## 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


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# 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

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**Background:** High retear rates of arthroscopic massive rotator cuff repair have been reported with relatively satisfactory functional outcomes.

**Purpose:** To assess the clinical and radiological outcomes of an arthroscopic repair of massive rotator cuff tears using a suture bridge technique. We also aimed to explore the various factors that may affect retears.

**Study Design:** Case-control study; Level of evidence, 3.

**Methods:** Sixty-six patients included in the study were divided into 2 groups according to the presence of retears on magnetic resonance imaging (MRI) evaluation at a minimum of 1 year after surgery. We evaluated the visual analog scale (VAS) for pain during motions, the University of California, Los Angeles (UCLA) score, and the absolute and relative Constant scores (mean follow-up, 25.4 months).

**Results:** Twenty-eight of the 66 patients (42.4%) in this study had a retear. At the final follow-up visit, pain VAS, UCLA score, and absolute and relative Constant scores in the completely healed group were significantly superior to those in the retear group, with 2, 29.5, 76.0, and 95.2 points and 4, 26.0, 70.6, and 87.3 points, respectively ($P < .05$). From univariate analysis, the preoperative mean acromiohumeral distance, extent of retraction, and degree of fatty infiltration of the supraspinatus and infraspinatus were significantly different between the completely healed (7.83 mm, 2.97 cm, 1.74, and 0.71, respectively) and the retear group (6.36 mm, 3.97 cm, 2.54, and 2.07, respectively; $P < .05$). From multivariate logistic regression analysis, the preoperative degree of fatty infiltration of the infraspinatus and extent of retraction were the 2 most important factors associated with retears.

**Conclusion:** Arthroscopic repair of massive rotator cuff tears using a suture bridge technique has a relatively high retear rate, and these structural failures appear to have a significant difference in clinical outcomes compared with the healed group. Degree of fatty infiltration of the infraspinatus and extent of retraction are the 2 most important factors associated with a retear. Orthopaedic surgeons should predict the possibility of retear before surgery and counsel patients about their expected functional results.

**Keywords:** shoulder; massive rotator cuff tear; arthroscopic repair; suture bridge technique; retear

A retear after surgical rotator cuff repair is one of the most common complications experienced. Several factors such as the patient's age, preoperative tear size, degree of muscular atrophy, degree of fatty infiltration of the cuff muscle, surgical technique, and inappropriate rehabilitation have been demonstrated to be associated with retears of the tendon.[1,15,17,18,22,29,37] Among these factors, the size of the rotator cuff tear has been known to have a significant effect on the structural integrity after a surgical repair.[24] Surgical repair of larger tears is technically difficult and associated with a distinctly higher retear rate compared with smaller tears.[7,18,19] Although it is generally believed that there is no relationship between retear after surgical repair and poor functional outcomes, there have been several published reports suggesting that retears can be associated with poorer functional results compared with a successful structural repair, particularly in the recovery of muscle strength.[20-22,26]

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Experimental evidence suggests the holding strength of the repair plays an important role in the prevention of retears.[35] According to biomechanical comparative studies, an arthroscopic repair using a suture bridge technique has been suggested as an effective alternative that can enhance the rotator cuff tendon footprint contact area and reduce the mean pressure.[33,34] However, few studies have reported clinical outcomes and cuff integrity of arthroscopic repair using a suture bridge technique,[32,39] and arthroscopic reparability of massive rotator cuff tears has not been established, which makes it challenging for orthopaedic surgeons to make preoperative assessment of arthroscopic massive rotator cuff repair.

The purpose of this study was to assess the clinical and radiological outcomes of arthroscopic repair using a suture bridge technique for patients with massive tears. By dividing the patients into healed and retear groups according to the presence of retears on magnetic resonance imaging (MRI) evaluation at a minimum of 1 year after surgery, we intended to see the functional outcomes and to determine which preoperative factors could predict postoperative cuff integrity.

## MATERIALS AND METHODS

### Patient Selection

This study was approved by the Institutional Review Board at CHA Bundang Medical Center. The study included 94 consecutive patients from the Center for Joint Disease at our hospital, who underwent an arthroscopic repair of massive rotator cuff tears by using a suture bridge technique from June 2007 to January 2009, and the patients were followed up for at least 1 year.

