The American Journal of Sports Medicine

http://ajs.sagepub.com/

Retear Rate in the Late Postoperative Period After Arthroscopic Rotator Cuff Repair

Jae Hwa Kim, In Tae Hong, Keun Jung Ryu, Sun Tae Bong, Yoon Seok Lee and Jang Hwan Kim

Am J Sports Med 2014 42: 2606 originally published online September 3, 2014
DOI: 10.1177/0363546514547177

The online version of this article can be found at:
http://ajs.sagepub.com/content/42/11/2606

Published by:
SAGE
http://www.sagepublications.com

On behalf of:
American Orthopaedic Society for Sports Medicine
AOSSM

Retear Rate in the Late Postoperative Period After Arthroscopic Rotator Cuff Repair

Jae Hwa Kim,*† MD, PhD, In Tae Hong,† MD, Keun Jung Ryu,† MD, Sun Tae Bong,† MD, Yoon Seok Lee,‡ MD, and Jang Hwan Kim,† MD
Investigation performed at CHA Bundang Medical Center, CHA University School of Medicine, Seongnam, Korea

Background: Few clinical studies have evaluated the integrity of repaired tendons and identified the timing of retears through the use of serial imaging.

Hypothesis: Retears after arthroscopic rotator cuff repair are uncommon in the late postoperative period (after 3 months).

Study Design: Case series; Level of evidence, 4.

Methods: Among 221 arthroscopic rotator cuff repairs that were performed at a single hospital between May 2010 and February 2012, 61 were involved in this study. Rotator cuff tears consisted of 12 small, 31 medium, 8 large, and 6 massive rotator cuff tears. Additionally, 4 isolated subscapularis tears were included. For clinical evaluation, all patients were assessed both preoperatively and postoperatively by use of the University of California–Los Angeles Shoulder Rating Scale, absolute and relative Constant scores, and American Shoulder and Elbow Surgeons score; active range of motion was assessed as well. For radiological evaluation, all 61 patients had a magnetic resonance imaging (MRI) evaluation at 3 months postoperatively. Among them, 23 patients were evaluated for repaired tendon integrity on postoperative MRI at a minimum of 1 year after surgery (mean, 14.1 months; range, 12-19 months), and results were classified according to the Sugaya classification: type I, sufficient thickness with homogeneously low intensity on each image; type II, sufficient thickness, partial high-intensity area; type III, less than half the thickness without discontinuity; type IV, minor discontinuity; and type V, major discontinuity. The remaining 38 patients, who refused to undergo MRI again for financial reasons, were evaluated through ultrasound.

Results: Statistically significant clinical improvements were observed after surgery. The MRI conducted at 3 months postoperatively identified 9 patients with Sugaya type I, 28 patients with type II, and 24 patients with type III repairs. No patients showed Sugaya type IV or V repairs at postoperative 3 months. Thirty-seven patients who had shown Sugaya type I or II repairs on 3-month postoperative MRI had no retear on imaging study at a minimum of 1 year. Of 24 patients who had shown type III repairs on 3-month postoperative MRI, 1 patient exhibited retear (Sugaya type IV) on 1-year postoperative MRI and 3 patients showed full-thickness retear on 1-year postoperative ultrasonography. All 4 of these patients had had large to massive tears preoperatively.

Conclusion: Retears occurred infrequently in the late postoperative period (after 3 months) in well-healed tendons that had shown intact cuff repair integrity with sufficient mechanical and biological healing within the first 3 postoperative months.

Keywords: rotator cuff repair; rotator cuff retear; timing of retear; cuff integrity; cuff healing process

Arthroscopic repair has been widely performed in the treatment of rotator cuff tears. Many studies have reported improved outcomes for arthroscopically repaired rotator cuff tears.[11,12] Nevertheless, in large and massive tears of the rotator cuff, high rates of retear after arthroscopic repair have been reported and remain a significant clinical problem.[11,19,28] The patient's age, preoperative tear size, degree of muscular atrophy, degree of fatty infiltration, surgical technique, and inappropriate postoperative rehabilitation are suggested to be factors that cause retear after surgical repair.[4,10,11,15,24,34]

The timing of retear of a repaired tendon is not clear.[16] The biological healing of the repaired rotator cuff tendon to

*Address correspondence to Jae Hwa Kim, MD, PhD, Department of Orthopaedic Surgery, CHA Bundang Medical Center, CHA University School of Medicine, 351 Yatap-dong, Bundang-gu, Seongnam 463-712, Korea (e-mail: drjkim@cha.ac.kr).

