milliseconds/echo time, milliseconds]); coronal oblique proton density-weighted fat-suppressed spin echo (3616/30 [repetition time, milliseconds/echo time, milliseconds]); sagittal oblique T2-weighted fast spin echo (3500/98 [repetition time, milliseconds/echo time, milliseconds]); sagittal oblique proton density-weighted fat-suppressed spin echo (3616/30 [repetition time, milliseconds/echo time, milliseconds]); and axial T2-weighted fast spin echo (3500/98 [repetition time, milliseconds/echo time, milliseconds]); axial proton density-weighted fat-suppressed spin echo (3616/30 [repetition time, milliseconds/echo time, milliseconds]). Imaging parameters included a 4-mm section thickness, no intersection gap, a 16-cm field of view, and a matrix size of 512 × 512.

The lesions that often accompany PTRCTs on MRI have been reported previously: (1) fibrosis in the RI, (2) swelling of the rotator cuff tendon, (3) cystic change of the humeral head, and (4) thickening of the capsule at the axillary recess (AR).<sup>15</sup> In healthy shoulders without fibrosis in the RI, the RI space demonstrated intermediate homogeneous signal intensity in the sagittal oblique T2-weighted image and lower signal intensity in the proton density-weighted fat-suppressed image. The CHL, the undersurface of the coracoid process, and the upper margin of the SC could be clearly distinguished in both images. In patients with fibrosis in the RI, the CHL, the undersurface of the coracoid process, and the upper margin of the SC could not be distinguished because the tissue in the RI with infiltration of the subcoracoid fat demonstrated low signal inhomogeneous density in the sagittal oblique T2-weighted image. In the proton density-weighted fat-suppressed image, its tissue showed intermediate inhomogeneous intensity and distinguished thickened

CHL from the tissue. The thickness of the CHL >2 mm with RI infiltration of the subcoracoid fat was considered abnormal (Fig. 1).<sup>3</sup> Tendon thickness at the lateral edge of the acromion was compared with that of the lateral portion.<sup>11</sup> In healthy shoulders, tendon thickness decreased gradually, leading to its insertion.<sup>15</sup> The tendon was considered swollen if the thickest part was out of the lateral edge of the acromion (Fig. 2). The cystic change of the humeral head on MRI was defined as a round or oval area in the proximal humerus, larger than 2 mm in diameter and with low signal intensity on T1-weighted images and high signal intensity on T2-weighted images.<sup>23</sup> The thickness of the capsule at the AR was measured on coronal oblique T2-weighted images, and a cutoff value was determined to be 3 mm in thickness (Fig. 3).<sup>9</sup> The lesions of MRI were evaluated blindly and independently by the two authors (HI and RS). In cases in which the results from the 2 observers were inconsistent, a final consensus decision was made based on the discussion between the 2 observers.

To evaluate repair integrity after surgery, each repaired rotator cuff was classified into 1 of 5 categories as described by Sugaya et al.<sup>24</sup> type I, sufficient thickness with homogeneous low intensity; type II, sufficient thickness with partial high intensity; type III, insufficient thickness without discontinuity; type IV, minor discontinuity in more than 1 slice; and type V, major discontinuity. Types IV and V were regarded as a retear.

The presence of an acromial spur was assessed on preoperative anteroposterior views with the arm in the dependent position. Also, as was previously reported,<sup>8</sup> plain radiographs with the arm passively elevated at maximum elevation were assessed for glenohumeral position preoperatively, at 6 months, and at the last follow-up. It was determined whether the humerus was as high as the scapular spine and could reach the zero position (Fig. 4).<sup>6,22</sup>

