Risk factors for retear of large/massive rotator cuff tears after arthroscopic surgery: an analysis of tearing patterns

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Abstract

Background: Previous studies have evaluated the risk factors for retear of large/massive rotator cuff tears (RCTs) that were treated arthroscopically; however, most studies did not evaluate tear patterns. The present study hypothesized that postoperative risk factors are affected by the tearing patterns in large/massive cuff tears in patients undergoing arthroscopic rotator cuff repair (ARCR).

Methods: One hundred fifty patients with large/massive cuff tears underwent ARCR at our institution. Of these, 102 patients were enrolled in this study, with an average symptom duration of 36.3 ± 43.9 months and average age of 63.9 ± 9.4 years. According to the arthroscopic findings and magnetic resonance imaging (MRI), the 102 patients were divided into three groups based on the tendon location: anterosuperior tears (N = 59, group AS), posterosuperior tears (N = 21, group PS), and anteroposterior-extending tears (N = 22, group APE). Functional outcome was evaluated preoperatively and postoperatively using the Japanese Orthopedic Association (JOA) score and the University of California, Los Angeles (UCLA) score. Retear was evaluated with MRI at a minimum of 1 year after surgery, using Sugaya’s classification; Types IV and V were considered postoperative retears. Factors affecting postoperative retear were examined with univariate and multivariate analyses.

Results: JOA/UCLA scores significantly improved postoperatively in the three groups (P < 0.01 for all). Postoperative retear was noted in 26 of 102 patients (25.5%) in this series: 10 patients in group AS (16.9%), 9 in group PS (42.9%), and 7 in group APE (31.8%). The retear rate was significantly higher in group PS than in the other two groups (P = 0.02). Multivariate analysis showed that decreased preoperative active external rotation range was a unique risk factor for postoperative retear in the PS and APE groups (95% confidence interval: 0.02–0.18, cut-off value: 25°, with an area under the curve of 0.90, P = 0.0025).

Conclusions: Although multivariate analysis failed to detect significant risk factor for retear in patients with anterosuperior large/massive cuff tears who undergo ARCR, it demonstrated that active external rotation less than 25° before surgery is a significant risk factor in those with posterosuperior large/massive tears. This study may help surgeons understand the results of arthroscopic surgery in patients with large/massive tears.

Keywords: Tearing pattern, Arthroscopic rotator cuff repair, Postoperative retear
Background
Arthroscopic rotator cuff repair (ARCR) produces good clinical results, although retear is a significant concern after surgery. Compared with small- and middle-sized rotator cuff tears (RCTs), the retear rate is relatively high in large and massive tears, even if the tear is completely covered during surgery [1–4]; some authors reported that the retear rate was 40–94% in these tears [3–6].

A number of studies have consistently sought to determine the risk factors for postoperative retear in large and massive cuff tears. For example, a recent systematic review reported that the risk factors for retear after ARCR in RCTs included age, tear size, fatty degeneration (FD), the number of tendons involved, acromiohumeral interval, surgical technique, and bone mineral density [7]. One study used a multivariate regression analysis to demonstrate that preoperative FD of the infraspinatus was the most independent predictor of retear in large and massive RCTs in patients who underwent ARCR [8]. Kim et al. [9] reported that the extent of retraction was importantly associated with retear after surgery.

Based on the tendon location involved, large and massive RCTs are classified into three types: anterosuperior tears, posterosuperior tears, and anteroposterior-extending tears. However, previous studies collectively examined large and massive RCTs without sub-dividing the tear pattern as described above. Therefore, the purposes of the present study were to evaluate risk factors affecting postoperative retear in each group. We hypothesized that in large and massive tears, the risk factors for postoperative retear differ among the groups, when sub-divided by the tear pattern.

Methods
The patients provided informed consent, and this retrospective study was approved by the authorized institutional review board at the Ethical Committee of Kurume University (#12333).

Patients
Between April 2005 and August 2013, 150 patients with cuff tears defined as large or massive [6] underwent ARCR in our institution. The inclusion criteria were (1) individuals who had large or massive rotator cuff tears that repaired completely during surgery, (2) those who were available for evaluation of function and magnetic resonance imaging (MRI) preoperatively and at a minimum of 1 year after surgery, and (3) those who underwent an appointed postoperative rehabilitation program. The exclusion criteria were (1) individuals with advanced glenohumeral arthritis or fractures around the shoulder, (2) those who underwent open repair, partial repair, revision surgeries, or any previous shoulder surgery, (3) those who had MRI film without the “Scapula - Y” view on the sagittal-oblique plane, (4) those who refused to undergo postoperative clinical assessment and MRI, and (5) those who had preoperative stiffness that showed less than 100° in passive elevation or 10° in external rotation [10]. Consequently, 102 patients were enrolled in this study.