†Department of Orthopaedic Surgery, CHA Bundang Medical Center, CHA University School of Medicine, Seongnam, Korea.

‡Department of Orthopaedic Surgery, CHA Gumi Medical Center, CHA University School of Medicine, Gumi, Korea.

The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

The American Journal of Sports Medicine, Vol. 42, No. 11
DOI: 10.1177/0363546514547177

the humerus is estimated to require a minimum of 8 to 12 weeks.[20] In recent histological evaluations of rotator cuff repair in a primate model, the fibers holding the bone-tendon junction together did not appear in considerable numbers before 12 weeks. By 15 weeks, the bone-tendon junctions were almost, but not quite, mature.[32] A few clinical studies have evaluated the repaired tendon integrity and identified the timing of retear using serial imaging.[1,22,26,27] The studies so far have suggested that retears commonly appear in the early postoperative period (before 3 months). Therefore, 2 questions remain: Is retear of arthroscopically repaired rotator cuffs uncommon in the late postoperative period (after 3 months)? If retears occur, what are the predictable risk factors?

Understanding the factors that affect the structural integrity of the repaired tendon and identifying the timing of the retear of repaired tendon during the postoperative period will help orthopaedic surgeons design better preoperative plans and will improve postoperative rehabilitation. These advances will also allow surgeons to optimize the healing rate and improve outcomes after arthroscopic rotator cuff repair.

The primary objective of this study is to use imaging modalities to evaluate the timing of retear after arthroscopic repair of rotator cuff tears. This study is designed to evaluate the maintenance of integrity of the repaired tendon in the late postoperative period (at a minimum of 1 year) in patients who did not show cuff discontinuity on magnetic resonance imaging at 3 months postoperatively. Our hypothesis is that retears will be uncommon in the late postoperative period (between 3 months and 1 year).

MATERIALS AND METHODS

Patient Selection

This retrospective study was approved by our institutional review board. From May 2010 to February 2012, 221 arthroscopic rotator cuff repairs were performed at our hospital. Among 221 patients, 57 patients who had a partial-thickness rotator cuff tear and 69 patients who did not undergo imaging studies to evaluate the cuff retear after operation were excluded from this study. Of the remaining 95 patients, 25 patients who exhibited full-thickness retear on 3-month postoperative magnetic resonance imaging (MRI) were excluded as well. Additionally, we excluded 9 patients who (1) underwent partial repair of the rotator cuff, (2) were not available for functional outcome assessment and MRI evaluation preoperatively, and (3) underwent revision surgery due to additional trauma after surgery. Finally, 61 patients were enrolled in the study (Figure 1).

There were 30 male and 31 female patients involved in this study. The mean age at the time of operation was 57.3 years (range, 31-81 years), and the mean follow-up period was 15.8 months (range, 12-22 months). The right shoulder was involved in 42 cases and the left shoulder was involved in 19 cases. Forty-nine patients had involvement of the dominant arm. There were 12 small, 31 medium, 8 large, and 6 massive rotator cuff tears. Additionally, 4 isolated subscapularis tears were included (Table 1). In this study, a massive rotator cuff tear was defined as a tear greater than 5 cm in diameter or a tear involving detachment of at least 2 entire tendons.[13]

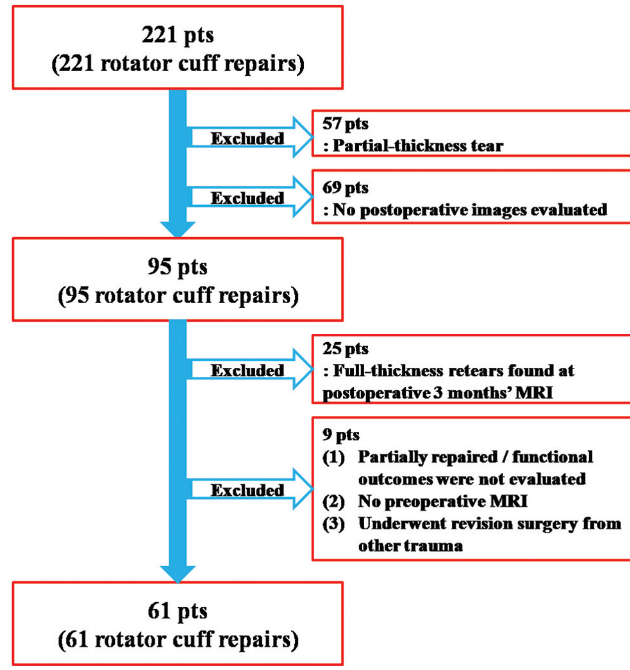

Figure 1. Study flow chart. Among 221 arthroscopically repaired rotator cuff tears initially included, 160 patients were excluded for various reasons. Ultimately, 61 rotator cuff repairs were analyzed in the study.