### Surgical technique and postoperative management

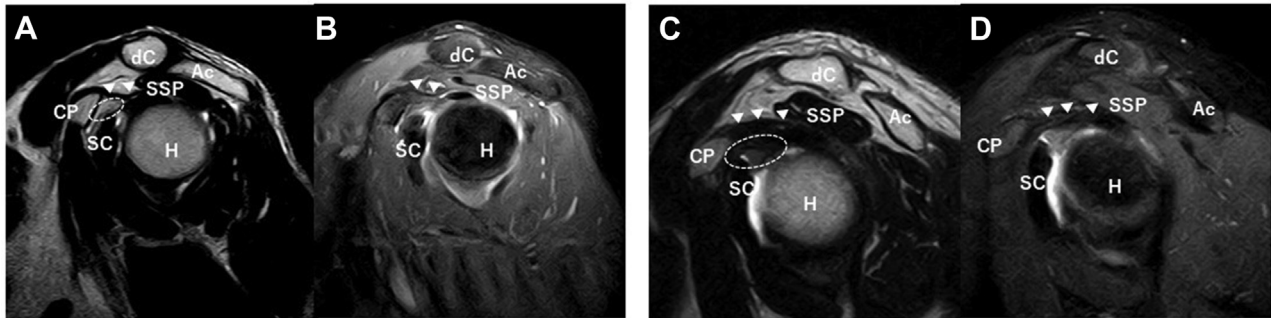
All operations were performed with the patient in the beach-chair position under general anesthesia. The fibers of the anterior deltoid muscle were split after a skin incision approximately 5 cm long. Any acromioplasty was limited to the removal of osteophytes with a flat chisel. The coracoacromial ligament was released partially in all patients. All PTRCTs were repaired after conversion to a full-thickness tear by releasing the remaining tissue from the footprint. It is supposed to be difficult to determine the size and extension of the articular side tear at open surgery. The tear site could be detected by palpation because it felt softer than the surrounding tendon despite smooth appearance from the bursal side. Exact extension of the tear was determined after exploring the articular side. The tendon was repaired using the standard McLaughlin procedure.<sup>17</sup> The bone trough was made at the footprint, and the cuff was repaired to the greater tuberosity after the degenerative edge of the torn cuff was resected.

Postoperatively, the shoulder was kept in an abduction brace for 4–6 weeks. Each patient was supervised by a physical therapist.

**Table I**  
Patient demographics

	Group A	Group B	P value
Number of shoulders	56	20	
Age (yr)	64.2 ± 7.3	63.7 ± 10.1	.431 (unpaired <i>t</i> -test)
Sex, male/female (n)	18/35	9/11	.384 ( $\chi^2$ test)
Dominant arm involvement (n)	40	17	.575 ( $\chi^2$ test)
DM (n)	5	2	.710 ( $\chi^2$ test)

DM, diabetes mellitus.



**Figure 1** A case without fibrosis in the rotator interval (RI). (A) The RI space demonstrated intermediate homogeneous signal intensity in the sagittal oblique T2-weighted image. The coracohumeral ligament (CHL) (white arrow heads), the undersurface of the coracoid process (CP), and the upper margin of the subscapularis (SC) can be clearly distinguished in this image (dotted area). (B) The space in the same case without fibrosis shows relatively low signal intensity in the proton density-weighted fat-suppressed image. The CHL (white arrow heads), the undersurface of the CP, and the upper margin of the SC cannot be distinguished (dotted area) because the tissue in the space with infiltration of the subcoracoid fat shows a similar signal intensity. (D) The space in the same case with fibrosis shows intermediate inhomogeneous intensity in the proton density-weighted fat-suppressed image. This image shows that the CHL is much thicker than the one without fibrosis. dC, distal clavicle; Ac, acromion; H, humeral head. SSP, supraspinatus.

Pendulum exercises and assisted ROM exercises were started within several days after surgery. Active exercises were started 6 weeks after surgery. Strenuous intrinsic or extrinsic muscle training was initiated 3 months after surgery, and all occupational or sports activities were permitted 6 months postoperatively.

*Statistical analysis*

The number of the patients was determined to include at least 20 patients in each group in accordance with the previous comparative study showing that both the groups had good functional outcomes postoperatively.<sup>13</sup> An unpaired *t*-test was performed to compare scores and angular values of ROM between the groups. A paired *t*-test was used to compare pre- and postoperative scores and angular values within groups. A  $\chi^2$  test was used to compare categorical data, and statistical significance was set at *P* < .05. Inter-reader agreement of each MRI finding was assessed using kappa statistics ( $\kappa$ ).