Inclusion criteria were patients who (1) had a full-thickness massive rotator cuff tear larger than 5 $cm^6$ or with at least 2-tendon involvement,[19] as verified by preoperative MRI and arthroscopic findings; (2) underwent a complete arthroscopic rotator cuff repair using a suture bridge technique; and (3) were available for functional outcome assessment and MRI evaluation preoperatively and at a minimum of 1 year after surgery. Exclusion criteria were patients who had (1) arthritic change of the glenohumeral joint; (2) partial repair of the rotator cuff; (3) repair with other techniques, for example, a single-row repair or mini-open; (4) any previous shoulder surgery; and (5) refused to undergo postoperative MRI. Sixteen patients were lost during follow-up. Eight patients were excluded because they had a partial repair for a torn cuff tendon. Four patients were excluded because they refused to undergo postoperative MRI 12 months after the surgery. With these exclusion criteria, a total of 66 patients were chosen for this study. The patients were divided into 2 groups according to the presence of retear on MRI evaluation at a minimum of 1 year after surgery.

### Clinical and Radiological Assessments

For clinical evaluation, all patients were evaluated both preoperatively and postoperatively at an average of 25.4 months (range, 15-41 months) using a visual analog scale (VAS) for pain during motions, the University of California, Los Angeles (UCLA) shoulder rating scale,[13] and absolute and relative Constant scores.[9,10] The VAS for pain during motions was rated from 0 to 10, with 0 indicating no pain and 10 indicating worst pain. The UCLA is a 35-point scale, with 10 points for pain, 10 points for function, and 5 points each for motion, strength, and patient satisfaction. A score from 34 to 35 is considered an excellent result and a score from 29 to 33 a good result. Any score less than 28 is considered a poor result. The absolute Constant score is a 100-point scoring system in which 35 points are allocated for subjective assessments of pain and function. The remaining 65 points are for objective assessments of range of movement and strength. A relative Constant score[9] is calculated by dividing the obtained score of the patients by the age- and gender-matched score of the Constant population.[8] Clinical data were collected by 2 orthopaedic surgeons in a blind fashion who did not participate in the operations (4 years and 3 years of experience, respectively).

For radiological evaluation, the patients were evaluated preoperatively using a standardized radiographic examination (a true anteroposterior radiograph with the arm in neutral rotation). The acromiohumeral distance (AHD), the distance between the tangent to the densified inferior edge of the acromion and the parallel tangent to the superior part of the humeral head, was measured in millimeters on the anteroposterior radiograph.[2] The rays were aligned to the inferior side of the acromion, visualizing the subacromial space and glenohumeral joint space. This measurement was performed by 2 independent radiologists (14 years and 8 years of experience, respectively).

All 66 patients had a standardized MRI examination with two 1.5-T superconducting magnets (Magnetom Vision and Sonata, Siemens Medical Systems, Erlangen, Germany) preoperatively and a minimum of 1 year after surgery (mean, 13.8 months; range, 12-18 months). The MRI scans were reviewed in a blinded fashion by 2 experienced musculoskeletal radiologists (14 years and 8 years of experience, respectively) using PACS (Picture Archiving and Communication System, Marosis, Infinitti, Seoul, Korea) workstations. Preoperatively, the tear size, extent of retraction of the torn tendon, degree of fat infiltration to cuff muscles, number of involved tendons, and concomitant abnormalities were assessed. The tear size was measured in the maximum anterior-to-posterior length on the sagittal oblique views, and the extent of retraction of the torn tendon was measured in the maximum medial-to-lateral length on the coronal oblique distance as described by Davidson et al.[11] Intramuscular fatty infiltration of the supraspinatus, infraspinatus, and subscapularis muscles was measured at the most lateral oblique sagittal T1-weighted image on which the scapular spine was in contact with the scapular body (the so-called Y-shaped view) with the 5-stage grading system.[16,21] A global fatty infiltration index (GFII),[22] the average of the Goutallier stage of the 3 rotator cuff muscles, was calculated.