According to the arthroscopic and MRI findings, the 102 patients were divided into three groups based on the tendon location: anterosuperior tears [11] in the subscapularis and the supraspinatus, in which the tear extended from the lesser tuberosity to the superior facet (N = 59, group AS); posterosuperior tears in the supraspinatus and the infraspinatus/teres minor, in which the tear extended from the superior facet to the middle or inferior facet (N = 21, group PS); and anteroposterior-extending tears, in which the tear extended from the lesser tuberosity to the middle or inferior facet (N = 22, group APE). When large or massive tears were evaluated according to the classification of DeOrio and Cofield [12], there were 56 patients with a large tear (94.9%) and 3 patients with a massive tear (5.1%) in Group AS, 19 patients with a large tear (90.5%) and 3 patients with a massive tear (9.5%) in group PS, and 15 patients with a large tear (58.2%) and 7 patients with massive tears (31.8%) in group APE. There was no statistical difference in demographic data among the three groups, except for the incidence of hypertension and distribution of massive tears. Details of the patients’ characteristics are shown in Table 1.

Surgical procedure
Arthroscopic surgery was indicated when successful non-operative treatment, such as anti-inflammatory medications, physical therapy, subacromial or glenohumeral injections of corticosteroids or hyaluronic acid, or activity modification, was not achieved within 3 months of the first visit.

ARCR was conducted with the patient in the beach chair position under general anesthesia. At first, a glenohumeral examination was performed through a posterior portal and then transferred to the subacromial bursa. After making a lateral portal, we identified the ruptured tendon edge and evaluated its flexibility by grasping the tendon and reducing the edge to the original footprint. Capsular release was conducted from the anterior, anterolateral, or posterolateral portal; if needed, tenotomy of the long head biceps was performed. The method of cuff repair was selected based on the operative findings, tendon mobility, and tear condition with a single-row, double-row, or suture bridge technique (Table 1).

Rehabilitation protocol
Postoperatively, the patient’s arm was fixed into a sling with an abduction pillow. Passive range of motion (ROM) exercises of the shoulder were conducted 4 days after surgery. Active ROM exercises and isometric exercise were
started 6 weeks after surgery, and isotonic muscle strengthening exercises began 12 weeks after surgery.

**Evaluation of functional outcome**

Functional outcome was evaluated preoperatively and postoperatively. The visual analog scale was used to measure pain (rest, night, and motion), the range of active motion was measured with a goniometer, muscle strength was measured with a handheld dynamometer (Micro FET2, Hoggan Health Industry, West Jordan, UT, USA), Japanese Orthopedic Association (JOA) score, and the University of California, Los Angeles (UCLA) score. An independent physiotherapist who was blinded to this study performed physical tests.

**Evaluation of structural outcome**

Acromiohumeral distance was evaluated, using the Oizumi classification [13], on plain radiographs that were taken with the patients standing and their arm held in a neutral position.

Tear length and width were measured on MRI using the protocol of Davidson et al. [14] FD of the supraspinatus, infraspinatus/teres minor, and subscapularis were evaluated on the most lateral oblique sagittal T2-weighted MRI with the scapular body (the “Y-view”) [15, 16], using both Goutallier classification system and ImageJ [14]. The infraspinatus and teres minor were combined into a single measurement, because their borderline was not always clearly confirmed [17]. Muscle atrophy (MA) was evaluated using the relative ratio of the cross-sectional area of the subscapularis, supraspinatus, and infraspinatus/teres minor muscle belly to that of the supraspinatus fossa. For this measurement, we used ImageJ using the protocol of Nakamura et al. [18]

Retear of the rotator cuff was evaluated using Sugaya’s classification [19]: type I, sufficient thickness and evenly low intensity; type II, sufficient thickness and heterogeneous high intensity; type III, repaired cuff tear that kept its continuity but had insufficient thickness; type IV, minor discontinuity and the torn area was minimal in the sagittal plane; and type V, major discontinuity and torn area spread in the sagittal plane. Patients with types IV and V were admitted with postoperative retear [20]. An experienced, orthopedics-trained radiologist who was blinded to the study reviewed these images.