**Results**

Mean preoperative scores were  $40.8 \pm 15.3$  points (ASES),  $16.3 \pm 3.1$  points (UCLA), and  $63.1 \pm 9.6$  points (JOA) in the articular-sided group, and  $40.8 \pm 15.6$ ,  $16.9 \pm 3.0$ , and  $64.8 \pm 11.3$  points in the bursal-sided group, respectively. There was no difference between the groups (unpaired *t*-tests; *P* = .130, .086, and .291). Clinical outcome scores after surgery were significantly improved at the final follow-up (paired *t*-tests; *P* < .001) among the groups, and there were no significant differences in postoperative scores (Table II): ASES (articular-sided,  $86.2 \pm 7.7$  points; bursal-sided,  $87.4 \pm 5.6$  points; *P* = .282), UCLA (articular-sided,  $30.5 \pm 2.8$  points;  $30.3 \pm 1.7$  points; *P* = .368), and JOA (articular-sided,  $84.3 \pm 7.1$  points; bursal-sided,  $85.6 \pm 6.9$  points; *P* = .145).

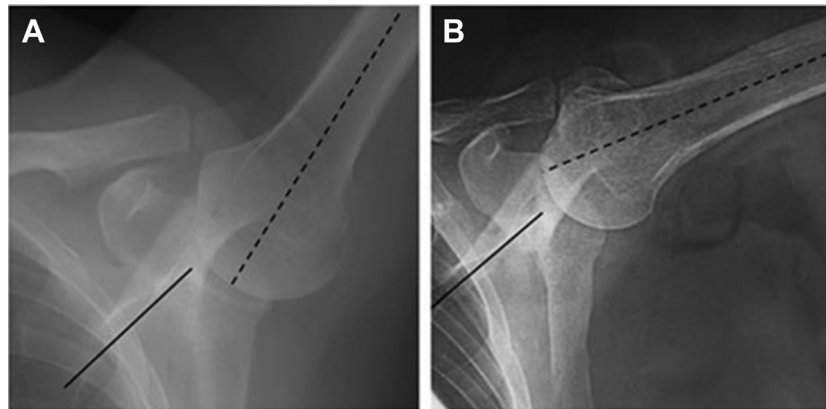
Preoperative active forward flexion, abduction, and external rotation were  $131 \pm 20.4$ ,  $96.8 \pm 27.1$ , and  $27.7 \pm 20.8$  in the articular-sided group, and  $129.0 \pm 22.9$ ,  $100.7 \pm 26.8$ , and  $35.9 \pm 26.7$  in the bursal-sided group, respectively. There was no



**Figure 2** Tendon thickness in the coronal oblique T2-weighted image. In healthy shoulders, thickness decreases as the tendon moves laterally toward its insertion from the level of the lateral edge of the acromion. The tendon appears thicker at point b than point a (lateral edge of the acromion [Ac]).



**Figure 3** Thickness of the capsule at the axillary recess was measured on coronal oblique T2-weighted images. In this case, the capsule was the thickest at the humeral insertion (between white arrows).



**Figure 4** Anteroposterior radiographs with arm elevation. In the zero position, the humeral axis (---) parallels the scapular axis (—), which is the junction of the blade and spine of the scapula. (A) Above the zero position, (B) below the zero position.

difference between the groups (unpaired *t*-tests; *P* = .441, .307, and .111). Only the value of abduction in the articular-sided group improved to 119.1 ± 21.7 (paired *t*-test; *P* < .001). There were no improvements in the other motions (Table III). Plain radiographs with arm elevation showed arms below the zero position preoperatively in 49 of 76 shoulders (64.5%). The number of shoulders with limitation increased to 52 shoulders (68.4%) at 6 months after surgery. It decreased with time, but 16 of 76 shoulders (21.1%) still had limitation of glenohumeral movement at the final follow-up.

Three cases had evidence of retear on postoperative MRI. They included 2 cases with an articular-sided tear and 1 case with a bursal-sided tear. There was no difference in the retear rate between the groups ( $\chi^2$  test; *P* = .698).