Retears of the rotator cuff tendons were assessed using established MRI criteria.[23,31] The diagnosis of a full-thickness retear was made when a high signal intensity

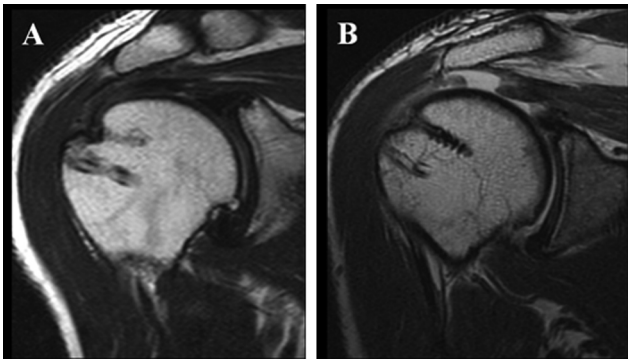


**Figure 1.** Postoperative coronal magnetic resonance imaging (MRI) scans in shoulders of each group. (A) Postoperative MRI showed the completely healed state of a repaired rotator cuff with homogeneously low intensity. (B) Postoperative MRI showed a type 2 retear pattern of a repaired rotator cuff (major discontinuity proximal to the medial row of the anchor).

area (fluid-equivalent signal) or discontinuity of the supraspinatus, infraspinatus, or subscapularis tendon was found in 1 or more of the standard T2-weighted images or proton density–weighted images (Figure 1). To compare the preoperative tear and postoperative retear of the rotator cuff, the sizes and extent of retraction of retears were assessed. We also evaluated the retear pattern according to the description by Cho et al.[5] In type 1, the retear is found on the footprint, whereas in type 2, medial failure is observed, while the footprint remains intact on the greater tuberosity.

## Surgical Procedure

Arthroscopic surgeries were performed by the senior author in all cases after any given patient had been diagnosed with massive rotator cuff tear. The surgeon had 15 years of experience focusing on shoulder surgery. After obtaining adequate visualization, we debrided the margin of the tear to gain better access to the tendon tissues. During arthroscopic examination, we confirmed the preoperatively diagnosed massive tear on MRI in each patient. The tear shape and presence of delamination were identified at the time of surgery.

If the mobility of a tendon was insufficient for repair, procedures to mobilize the tendon were performed. The footprint of the greater tuberosity was thoroughly debrided to the cortical bone, avoiding excessive removal of the bone tissue. A 4.5-mm Bio-Cork screw suture anchor (Arthrex, Naples, Florida) was inserted at the junction of the articular cartilage and the medial aspect of the footprint on the greater tuberosity. Sutures were passed through the tendon in a mattress fashion. The repair was performed en masse by passing the suture through the whole cuff. The sutures were then tied with a sliding knot. Each suture limb from the medial row was placed through the hole at the end of the push-lock device (3.5-mm Bio-PushLock, Arthrex). Pilot holes for the push-lock device were created using a punch 2 cm distal to the lateral edge of the footprint via the lateral portal. While a constant tension was maintained, a push-lock device was inserted into the pilot hole. After the device was fully engaged in the pilot hole, the sutures were cut.

Postoperatively, all shoulders were immobilized for 6 weeks using a sling immobilizer with an abduction pillow. Isometric rotator cuff exercises and relaxation of the muscles around the shoulder girdle were started on the day of the operation. After 6 weeks of immobilization, passive- and active-assisted exercises of forward flexion and external rotation were trained, and the patients were advised to avoid pain during any exercise. After 8 weeks postoperatively, all patients began strengthening exercises for rotator cuff and scapular stabilizers. Rehabilitation was consistently performed with the assistance of a physical therapist. Three months after the operation, the patients were permitted to practice light sports activities and then allowed to engage in full-strength sports and heavy labors after 6 months depending on the individual's functional recovery.