**Statistical analysis**

The statistical analysis was performed with JMP11 software (SAS, Cary, NC, USA). The Kruskal-Wallis test or χ² test was used to compare the continuous or nominal variables in demographics and functional and structural outcomes among the three groups. A Wilcoxon test was used for comparing the preoperative and postoperative functional outcomes in each group. Spearman’s ρ was calculated to observe the nonparametric correlation of structural outcomes and clinical outcomes. The correlation between the data evaluated with Goutallier’s classification and ImageJ was examined with Spearman’s correlation coefficient. For identifying the risk factors for retear after surgery, univariate analysis was first performed in each

Table 1 Patient demographic data

|                        | Group AS (N = 59)       | Group PS (N = 21)       | Group APE (N = 22)      |
|------------------------|-------------------------|-------------------------|-------------------------|
| Age (years)            | 62.8 ± 10.6 (39–82)     | 64.9 ± 8.8 (43–78)      | 66.4 ± 5.8 (54–76)      |
| Sex: male (%)/female (%) | 30 (50.1%)/29 (49.1%)   | 13 (62%)/8 (38%)        | 13 (59%)/9 (41%)        |
| Side: right (%)/left (%) | 43 (72.9%)/16 (27.1%)  | 11 (52.4%)/10 (47.6%)  | 19 (86.4%)/3 (13.6%)   |
| Symptom duration (week) | 30.8 ± 30.3 (4–156)    | 53.9 ± 69.9 (4–275)    | 34.1 ± 40.9 (2–150)    |
| Trauma (%)             | 34 (57.6%)              | 16 (76.2%)             | 12 (54.5%)              |
| Complication           |                         |                         |                         |
| Diabetes Mellitus (%)  | 7 (11.9%)               | 16 (76.2%)             | 2 (9.0%)                |
| Hypertension (%)       | 16 (27.1%)              | * 3 (14.3%)            | 10 (45.5%)              |
| De Orio and Cofield’s classification |                  |                         |                         |
| Large (%)              | 56 (94.9%)              | 19 (90.5%)             | 15 (58.2%)              |
| Massive (%)            | 3 (5.1%)                | 2 (9.5%)               | * 7 (31.8%)             |
| Surgical procedure     |                         |                         |                         |
| Suture bridge (%)      | 40 (67.8%)              | 14 (66.7%)             | 17 (77.3%)              |
| Simple row (%)         | 14 (23.7%)              | 4 (19.0%)              | 2 (9.0%)                |
| Double row (%)         | 5 (8.5%)                | 3 (14.3%)              | 3 (13.7%)               |
| LHB tenotomy (%)       | 29 (49.2%)              | 6 (28.6%)*             | 13 (59.0%)              |

Data are presented as mean ± standard deviation unless otherwise indicated. LHB, long head biceps

*Statistically significant (P < .05) among the three groups
Results

Preoperative and postoperative functional outcome

Preoperative JOA scores significantly improved from 57.9 ± 19.9 points preoperatively to 87.4 ± 10.0 points postoperatively in group AS, from 56.9 ± 15.4 points to 89.9 ± 6.6 points in group PS, and from 61.7 ± 7.5 points to 83.0 ± 11.4 points in group APE. Consistently, UCLA scores significantly improved from 18.2 ± 5.0 points preoperatively to 28.3 ± 7.2 points postoperatively in Group AS, from 17 ± 4.7 points to 29.4 ± 3.8 points in group PS, and from 15.9 ± 4.0 points to 28.3 ± 5.9 points in group APE. There were no significant differences of postoperative JOA/UCLA scores among the groups. The clinical outcomes scores are shown in Table 2.

Rest, motion, and night pain levels in the three groups were significantly improved postoperatively, except for rest pain in group APE, but it tended to have significance (P = 0.06). Most of the parameters in ROM and muscle strength in the three groups significantly improved or tended to have statistical significance after surgery.

Preoperative structural outcome

In the Oizumi classification, Class 0 was observed in 19, 6, and 3 patients; Class I in 30, 7, and 8 patients; Class II in 8, 7, and 4 patients, and Class III in 2, 1, and 5 patients in Group AS, PS, and APE, respectively. Only two patients in group APE had Class IV.

The average retraction of the torn tendon was 29.1 ± 6.2 mm in group AS, 31.2 ± 10.4 mm in group PS, and 37.1 ± 8.7 mm in group APE. The extent of the retraction was significantly larger in group PS and APE than in group AS (P = 0.002).

The average MA in group AS was 246.5 ± 83.5% in the subscapularis, 76.2 ± 19.8% in the supraspinatus, and 220 ± 51.9% in the infraspinatus/teres minor. For group PS, MA was 220.3 ± 67.4% in the subscapularis, 78.9 ± 18.6% in the supraspinatus, and 183.4 ± 38.5% in the infraspinatus/teres minor; for group APE, MA was 252.1 ± 82.4% in the subscapularis, 71.3 ± 16% in the supraspinatus, and 187.4 ± 54.8% in the infraspinatus/teres minor.