The lesions accompanied by articular- and bursal-sided PTRCTs are presented in Table IV. Fibrosis in the RI was shown in 46 of the 76 shoulders (56.6%). The finding was demonstrated more frequently in articular-sided tears than in bursal-side tears ( $\chi^2$  test; *P* = .006). The limitation of glenohumeral movement on plain radiographs with arm elevation was compared between the cases with and without RI fibrosis. Thirty-six of the 46 shoulders with fibrosis (78.2%) and 13 of the 30 shoulders without fibrosis (43.3%) showed glenohumeral restriction with the humerus below the zero position. There was a statistical difference in its distribution ( $\chi^2$  test; *P* = .002). In addition, 2 cases with fibrosis and 1 case without fibrosis showed restriction 6 months after surgery. At the final follow-up, 13 shoulders with fibrosis (28.3%) and 3 shoulders without fibrosis (10.0%) had a limitation, with no statistical difference ( $\chi^2$  test; *P* = .056) between them. An acromial spur was observed in 11 shoulders (14.5%). The finding was more frequent in bursal-sided tears than in articular-sided tears ( $\chi^2$  test; *P* = .008).

The readers were concordant 92.1% ( $\kappa$  = 0.833) for fibrosis in the RI, 92.1% ( $\kappa$  = 0.840) for swelling of the rotator cuff tendon, 94.7% ( $\kappa$  = 0.872) for the cystic change of the humeral head, and 84.2% ( $\kappa$  = 0.616) for thickening of the capsule at the AR.

**Discussion**

PTRCT is a common type of shoulder disorder. If patients with PTRCTs have high-grade involvement (50%) or are Ellman classification<sup>4</sup> grade 3, and have consistent pain or develop shoulder dysfunction, surgical intervention is generally recommended. Several studies<sup>10,13,14</sup> reported outcomes of repair after conversion to full-thickness tears comparing bursal- and articular-sided PTRCTs. One of them showed that bursal-sided PTRCTs had higher retear rates than articular-sided PTRCTs,<sup>14</sup> whereas the others did not detect a difference in the outcomes. Various features need to be examined to understand the difference in pathogenesis between articular- and bursal-sided PTRCTs.

Clinical features of adhesive capsulitis and PTRCTs may overlap each other and some cases with PTRCT demonstrated severe shoulder stiffness.<sup>5</sup> The main finding of adhesive capsulitis is thickening of the CHL and the RI.<sup>21</sup> The release of these structures is considered a valuable procedure in mobilizing the joint.<sup>12</sup> It is possible that the CHL and the RI were affected in cases of PTRCT as well. Preoperative MRI demonstrated fibrosis of the RI in 61% of the shoulders with a PTRCT, and patients with articular-sided PTRCTs were more likely to be affected than those with bursal-sided PTRCTs (70% vs. 35%) in the current study.

Fibrosis in the RI may cause a loss of motion. In a cadaveric study, Harryman et al<sup>7</sup> reported that sectioning of the RI increased the ROM of the shoulder, especially in flexion, extension, adduction,

**Table II**  
Pre- and postoperative shoulder scores

	Total	Group A	Group B	<i>P</i> value (unpaired <i>t</i> -test)
Preoperative ASES	44.0 ± 15.3	40.8 ± 15.3	40.8 ± 15.6	.130
Postoperative ASES	86.6 ± 6.9	86.2 ± 7.7	87.4 ± 5.6	.282
<i>P</i> value (paired <i>t</i> -test)	<.001	<.001	<.001	
Preoperative UCLA	16.6 ± 3.0	16.3 ± 3.1	16.9 ± 3.0	.086
Postoperative UCLA	30.4 ± 2.4	30.5 ± 2.8	30.3 ± 1.7	.368
<i>P</i> value (paired <i>t</i> -test)	<.001	<.001	<.001	
Preoperative JOA	64.2 ± 10.3	63.1 ± 9.6	64.8 ± 11.3	.291
Postoperative JOA	84.3 ± 7.1	83.4 ± 7.4	85.6 ± 6.9	.145
<i>P</i> value (paired <i>t</i> -test)	<.001	<.001	<.001	

ASES, American Shoulder and Elbow Surgeons Score; JOA, Japanese Orthopaedic Association score; UCLA, University of California, Los Angeles Shoulder Rating Scale. Data are expressed as mean ± standard deviation.