## Statistical Analysis

All continuous variables were tested for normality using the Kolmogorov-Smirnov test and found that preoperative and postoperative VAS rejected normal distribution. Measurements were expressed as mean ± standard deviation with its 95% confidence interval (CI) for continuous variables that accept normal assumption. However, for variables that rejected normal assumption, measurements were expressed as median with its 95% CI. Comparison between preoperative and postoperative VAS scores was performed with the Wilcoxon signed-rank test, and the other functional scores (UCLA and absolute and relative Constant scores) were compared with a paired $t$ test. When we compared the healed group with the retear group, we used the $t$ test for continuous variables that allowed normal assumption; however, we used the Mann-Whitney $U$ test for VAS. Also, we used the $\chi^2$ test for several discrete variables. Finally, we performed multivariate logistic regression to identify factors influencing retears of a repaired massive rotator cuff. We included all the variables that showed a statistically significant difference between the healed and retear groups from a univariate analysis and did regression analysis in a stepwise manner to find affecting important factors for retears. $P < .05$ were considered statistically significant throughout the article. The statistical software MedCalc (version 11.6, MedCalc Software, Mariakerke, Belgium) and R (version 2.12, Comprehensive R Archive Network, GNU General Public License, Massachusetts) were used for all statistical analyses.

# RESULTS

Based on the MRI taken at a minimum of 1 year after surgery, the overall retear rate was 42.4% (28 cases). The mean age at the time of surgery was 61.2 years (range, 50-75 years) in the completely healed group and 62.7 years (range, 46-81 years) in the retear group ($P$ = .482). The mean time of follow-up was 23.5 months (range, 15-38 months) in the completely healed group and 28.7 months

TABLE 1
Comparisons of Healed and Retear Group on Demographics and Surgical Procedures[a]

| | Healed Group (n = 38) | Retear Group (n = 28) | *P* Value |
|---|---|---|---|
| Age, y | 61.2 ± 7.9 (50-75) | 62.7 ± 9.6 (46-81) | .482 |
| Sex, male:female | 20:18 | 14:14 | .833 |
| Involved side, dominant:nondominant | 32:6 | 23:5 | .824 |
| Time to operation, mo | 7.9 ± 9.2 (1-36) | 6.6 ± 10.0 (0.5-48) | .594 |
| Medical history | | | |
| Diabetes mellitus, n | 5 | 2 | .433 |
| Hypertension, n | 11 | 9 | .780 |
| Cerebrovascular accident, n | 2 | 4 | .208 |
| Injury mechanism | | | |
| Overuse, n | 21 | 13 | .478 |
| Trauma, n | 14 | 13 | .434 |
| Sports, n | 3 | 1 | .467 |
| Acromioplasty, n | 28 | 22 | .647 |
| Distal clavicle resection, n | 7 | 4 | .656 |
| Biceps tenotomy/tenodesis, n | 13 | 13 | .315 |
| Time of follow-up, mo | 23.5 ± 7.7 (15-38) | 28.7 ± 8.2 (18-41) | .072 |

[a]Values are expressed as mean ± standard deviation (range) unless otherwise indicated.

TABLE 2
Clinical Outcomes Comparing Healed Group With Retear Group[a]

| | Total (N = 66) | Healed Group (n = 38) | Retear Group (n = 28) | *P* Value (Healed vs Retear) |
|---|---|---|---|---|
| Pain VAS, median (95% CI) | | | | |
| Preoperative | 6 (6.0-7.4) | 6 (6.0-7.5) | 6 (6.0-8.0) | .816 |
| Postoperative | 3 (2-3) | 2 (1.0-2.0) | 4 (3.0-4.0) | <.001 |
| *P* value (preoperative vs postoperative) | <.001 | <.001 | <.001 | |
| UCLA | | | | |
| Preoperative | 13.7 ± 3.1 (12.9-14.4) | 13.7 ± 3.2 (12.6-14.7) | 13.6 ± 2.9 (12.5-14.8) | .958 |
| Postoperative | 28.0 ± 3.3 (27.2-28.8) | 29.5 ± 2.5 (28.7-30.3) | 26.0 ± 3.2 (24.8-27.3) | <.001 |
| *P* value (preoperative vs postoperative) | <.0001 | <.001 | <.001 | |
| Absolute Constant score | | | | |
| Preoperative | 44.6 ± 8.3 (42.8-46.7) | 44.1 ± 8.8 (41.2-47.0) | 45.4 ± 7.7 (42.4-48.4) | .542 |
| Postoperative | 75.2 ± 9.4 (72.9-77.5) | 78.5 ± 7.5 (76.0-81.0) | 70.6 ± 10.0 (66.8-74.5) | <.001 |
| *P* value (preoperative vs postoperative) | <.0001 | <.001 | <.001 | |
| Relative Constant score | | | | |
| Preoperative | 55.9 ± 11.9 (53.0-58.8) | 54.7 ± 12.3 (50.7-58.8) | 57.5 ± 11.3 (53.1-61.8) | .356 |
| Postoperative | 93.5 ± 15.3 (89.7-97.2) | 95.2 ± 13.1 (90.9-99.5) | 87.3 ± 13.8 (81.9-92.6) | .021 |
| *P* value (preoperative vs postoperative) | <.0001 | <.001 | <.001 | |