The average FD, measured with Image J, for group AS was 5.35 ± 8.25% in the subscapularis, 7.84 ± 10.24% in the supraspinatus, and 3.35 ± 4.92% in the infraspinatus/teres minor; for group PS, FD was 3.5 ± 5.2% in the subscapularis, 11.42 ± 10.15% in the supraspinatus, and 8.52 ± 9.23% in the infraspinatus/teres minor; and for group APE, FD was 6.0 ± 7.23% in the subscapularis, 12.2 ± 9.7% in the supraspinatus, and 6.05 ± 5.2% in the infraspinatus/teres minor.

A low-grade Goutallier stage (stages 0 to 2) was seen in over 80% patients in all three groups. A high-grade Goutallier stage (stages 3 and 4) in group AS was seen in the subscapularis of two patients, supraspinatus of nine patients, and infraspinatus/teres minor of two patients; in Group PS, in the subscapularis of no patients, supraspinatus of three patients, and infraspinatus/teres minor of three patients. In Group APE, a high-grade Goutallier stage was seen in the subscapularis of two patients, supraspinatus of five patients, and infraspinatus/teres minor of three patients. The global fatty degeneration index (GFDI) was 1.02 ± 0.62 in Group AS, 1.36 ± 0.5 in group PS, and 1.29 ± 0.5 in group APE. There was no significant difference among the three groups in GFDI (Table 3).

Postoperative structural outcome

Postoperative retear (Sugaya types IV and V) was noted in 26 of 102 patients (25.5%) in this series: 10 patients in group AS (16.9%), 9 patients in group PS (42.9%), and 7 patients in group APE (31.8%). The retear rate was

| Table 2 | Preoperative and postoperative clinical outcome in three groups |
|---------|-----------------------------------------------------------------|
|         | Group AS (N = 59) | Group PS (N = 21) | Group APE (N = 22) |
| JOA score | Preoperative | 57.9 ± 19.9 | 56.9 ± 15.4 | 61.7 ± 7.5 |
|          | Postoperative | 87.4 ± 10.0 | 89.9 ± 6.6 | 83.0 ± 11.4 |
|          | P value       | < 0.001      | < 0.001     | < 0.001    |
| UCLA score | Preoperative | 18.2 ± 5.0 | 17 ± 4.7 | 15.9 ± 4.0 |
|           | Postoperative | 28.3 ± 7.2 | 29.4 ± 3.8 | 28.3 ± 5.9 |
|           | P value       | < 0.001      | < 0.001     | < 0.001    |

JOA: Japanese Orthopedic Association, UCLA: University of California, Los Angeles
significantly higher in group PS than in groups AS and APE ($P = 0.02$) (Table 4).

**Surgical technique and postoperative retear**

Single-row technique was performed in 20 patients: 14 in group AS; 4 in group PS; 2 in group APE. Postoperative retear occurred in 8 patients (40.0%): 4 in group AS (28.6%); 3 in group PS (75.0%); 1 in group APE (50.0%).

Double-row technique was performed in 11 patients: 5 in group AS; 3 in group PS; 3 in group APE. Postoperative retear occurred in 2 patients (18.2%): none in group AS (0.0%); 2 in group PS (66.7%); none in group APE (0.0%). Details are shown in Table 5.

**Table 3** Preoperative structural outcome in three groups

| Ozumi classification | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------------|------------------|------------------|-------------------|
| Grade O              | 19 (32.2%)       | 6 (28.6%)        | 3 (13.6%)         |
| Grade I              | 30 (50.8%)       | 7 (33.3%)        | 8 (36.4%)         |
| Grade II             | 8 (13.6%)        | 7 (33.3%)        | 4 (18.2%)         |
| Grade III            | 2 (3.4%)         | 1 (4.8%)         | 5 (22.7%)         |
| Grade IV             | 0 (0%)           | 0 (0%)           | 2 (9.1%)          |
| Retraction (mm)      | 29.1 ± 6.2       | 31.2 ± 10.4      | 37.1 ± 8.7        |
| Width (mm)           | 34.7 ± 6.0       | 37.2 ± 10.4      | 45.0 ± 9.8        |

**Muscle atrophy (%)**

|                | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------|------------------|------------------|-------------------|
| SSC            | 246.5 ± 83.5     | 220.3 ± 67.4     | 252.1 ± 82.4      |
| SSP            | 76.2 ± 19.8      | 78.9 ± 18.6      | 71.3 ± 16         |
| ISP/TM         | 220.4 ± 51.9     | 183.4 ± 38.5     | 187.4 ± 54.8      |