TABLE 1
Patient Demographics

	Total (N = 61 patients [61 rotator cuff repairs])
Sex, male/female, n	30/31
Age, mean (range), y	57.3 (31-81)
Follow-up, mean (range), mo	15.8 (12-23)
Dominancy, dominant/nondominant, n	49/12
Tear size, small/medium/large/ massive, n[a]	11/32/8/6
Isolated subscapularis tendon tears, n	4

[a]A massive tear was defined as a tear >5 cm in diameter or a tear involving detachment of at least 2 entire tendons.

Clinical and Radiological Assessment

For clinical evaluation, all patients were evaluated both preoperatively and postoperatively by use of the University of California–Los Angeles (UCLA) Shoulder Rating Scale,[8] absolute and relative Constant scores,[6,7] American Shoulder and Elbow Surgeons (ASES) Shoulder Score,[30] and active range of motion. For shoulder range of motion, forward elevation and abduction were tested actively. External rotation and internal rotation of the shoulder were evaluated with the shoulder in adduction, the elbow in 90° of flexion, and the forearm in the neutral position.

For the radiological evaluation, all 61 patients had a standardized MRI examination with 1.5-T superconducting magnets (Magnetom Vision and Sonata; Siemens Medical Systems) or 3.0-T superconducting magnets (Signa HDxt 3.0T; General Electronic Healthcare) preoperatively and at 3 months after surgery. Of the 61 patients, 23 patients were evaluated for repaired tendon integrity on postoperative MRI at a minimum of 1 year after surgery. The average mean time between surgery and evaluation was 14.1 months (range, 12-19 months). The remaining 38 patients, who refused MRI evaluation for financial reasons, were evaluated through ultrasound (APLIO MX; Toshiba). The average mean time of evaluation was 15.8 months with a range of 12 to 23 months. An experienced musculoskeletal radiologist who was blind to the clinical and functional outcome of patients performed all follow-up ultrasonographic examinations according to standard protocol.[9] The MRI and ultrasonographic examinations were interpreted by the same radiologist using picture archiving and communication system (PACS) workstations (Marosis; Infinitti).

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 as the maximum anterior-to-posterior length from the sagittal oblique views. The extent of retraction of the torn tendon was measured as the maximum medial-to-lateral length on the coronal oblique distance as described by Davidson et al.[8] Fatty degeneration was evaluated for each muscle by use of the 5-stage grading system developed by Goutallier et al[14,15] for MRI.

Oblique coronal, oblique sagittal, and transverse views of T2-weighted images on MRI were used to classify postoperative cuff integrity into 5 categories according to Sugaya et al[33]: type I, repaired cuff appeared to have sufficient thickness compared with normal cuff with homogeneously low intensity on each image; type II, sufficient thickness compared with normal cuff associated with partial high-intensity area; type III, insufficient thickness with less than half the thickness when compared with normal cuff, but without discontinuity, suggesting a partial-thickness delaminated tear; type IV, presence of a minor discontinuity in only 1 or 2 slices on both oblique coronal and sagittal images, suggesting a small, full-thickness tear; and type V, presence of a major discontinuity observed in more than 2 slices on both oblique coronal and sagittal images, suggesting a medium or large full-thickness tear. We defined *retear* as Sugaya classification type IV and V.

In postoperative ultrasonography, a full-thickness retear was diagnosed if a focal defect in the rotator cuff could be separated from the torn tendon by compression of the deltoid muscle with a probe or if the cuff retracted to such an extent that the torn ends could be distinctly visualized.[2,36]

Surgical Procedure

Arthroscopic surgeries were performed by the senior author (J.H.K.) in all cases when a given patient had been diagnosed with a full-thickness rotator cuff tear. The surgeon had 15 years of experience, focusing on shoulder surgery. After adequate visualization was obtained, debridement was performed to the margin of the tear to remove the unhealthy tendon and to gain better access to the tendon tissues. Tear shape was confirmed and the presence of delamination identified during arthroscopic examination. 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 without excessive removal of the bone tissue.