[a]Values are expressed as mean ± standard deviation (95% confidence interval [CI]) unless otherwise indicated. VAS, visual analog scale; UCLA, University of California, Los Angeles.

(range, 18-41 months) in the retear group ($P = .072$). Other demographics and surgical procedures showed no statistical differences between the 2 groups (Table 1).

## Clinical Assessment

Statistically significant clinical improvements were observed after surgery in both the healed and retear groups. Each of the postoperative pain and functional scores were significantly better in the completely healed group (pain VAS: 2; UCLA: 29.5 points; absolute Constant score: 78.5 points; relative Constant score: 95.2 points) than in the retear group (pain VAS: 4, $P < .001$; UCLA: 26.0 points, $P < .001$; absolute Constant score: 70.6 points, $P < .001$; relative Constant score: 87.3 points, $P = .021$) (Table 2).

## Radiological Assessment

On univariate analysis, there were no statistically significant differences between the 2 groups except on the preoperative mean AHD, the extent of retraction of the torn tendon, and the fatty infiltration of the cuff muscles including the supraspinatus and infraspinatus. The mean preoperative AHD was significantly wider in the completely

TABLE 3
Comparison of Preoperative Radiological and Intraoperative Findings Between Healed and Retear Group[a]

| | Healed Group (n = 38) | Retear Group (n = 28) | *P* Value |
|---|---|---|---|
| Acromiohumeral distance, mm | 7.83 ± 1.96 (7.19-8.48) | 6.36 ± 2.44 (5.42-7.31) | .008 |
| Tear shape | | | |
| U shape, n | 26 | 22 | .360 |
| L shape, n | 7 | 2 | .187 |
| Crescent shape, n | 5 | 4 | .895 |
| Delamination, n | 21 | 20 | .181 |
| Tear size, cm | 4.38 ± 0.55 (4.20-4.56) | 4.44 ± 0.59 (4.21-4.67) | .669 |
| Extent of retraction, cm | 2.97 ± 0.66 (2.75-3.19) | 3.97 ± 0.58 (3.75-4.20) | <.001 |
| Degree of fat infiltration (Goutallier classification) | | | |
| Supraspinatus | 1.74 ± 0.92 (1.43-2.04) | 2.54 ± 0.84 (2.21-2.86) | <.001 |
| Infraspinatus | 0.71 ± 0.77 (0.46-0.96) | 2.07 ± 1.02 (1.68-2.47) | <.001 |
| Subscapularis | 0.79 ± 0.84 (0.51-1.07) | 0.93 ± 1.12 (0.49-1.36) | .567 |
| No. of involved tendons, 2:3 | 30:8 | 18:10 | .186 |

[a]Values are expressed as mean ± standard deviation (95% confidence interval) unless otherwise indicated.

TABLE 4
Results of Stepwise Multivariate Logistic Regression and Equation of the Probability of Retear as a Function of Significant Factors Influencing Retears of Massive Rotator Cuff Repair

| | Coefficient | *P* Value | Odds Ratio | 95% Confidence Interval |
|---|---|---|---|---|
| Constant | −9.125 | | | |
| Extent of retraction, cm | 1.972 | .002 | 7.183 | 2.099-24.576 |
| Degree of fat infiltration | | | | |
| Infraspinatus | 1.485 | .003 | 4.414 | 1.673-11.645 |