**Fatty degeneration (%)**

|                | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------|------------------|------------------|-------------------|
| SSC            | 5.35 ± 8.25      | 3.5 ± 5.20       | 6.0 ± 7.23        |
| SSP            | 7.84 ± 10.24     | 11.42 ± 10.15    | 12.2 ± 9.7        |
| ISP/IM         | 3.35 ± 4.92      | 8.52 ± 9.23      | 6.05 ± 5.2        |

**Goutallier classification SSC**

|                | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------|------------------|------------------|-------------------|
| Stage 0        | 24 (40.7%)       | 9 (42.9%)        | 6 (27.3%)         |
| Stage 1        | 26 (44.1%)       | 8 (38.1%)        | 5 (22.7%)         |
| Stage 2        | 7 (11.9%)        | 4 (19.0%)        | 9 (40.9%)         |
| Stage 3        | 2 (3.4%)         | 0 (0%)           | 1 (4.5%)          |
| Stage 4        | 0 (0%)           | 0 (0%)           | 1 (4.5%)          |

**Goutallier classification SSP**

|                | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------|------------------|------------------|-------------------|
| Stage 0        | 13 (22%)         | 2 (9.5%)         | 2 (9.0%)          |
| Stage 1        | 16 (27.1%)       | 5 (23.8%)        | 5 (22.7%)         |
| Stage 2        | 21 (35.6%)       | 11 (52.4%)       | 10 (45.5%)        |
| Stage 3        | 7 (11.9%)        | 2 (9.5%)         | 1 (4.5%)          |
| Stage 4        | 2 (3.4%)         | 1 (4.8%)         | 4 (18.2%)         |

**Goutallier classification ISP/TM**

|                | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------|------------------|------------------|-------------------|
| Stage 0        | 28 (47.5%)       | 5 (22.7%)        | 5 (22.7%)         |
| Stage 1        | 26 (44.1%)       | 6 (27.3%)        | 9 (40.9%)         |
| Stage 2        | 3 (5.0%)         | 7 (31.8%)        | 5 (22.7%)         |
| Stage 3        | 2 (3.4%)         | 3 (13.6%)        | 1 (4.5%)          |
| Stage 4        | 0 (0%)           | 0 (0%)           | 2 (9.0%)          |

**GFDI**

|                | Group AS (N = 59) | Group PS (N = 21) | Group API (N = 22) |
|----------------|------------------|------------------|-------------------|
| SSC            | 1.02 ± 0.62      | 1.36 ± 0.5       | 1.29 ± 0.5        |

**Note:** SSC subscapularis, SSP supraspinatus, ISP/TM infraspinatus/teres minor, GFDI global fatty degeneration index.
Risk factors affecting postoperative retear

First, various parameters were evaluated to determine the risk factors for retear after surgery, using univariate analysis. Retraction \((P = 0.039)\), width \((P = 0.0023)\), FD of the supraspinatus \((P = 0.0043)\), the Goutallier classification of the supraspinatus \((P = 0.001)\), and GFDI \((P = 0.008)\) were significant risk factors in group AS: Preoperative active external rotation range \((P = 0.001)\), preoperative muscle strength of flexion \((P = 0.02)\), and FD of the infraspinatus/teres minor \((P = 0.048)\) were evaluated using ImageJ in group PS. FD of the supraspinatus \((P = 0.002)\) and the infraspinatus/teres minor \((P = 0.0074)\) were evaluated using ImageJ and GFDI \((P = 0.0123)\) in group APE. The Goutallier stage of the infraspinatus in group PS and APE was not a significant risk factor, but it tended to have statistical significance (Table 6).

Next, multivariate analysis using stepwise methods was performed. Preoperative external rotation range was the only risk factor for postoperative retear in groups PS and APE \((P = 0.014 \text{ and } 0.016, \text{ respectively})\). For the prediction of postoperative retear, receiver operating characteristic (ROC) curve analysis demonstrated that the cut-off value in the preoperative external rotation range was 25°, showing that the retear risk increased 2.12-fold as the preoperative external rotation range decreased by 5° (Fig. 1).