Depending on the tear size, repairs to the rotator cuff tendon tears were performed by single-row or suture-bridge technique. Single-row repair was performed for small supraspinatus tears (11 cases), and double-row repair with suture-bridge technique was performed for medium to massive tears (46 cases). Subscapularis tears (4 cases) were repaired by arthroscopic single-row technique in the standard manner[29] with the following key points: 4-portal placement (posterior, anterior, anterolateral, accessory anterolateral portals), visualization of the injury with a 30° arthroscope and a 70° arthroscope, manipulation of the arm into maximal internal rotation to assist in assessing the footprint, appropriate anchor placement, and suture passage through the tendon and tying secure arthroscopic knots.

To repair supraspinatus or infraspinatus tears, a 4.5-mm Bio-Cork screw suture anchor (Arthrex Inc) was inserted at the junction of the articular cartilage and the medial aspect of the footprint on the greater tuberosity. For the single-row repair, the rotator cuff repair was performed by first placing a suture shuttle through the tendon by use of the suture hook (Linvatec). The shuttle was used to bring one end of the suture through the tendon. The suture (FiberWire; Arthrex Inc) was then tied with a sliding knot. For the suture-bridge repair, 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 Inc). 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.

Postoperative Rehabilitation

Postoperatively, all patients were placed in a sling immobilizer with an abduction pillow for 6 weeks. Postoperative isometric rotator cuff exercises and relaxation of the muscles around the shoulder girdle began the day of the operation. Each patient's postoperative rehabilitation protocol was individualized according to tear size, as confirmed by arthroscopic examination, and the patient's postoperative symptoms.

Periscapular range of motion exercises began immediately after surgery. For small to medium-sized rotator

TABLE 2
Radiologic Results of Tendon Healing at 3 Months[a]

MRI (Sugaya classification)	No. of Small to Medium Tears[b]	No. of Large to Massive Tears[b]
I	8	1
II	22, 4 subscapularis	2
III	13	11

[a]MRI, magnetic resonance imaging.
[b]At 3-month postoperative MRI, significantly worse cuff integrity by Sugaya classification was found in the subjects with large to massive tear compared with the subjects with small to medium tear (P = .003).

TABLE 3
Radiologic Results of Tendon Healing at 1 Year[a]

Imaging Modality	No. of Small to Medium Tears[b]	No. of Large to Massive Tears[b]
MRI (Sugaya classification, n = 23)		
I	6, 2 subscapularis	0
II	10	4
III	0	0
IV	0	1
Ultrasound (n = 38)		
Intact	27, 2 subscapularis	6
Full-thickness retear	0	3

[a]MRI, magnetic resonance imaging.
[b]P values for comparing the groups (small to medium tears vs large to massive tears) via the 2 imaging modalities: P = .09 (MRI), P = .01 (ultrasound).

cuff tears, passive-assisted exercises began at the end of 3 postoperative weeks. Patients were advised to avoid pain during any exercise. Strengthening exercises began at 6 weeks. For large to massive rotator cuff tears, after 6 weeks of immobilization, passive- and active-assisted exercises involving forward flexion and external rotation were begun.[18,21] 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, patients were permitted to practice light sports activities. After 6 months, patients were allowed to engage in intense sports activities and heavy labor depending on each individual's functional recovery.

Statistical Analysis

All continuous variables were tested for normality with the Kolmogorov-Smirnov test. Measurements were expressed as mean ± standard deviation with 95% confidence intervals for continuous variables that accepted normal assumptions. Preoperative and postoperative range of motion of the shoulder and functional scores (UCLA, absolute and relative Constant, and ASES scores) were compared with a paired t test. When we compared the healed group with the unhealed group, we used the Wilcoxon rank-sum test because of the small sample size in the unhealed group. Also, we used the chi-square or Fisher exact test for several discrete variables. $P < .05$ was considered statistically significant. The statistical software MedCalc (v 11.6; MedCalc Software) and R (v 2.12; Comprehensive R Archive Network, GNU General Public License) were used for all statistical analyses.

RESULTS

Based on the imaging study conducted at a minimum of 1 year after surgery, the overall retear rate was 6.6% (4 cases) in patients whose repaired tendon was intact 3 months postoperatively according to MRI. The 3-month postoperative Sugaya classifications of MRI results showed 9 patients with type I (8 small to medium, 1 large to massive), 28 patients with type II (22 small to medium, 2 large to massive, 4 isolated subscapularis), and 24 patients with type III repairs (13 small to medium, 11 large to massive) (Table 2). Subsequently, 1-year postoperative MRI of 23 patients showed 8 patients with type I, 14 patients with type II, and 1 patient with type IV repairs. One-year postoperative ultrasound of 38 patients identified 35 patients with intact tendons and 3 patients with full-thickness retears (Table 3).