healed group (7.83 ± 1.95 mm; 95% CI, 7.19-8.48) than in the retear group (6.36 ± 2.98 mm; 95% CI, 5.42-7.31) ($P$ = .008). There were 7 of 38 cases with AHD <6 mm in the completely healed group. The preoperative extent of retraction of the torn tendon was significantly greater in the retear group (3.97 ± 0.58 cm; 95% CI, 3.75-4.20) than in the completely healed group (2.97 ± 0.66 cm; 95% CI, 2.75-3.19) ($P$ < .001). The preoperative degree of fatty infiltration of the supraspinatus muscle was significantly higher in the retear group (2.54 ± 0.84; 95% CI, 2.21-2.86) than in the completely healed group (1.74 ± 0.92; 95% CI, 1.43-2.04) ($P$ < .001). The preoperative degree of fatty infiltration of the infraspinatus muscle was significantly higher in the retear group (2.07 ± 1.02; 95% CI, 1.68-2.47) than in the completely healed group (0.71 ± 0.77; 95% CI, 0.46-0.96) ($P$ < .001).

The preoperative tear involved the supraspinatus tendon in all cases, the infraspinatus tendon in 58 (87.9%) cases, and the subscapularis tendon in 26 (39.4%) cases. Eighteen (27.3%) cases involved all 3 tendons, and 48 (72.7%) cases involved only 2 tendons. The ratio of the preoperative 3-tendon involvement was higher in the retear group than in the healed group, but it was not statistically significant ($P$ = .186) (Table 3).

However, on stepwise multivariate logistic regression analysis, only 2 factors were found to be statistically significant. The preoperative extent of retraction ($P$ = .002) and preoperative degree of fatty infiltration of the infraspinatus ($P$ = .003) were revealed to be associated with a retear as predictive factors (Table 4 and Figure 2). Moreover, retears were observed in more than half of the patients with GFII >1 and in all of the patients with GFII >2. The GFII was significantly different between the healed and the retear group ($P$ < .001) (Table 5).

With regard to characteristics of retears, the extent of retraction of the retear was 2.845 ± 0.760 cm (95% CI, 2.422-3.207), and the retear size was 2.545 ± 0.770 cm (95% CI, 2.418-2.773). The retear patterns on postoperative MRI showed that 11 retears (39.3%) were of type 1 and 17 retears (60.7%) were of type 2. Pearson correlation analysis was performed to see the relationship between the extent of retraction of the preoperative tear and postoperative retear, and it was found that the correlation coefficient was not statistically significant ($P$ = .08). Likewise, the Pearson correlation coefficient between the preoperative tear size and postoperative retear size was not statistically significant either ($P$ = .180).

## DISCUSSION

To our knowledge, this is the first comparative study to evaluate the structural integrity of arthroscopically repaired tendons for patients with massive rotator cuff

TABLE 5
Prevalence of Tendon Healing According to Preoperative Cuff Muscle Fatty Infiltration[a]

| | Global Fatty Degeneration Index | | | | |
|---|---|---|---|---|---|
| | <0.25 (n = 0) | 0.25-1.0 (n = 18) | 1.0-1.5 (n = 28) | 1.5-2.0 (n = 10) | ≥2.0 (n = 10) |
| Healed group (n = 38) | 0 | 16 (42.1) | 19 (50) | 3 (7.9) | 0 |
| Retear group (n = 28) | 0 | 2 (7.2) | 9 (32.1) | 7 (25) | 10 (35.7) |

[a]Values are expressed as n (%). $P < .001$ via $\chi^2$ test for trend.

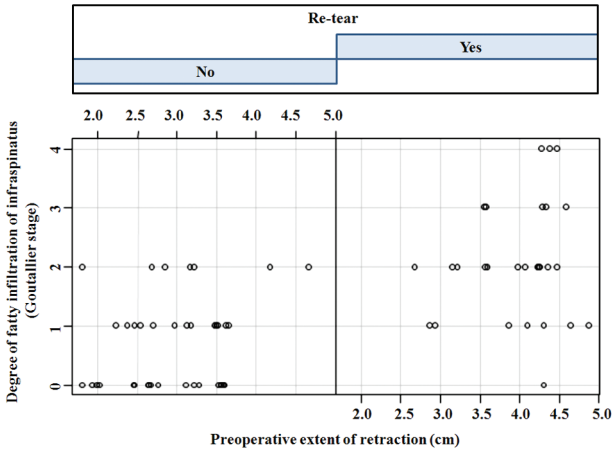


**Figure 2.** Scatter plot showing preoperative extent of retraction against the degree of fat infiltration of the infraspinatus for any given retear status. Preoperative extent of retraction and fatty infiltration of the infraspinatus were significant factors influencing retears of repaired massive rotator cuff tendons.