Table 5 Univariate analysis in three groups

|          | Group AS (N = 59) | Group PS (N = 21) | Group APE (N = 22) | Total (N = 102) |
|----------|------------------|------------------|-------------------|-----------------|
| Suture bridge | 55 (77.5%)       | 16 (22.5%)       | 71                |
| Group AS   | 34 (85.0%)       | 6 (15.0%)        | 40                |
| Group PS   | 10 (71.4%)       | 4 (28.6%)        | 14                |
| Group APE  | 11 (64.7%)       | 6 (35.3%)        | 17                |
| Single row | 12 (60.0%)       | 8 (40.0%)        | 20                |
| Group AS   | 10 (71.4%)       | 4 (28.6%)        | 14                |
| Group PS   | 1 (25.0%)        | 3 (75.0%)        | 4                 |
| Group APE  | 1 (50.0%)        | 1 (50.0%)        | 2                 |
| Double row | 9 (81.8%)        | 2 (18.2%)        | 11                |
| Group AS   | 5 (100%)         | 0 (0%)           | 5                 |
| Group PS   | 1 (33.3%)        | 2 (66.7%)        | 3                 |
| Group APE  | 3 (100%)         | 0 (0%)           | 3                 |

Correlation between active external rotation range and its related variables

Since multivariate analysis showed that active external rotation range (AERR) is a unique risk factor for postoperative retear in groups PS and APE, we further evaluated the correlation between AERR and its related variables in these groups. There was statistical significance between AERR and FD, using ImageJ \((r = -0.36, P = 0.04)\). External rotation strength (ERS) was not significant, but it showed a trend \((P = 0.06)\). For FD of the infraspinatus, statistical significance was seen between the evaluation methods, using the Goutallier classification and ImageJ \((r = 0.82, P < 0.0001)\) (Table 7).

Discussion

The present study investigated the risk factors for retear after ARCR in large and massive cuff tears, dividing these tears into three groups (i.e., group AS, PS, and APE). Although univariate analysis revealed that the groups had different characteristics, step-wise multivariate analysis showed that preoperative, decreased active external rotation in group PS and APE was a unique risk factor for retear after surgery, with a cut-off value of 25°. To our knowledge, such data have not been reported.

Previous studies that used multivariate analysis demonstrated that the Goutallier stage of the infraspinatus is a risk factor for postoperative retear in large and massive tears [8, 21]. In the present study, the Goutallier stage of the infraspinatus in Group PS and APE was a significant factor for postoperative retear in univariate analysis, but not in multivariate analysis. The average Goutallier stage of the infraspinatus was relatively low (0.9) in the present study, compared with 1.2 in a study by Oh et al. [8] and 2.1 in a study by Chung et al. [21] Thus, this may partly explain why the Goutallier stage of the infraspinatus did not reach statistical significance in the present study.

FD of the infraspinatus caused postoperative retear and led to limitations of external rotation [22]. Loss of active external rotation is related to tears in the infraspinatus and teres minor [23]. In the present study, there was a significant correlation between the decrease of active external rotation range and FD, evaluated with ImageJ. Taken together, these results supported our data that decreased
active external range is significantly associated with post-operative retear in patients who undergo ARCR for treatment of large or massive tears.

In the present study, multivariate analysis showed that decreased active external range before surgery was a risk factor for retear in group PS and APE. The preoperative characteristics in these two groups revealed a similar tendency, except for distribution of large or massive tears. Thus, less fatty involvement of the subscapularis in the two groups may have contributed to the similar data.

In AS cuff tears, the retear rate after surgery was reported to be 6–18% [24–26]. Consistent with these studies, our study found 10 postoperative retear cases (16.9%, N = 59 cases) in group AS. A previous study found that the Goutallier stage of the subscapularis was associated with postoperative retear in AS cuff tears [25], while the Goutallier stage of the supraspinatus was responsible for retear after ARCR in the present study. A high-grade Goutallier stage was found in the supraspinatus in nine cases (15.3%) and in the subscapularis in two cases (3.4%) in group AS. Thus, this might have affected our data. Although univariate analysis in the present study showed a certain risk for postoperative retear in anteroposterior cuff tears, no significant factors were noted in the multivariate analysis. Studies on these points are now underway at our institution.

Although most tears occurred in the supraspinatus tendon, tearing in this tendon did not influence retear after surgery in group PS and APE. Mochizuki et al. [27, 28] reported that the footprint of the supraspinatus tendon on the greater tuberosity is much smaller than previously believed, and this area of the greater tuberosity is actually occupied by a substantial amount of the infraspinatus tendon. This may mean that during surgery, infraspinatus tendon repair rather than supraspinatus tendon repair may be closely associated not only with footprint coverage at the greater tuberosity, but also with retear after surgery at the site.

The limitations of the present study were its retrospective cohort, short-term follow up, and small sample size, especially in group PS and APE in comparison with group AS. Further studies with longer follow-up and larger cohorts are needed to address these limitations. However, the strength of this study was that we clearly demonstrated that decreased active external range is a risk factor for large and massive tears, especially in PS and APE cuff tears.