**Table III**  
Pre- and postoperative active shoulder range of motion

	Total	Group A	Group B	P value (unpaired t-test)
Preoperative active forward flexion	130.9 ± 21.2	131 ± 20.4	129.0 ± 22.9	.441
Postoperative active forward flexion	140.9 ± 14.1	141.3 ± 11.5	140.5 ± 18.7	.425
P value (paired t-test)	.001	.002	.047	
Preoperative active abduction	98.7 ± 26.5	96.8 ± 27.1	100.7 ± 26.8	.307
Postoperative active abduction	117.5 ± 21.9	119.1 ± 21.7	114.7 ± 23.4	.258
P value (paired t-test)	<.001	<.001	.036	
Preoperative external rotation	31.5 ± 23.1	27.7 ± 20.8	35.9 ± 26.7	.111
Postoperative external rotation	27.4 ± 17.6	25.5 ± 15.1	30.4 ± 1.7	.183
P value (paired t-test)	.145	.206	.258	

Data are expressed in degrees, mean ± standard deviation.

and external rotation. In the current study, the loss in ROM was not apparent preoperatively, but glenohumeral movement evaluated on plain radiographs with arm elevation was more limited in patients with fibrosis than in patients without fibrosis. The glenohumeral joint in patients with fibrosis may be limited in the other directions as well, but only elevation was evaluated using plain radiographs with arm elevation because the glenohumeral position could be easily evaluated using the relationship between the anatomical landmarks.<sup>8</sup> Regarding MRI findings, a partial tear and stiffness are not 2 separate, unrelated findings, particularly when the tear is articular-sided.

Several studies have investigated acromial spurs.<sup>11,14,19,20</sup> Ozaki et al<sup>20</sup> reported in their cadaver study that pathologic and structural changes on the undersurface of the acromion were associated with bursal-sided rotator cuff tears, whereas its undersurface with articular-sided tears was undamaged. Kim et al<sup>14</sup> showed that bursal-sided tears had a higher incidence of impingement sign on the preoperative examination with a high prevalence of protruded spur on the acromion undersurface and an improvement after surgery. However, they also reported that the preoperative incidence of the Neer impingement sign<sup>18</sup> was greater than 50% even in the articular-sided tears without protruded spurs. The Neer impingement sign can be nonspecific and especially unreliable in cases where slight shoulder stiffness exists. Slight stiffness caused by fibrosis in the RI could relate to the impingement symptoms in their cases with articular-sided tears. The problem with bursal-sided tears may likely be localized around the tear where the bony spurs make contact during arm elevation.

Some limitations should be acknowledged in the current study. We used an open surgery. All the articular side tears needed to be confirmed by exploring intact bursal floor. There may be a bias of overseen other pathologies that could have influenced the result on MRI without arthroscopic diagnosis. We were not able to show how to treat stiffness. If stiffness existed around the joint, we manipulated the joint and released the adhesion in the subacromial bursa before repairing the torn tendon. Although we did not perform the preemptive extensive RI release as Kim et al<sup>12</sup> described, the RI

might be released during intraoperative manipulation in some of the cases. Postoperative stiffness decreased over a 2-year course after surgery, and we cannot determine whether the stiffness required surgical intervention during repair of the rotator cuff. In the current study, 1 case with a bursal-sided tear and 2 cases with an articular-sided tear had retear, and there was no difference in the retear rate between bursal- and articular-sided tears. This was not compatible with a past report, which showed a higher failure rate in bursal-sided tears.<sup>14</sup> How joint stiffness affects tendon healing still needs to be examined.

## Conclusions

Both articular- and bursal-sided PTRCTs showed significant functional improvements after surgery. The articular-sided tears had a lower incidence of an acromial spur but had a higher incidence of fibrosis in the RI, which led to a limitation in glenohumeral motion.

## Disclaimer

All the patients were treated in Katsuya Nobuhara's private hospital. Any other financial payments or other benefits from any commercial entity related to the subject of this article were not received with regard to the content/research work discussed in the manuscript.

The 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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**Table IV**  
Magnetic resonance imaging and plain radiographic findings

	Group A (n = 56)	Group B (n = 20)	P value ( $\chi^2$ test)
Tendon swelling	27 (48.2)	5 (25.0)	.177
RI fibrosis	39 (69.6)	7 (35.0)	.006
Capsule thickening	20 (35.7)	5 (25.0)	.069
Cyst	19 (33.9)	11 (55.0)	.159
Acromial spur	4 (7.1)	7 (35.0)	.008

RI, rotator interval.

Data are expressed as n (%).

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