tears and its correlation with clinical outcomes. There are 2 main findings in this study. First, the structural integrity of the repair site correlated with clinical improvement. Second, using univariate analysis, the amount of fatty infiltration of the supraspinatus and infraspinatus muscles, extent of retraction of the torn tendon, and AHD were contributing factors for structural integrity of the repair site. However, using multivariate regression analysis to exclude confounding factors, we found that only 2 variables, extent of retraction of the torn tendon and degree of fatty infiltration of the infraspinatus muscle, were the most important factors that made a repaired massive rotator cuff go on to retear.

Massive tears of the rotator cuff, defined as a tear larger than 5 cm or involving at least 2 tendons, are usually associated with a higher retear rate after surgical repairs.[7,12,13,18,19] Recent studies have demonstrated that the postoperative healing rate of arthroscopic massive rotator cuff repair is between 47% and 87%,[25,27,32,36] and healing rates are improving. In this study, the retear rate was 42.4%, which is similar to previously published results.

Retear does not always mean clinical failure but can be associated with poorer function and worse degenerative changes of the rotator cuff muscles compared to successful repairs.[20-22,26] The integrity of the repair site has been shown to be correlated with clinical improvement, particularly in the recovery of muscle strength.[1,26] Therefore, the repair of massive tears should be the treatment of choice if the tear is reparable. Although repair of massive rotator cuff tears may provide an acceptable functional outcome, the results are sometimes less predictable than smaller tears, especially in terms of cuff healing.[3,14,17,19,40] In this study, there was a statistically significant difference between the healed and retear group with regard to pain VAS score during motions, the UCLA score, and both absolute and relative Constant scores. Poorer clinical outcomes were more frequently observed in the retear group. We assume that this can be attributed to the size and extent of the retraction of the retear. The average retear size was 2.545 ± 0.770 cm (95% CI, 2.418-2.773), and the extent of retraction of the retear was 2.845 ± 0.760 cm (95% CI, 2.422-3.207), which corresponded to a medium- to large-sized rotator cuff tear, although smaller than the preoperative tear size. The clinical outcomes in the retear group may be gradually deteriorated with time, and patients with high functional demands would not be satisfied. Therefore, another treatment option, which is more effective than a failed rotator cuff repair and has similar functional outcomes with a completely healed repair, would be particularly beneficial for a patient who is strongly expected to have retears.

According to prior studies, several factors have been demonstrated to be associated with retears. These factors include the age of the patient at the time of surgery, size of the original tear, degree of muscular atrophy, degree of fatty infiltration of the cuff muscle, surgical technique, and inappropriate rehabilitation.[1,15,17,18,22,29,37] The age of the patient and tear size were considered important factors for tendon healing. Boileau et al[1] reported a negative relationship between the age of the patient and the rate of tendon healing. Gazielly et al[18] reported that small tears tend to have better tendon healing. However, in this study, we could not observe differences in the age of patients and the original tear size between the healed and retear group ($P = .482$ and $P = .427$, respectively). This may be because of a relatively similar age group and the tear size among the study participants as well as a relatively small patient pool. Meanwhile, we observed healing of the torn cuff in elderly patients with large tears. From these cases, we suspected that other important factors exist that may affect tendon healing.

From the multivariate analysis, we could verify that factors such as the degree of fatty infiltration of the

infraspinatus muscle and the preoperative extent of retraction are significantly important factors that can predict retears. Goutallier et al[22] report that retears were observed more often in patients with severe fatty infiltration in cuff muscles (particularly the infraspinatus and subscapularis) and with a preoperative GFII >1. A multivariate analysis study by Oh et al[30] revealed that fatty infiltration of the infraspinatus muscle was the best independent predictor for the integrity of the repaired tendon. In this study, retears were observed in more than half of the patients with GFII >1 and in all patients with GFII >2 and were found to be significantly associated with the degree of fatty infiltration of the infraspinatus muscle. On the other hand, the fatty infiltration of the subscapularis muscle was found not to be correlated with retears. We believe this is because there are more patients who had a posterosuperior type of massive tear that involved the supraspinatus and infraspinatus muscles than tears that involved the subscapularis muscle.