**Conclusions**

Although multivariate analysis failed to detect significant risk factor for retear in patients with anterosuperior large/massive cuff tears who undergo ARCR, it demonstrated

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### Table 6: Correlation between active external rotation range (AERR) and its related variables

| Group AS (N = 59) | P value | Group PS (N = 21) | P value | Group APE (N = 22) | P value |
|------------------|---------|------------------|---------|-------------------|---------|
| Retraction       | 0.039   | Preoperative ER  | 0.001   | SSP FD            | 0.002   |
| Width            | 0.0023  | Preoperative FLEX MS | 0.02   | ISP/TM FD        | 0.0074  |
| SSP FD           | 0.0043  | ISP/TM FD        | 0.048   | GFDI              | 0.012   |
| Goutallier SSP   | 0.001   | *Goutallier ISP  | 0.08    | *Goutallier ISP  | 0.068   |
| GFDI             | 0.0084  |                   |         |                   |         |

*There were no significant differences or trends

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### Table 7: Correlation between active external rotation range (AERR) and its related variables

| Correlation coefficient (r) | P Value |
|-----------------------------|---------|
| Preoperative ER             | 0.3     | 0.06   |
| Preoperative ER MS          | 0.36    | 0.04   |
| ISP FD                      | 0.154   | 0.37   |
| Preoperative ER MS          | 0.0154  | 0.93   |
| ISP FD                      | 0.82    | < 0.001|
| Goutallier ISP              | 0.05    | 0.77   |

*ER external rotation, MS muscle strength, ISP infraspinatus*
that active external rotation less than 25° before surgery is a significant risk factor in those with posterosuperior large/massive tears. This study may help surgeons understand the results of arthroscopic surgery in patients with large/massive tears.

Abbreviations
AER: Active external rotation range; ARC: Arthroscopic rotator cuff repair; AUC: Area under the curve; ERS: External rotation strength; FD: Fatty degeneration; GFDI: The Global Fatty Degeneration Index; JOA: Japanese Orthopedic Association; MA: Muscle atrophy; MRI: Magnetic resonance imaging; RCT: Rotator cuff tears; ROC: Receiver-operating characteristic; ROM: Range of motion; UCLA: The University of California, Los Angeles

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Availability of data and materials
All data supporting the results reported in a published article can be found in the reference section.

Authors’ contributions
HS planned the study design, data acquisition, analysis, and interpretation of data, and wrote the manuscript. MG supervised the study design, data analysis, and manuscript writing. YM, TO, and NS supervised the study design and data analysis. HH and HN carried out data acquisition and analysis. TK carried out the statistical data analysis. All authors read and approved the final manuscript.

Ethics approval and consent to participate
This retrospective study was approved by the authorized institutional review board at the Ethical Committee of Kurume University (approval no. 12333).

Consent for publication
All consents to publish from the patients took part in this study were obtained.

Competing interests
The authors declare that they have no competing interests.