In general, the extent of retraction of the torn cuff in massive tears can reflect the chronicity of the tear, without recent severe traumatic events. Chronic retracted rotator cuff tears correlated with severe fatty infiltration and muscle atrophy.[38] Lakemeier et al[28] found a significant correlation between the grade of fatty infiltration, cuff muscle atrophy, and the extent of retraction of the torn tendon and reported that the greater the extent of retraction, the more severe the fatty infiltration and atrophy of the cuff muscle. Interestingly, we found that the preoperative extent of retraction in the retear group was significantly greater than in the healed group ($P < .001$). Moreover, the extent of retraction was revealed to be the most important independent predictor for retears (odds ratio, 7.183). Therefore, greater preoperative extent of retraction can reflect poor quality of the torn cuff and can be a major risk factor for retears after surgical repair.

Recently, Cho et al[5] described differences in retear patterns depending on the operative techniques and found that medial cuff failures were frequently observed in patients who had undergone arthroscopic repair using the suture bridge technique. In this study, the medial cuff failures were observed in 17 cases of 28 retears (60.7%). There may be a possibility of strangulation and relatively quick necrosis of the repaired tendon at the medial row.[4] Medial cuff failure is challenging for orthopaedic surgeons to do revision surgery. Therefore, as mentioned by Cho et al,[4] meticulous surgical technique of the medial-row repair, such as adequate mobilization and tension, should be considered to prevent medial cuff failure in arthroscopic suture bridge repair.

From the results drawn above, we suggest that orthopaedic surgeons should consider these factors that affect retears and predict the possibility of retears on the preoperative evaluation of massive rotator cuff tears. It is very important to determine the reparability of massive rotator cuff tears preoperatively, not only for the selection of adequate surgical options such as primary repair or reverse total shoulder arthroplasty but also for giving a satisfactory explanation to the patient. If a patient is expected to have retears, careful discussion on the patient's functional demands and goals is needed to determine whether he or she is better suited for primary repair.

This study has some limitations. First, this is a retrospective study. However, we used the patients' data, which were planned and collected preoperatively to overcome this. Moreover, all surgical procedures had been performed by a single surgeon. Second, 16 patients were lost to follow-up. It represents 17% of the initially included 94 patients. Considering the high retear rate of massive rotator cuff repair, if all these patients experienced a retear, it would result in a higher retear rate. This could cause selection bias. As far as we know, 9 patients were followed up until 6 months postoperatively, and retears were not observed via ultrasonography at the last visit. Seven patients have not been followed up after surgery because of economic or personal reasons. Among them, 5 patients lost contact, and the other 2 patients refused to visit because they were living too far. Third, postoperative rehabilitation is critical to the success of surgical repair of a rotator cuff tear. Although numerous rehabilitation protocols have been proposed, the optimal period of immobilization after surgery that balances stiffness with tendon healing remains controversial. Multiple clinical studies have shown that early motion may result in devastating consequences.[17] We have adopted a conservative rehabilitation protocol of sling immobilization for the first 6 weeks after surgery, but we cannot vouch for the patients' compliance. Fourth, the follow-up period is relatively short to verify the course and clinical result of surgical repair. Further long-term study is needed to reach a firm conclusion.

The arthroscopic repair of massive rotator cuff tears using a suture bridge technique had a relatively high retear rate, and these structural failures appear to have a significant difference with regard to clinical outcomes compared with the healed group. This study demonstrated that the degree of fatty infiltration of the infraspinatus and preoperative extent of retraction are the 2 most important factors affecting retear. Orthopaedic surgeons should consider these factors that correlate with the possibility of retear before surgery and counsel patients about their expected functional results. Also, a biomechanically more improved repair technique or other treatment modalities that can bring better functional outcomes than a failed repair should be sought in the future.

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