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References
1. Berth A, Neumann W, Awiszus F, Pap G. Massive rotator cuff tears: functional outcome after debridement or arthroscopic partial repair. J Orthop Traumatol. 2010;11:13–20.
2. Burkhart SS, Barth JR, Richards DP, Zlatkin MB, Larsen M. Arthroscopic repair of massive rotator cuff tears with stage 3 and 4 fatty degeneration. Arthroscopy. 2007;23:347–54.
3. Burkhart SS, Danacoea SM, Pearce CE Jr. Arthroscopic rotator cuff repair: Analysis of results by tear size and by repair technique-marg convergence versus direct tendon-to-bone repair. Arthroscopy. 2001;17:905–12.
4. Galatz LM, Ball CM, Teeley SA, Middleton WD, Yamaguchi K. The outcome and repair integrity of completely arthroscopically repaired large and massive rotator cuff tears. J Bone Joint Surg Am. 2004;86-A:219–24.
5. Lo IK, Burkhart SS. Arthroscopic revision of failed rotator cuff repairs: technique and results. Arthroscopy. 2004;20:250–67.
6. Yoo JC, Ahn JH, Koh KH, Lim KS. Rotator cuff integrity after arthroscopic repair for large tears with less-than-optimal footprint coverage. Arthroscopy. 2009;25:1093–100.
7. Saccamanno MF, Siragusa G, Cazzato G, Donati F, Randelli P, Milano G. Prognostic factors influencing the outcome of rotator cuff repair: a systematic review. Knee Surg Sports Traumatol Arthosc. 2015; https://doi.org/10.1007/s00167-015-3700-y.
8. Oh JH, Kim SH, Ji HM, Jo KH, Bin SW, Gong HS. Prognostic factors affecting anatomic outcome of rotator cuff repair and correlation with functional outcome. Arthroscopy. 2009;25:30–9.
9. Kim JR, Cho YS, Ryu KJ, Kim HJ. Clinical and radiographic outcomes after arthroscopic repair of massive rotator cuff tears using a suture bridge technique: assessment of repair integrity on magnetic resonance imaging. Am J Sports Med. 2012;40:786–93.
10. Ueda Y, Sugaya H, Takahashi N, Matsuki K, Kawai N, Tokai M, et al. Rotator cuff lesions in patients with stiff shoulders: a prospective analysis of 379 shoulders. J Bone Joint Surg Am. 2015;97:1233–7.
11. Warner JJ, Higgins L, Parsons IM, Dowdy P. Diagnosis and treatment of anterosuperior rotator cuff tears. J Shoulder Elbow Surg. 2001;10:37–46.
12. DeOrio JK, Cofield RH. Results of a second attempt at surgical repair of a failed initial rotator cuff repair. J Bone Joint Surg Am. 1984;66:563–7.
13. Miyoshi N, Suenaga N, Katayama K, Otsuni N, Yamaguchi H, Matsuno T. Radiological classification of glenoid deformity in rheumatoid arthritis. Int J Rheumatol. 2011;2011:239894.
14. Davidson JF, Burkhart SS, Richards DP, Campbell SE. Use of preoperative magnetic resonance imaging to predict rotator cuff tear pattern and method of repair. Arthroscopy. 2005;21:1428.
15. Mehlhado JM, Calmet J, Olona M, Esteve C, Carmin A, Perez Del Palomar L, et al. Surgically repaired massive rotator cuff tears: MRI of tendon integrity, muscle fatty degeneration, and muscle atrophy correlated with intraoperative and clinical findings. AJR Am J Roentgenol. 2005;184:1456–63.
16. Lapner PL, Jiang L, Zhang T, Athwal GS. Rotator cuff fatty infiltration and atrophy are associated with functional outcomes in asymptomatic shoulder arthropathy. Clin Orthop Relat Res. 2015;473:674–82.
17. Lee E, Choi JA, Oh JH, Ahn S, Hong SH, Chai JW, et al. Fatty degeneration of the rotator cuff muscles on pre- and postoperative CT arthrography (CTA): is the Goutallier grading system reliable? Skelet Radiol. 2013;42:1259–67.
18. Nakamura H, Gotoh M, Mitsu Y, Honda H, Ohzono H, Shimokobe H, et al. Factors affecting clinical outcome in patients with structural failure after arthroscopic rotator cuff repair. Arthroscopy. 2016;32:732–9.
19. Sugaya H, Maeda K, Matsuki K, Morishita J. Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair. A prospective outcome study. J Bone Joint Surg Am. 2007;89:953–60.
20. Choi S, Kim MK, Kim GM, Roh YH, Hwang IK, Kang H. Factors associated with clinical and structural outcomes after arthroscopic rotator cuff repair with a suture bridge technique in medium, large, and massive tears. J Shoulder Elbow Surg. 2014;23:1675–81.
21. Chung SW, Kim JY, Kim MH, Kim SH, Oh JH. Arthroscopic repair of massive rotator cuff tears: outcome and analysis of factors associated with healing failure or poor postoperative function. Am J Sports Med. 2013;41:1674–83.
22. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Acta Radiol Diagn (Stockh). 1987;28:437–42.
23. Chung SW, Song JH, Kim JY, Min JH, Kim MJ, Shin JH. Percutaneous subacromial bursa needle arthroscopy for adhesions: a prospective multicentric study. Int J Shoulder Surg. 2010;25:1428–33.
24. Schnaser E, Toussaint B, Gillespie R, Lefebvre Y, Gobezie R. Arthroscopic treatment of anteroinferior rotator cuff tears. Orthopedics. 2013;36:e194–400.
25. Macaluso E, Abarca J, Moraitis C, Boughebri O, Dib C, Leclere FM, et al. Does preoperative subacromial fatty muscle infiltration really matter in anterosuperior rotator cuff tear repair outcomes? A prospective multicentric study. Orthop Traumatol Surg Res. 2014;100:485–8.
26. Ide J, Tokiyoshi A, Hirose J, Mizuta H. Arthroscopic repair of traumatic combined rotator cuff tears involving the subscapularis tendon. J Bone Joint Surg Am. 2007;89:2378–83.
27. Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, et al. Humeral insertion of the supraspinatus and infraspinatus: New anatomical findings regarding the footprint of the rotator cuff. J Bone Joint Surg Am. 2008;90:962–9.

28. Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, et al. Humeral insertion of the supraspinatus and infraspinatus: New anatomical findings regarding the footprint of the rotator cuff. Surgical technique. J Bone Joint Surg Am. 2009;91(Suppl 2 Pt 1):1–7.