In summary, 37 patients who had shown type I or II repair integrity on 3-month postoperative MRI had no retears on imaging study at a minimum of 1 year. Of 24 patients who had shown type III repair on 3-month postoperative MRI, 1 patient exhibited Sugaya type IV on 1-year postoperative MRI and 3 patients showed full-thickness retear on their 1-year postoperative ultrasonography (Figure 2).

Statistically significant clinical improvements were observed after surgery. The overall range of shoulder motion increased ($P < .001$). In addition, there were significant improvements in the overall UCLA score (from a baseline mean of 19.7 ± 6.7 to 31.3 ± 4.5), absolute and relative Constant score (from a baseline mean of 62.8 ± 15.0 and 71.8 ± 15.2 to 77.8 ± 9.6 and 89.3 ± 8.2, respectively), and ASES score (from a baseline mean of 63.9 ± 20.7 to 82.3 ± 14.4) ($P < .001$).

DISCUSSION

The aim of this study was to use imaging studies to determine the timing of retear after arthroscopic repair of rotator cuff tears under the hypothesis that retear would occur most commonly within 3 months postoperatively and would be uncommon in the late postoperative period (between 3 months and 1 year). The most important finding of our study is that retears occur infrequently in the late postoperative period (after 3 months). In this study, of the 95 patients whose tendon integrity was evaluated with MRI at 3 months postoperatively, 25 patients showed full-thickness retear (26%). However, retears occurred in only 4 of 61 cases (6.6%) between 3 months and 1 year postoperatively. Most of the cases of retear occurred within

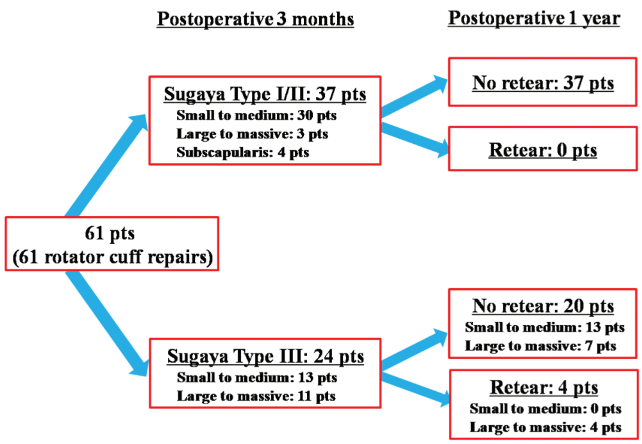

Figure 2. Summary of radiologic results. Thirty-seven patients who had shown type I or II repair on 3-months postoperative MRI had no retears on imaging study at a minimum of 1 year. Of 24 patients who had shown type III repair on 3-month postoperative MRI, 1 patient exhibited type IV repair on 1-year postoperative MRI and 3 patients showed full-thickness retear on their 1-year postoperative ultrasonography.

3 months postoperatively. A total of 37 patients who had Sugaya type I or II repair on MRI at 3 months postoperatively did not show retears after 1 year postoperatively, including 3 patients with large to massive tears. However, retears were observed in 4 of 24 patients (16.6%) who had shown Sugaya classification type III on 3-month postoperative MRI. All retears occurred in patients with large to massive tears. Also, of 24 patients, 5 patients (1 small to medium tear, 4 large to massive tears) with Sugaya classification type III on 3-month postoperative MRI were evaluated by 1-year postoperative MRI. Interestingly, of 4 patients with large to massive tears, 1 exhibited retear (Sugaya type IV) and the remaining patients showed Sugaya type II repair on 1-year postoperative MRI; that is, these 3 patients appeared to be on the road to recovery from type III to type II repair. This can be explained as a “delayed biological healing process.”

Arthroscopic rotator cuff repair has recently been widely accepted as a successful surgical method for the treatment of rotator cuff tear. Although new research has reported that the rate of retear has been reduced as surgical techniques advance, the retear rate is still fairly high and varies widely—from 13% to 94%.[3,11] Moreover, there has been a growing interest in retears after arthroscopic rotator cuff repair since research has shown the strong correlation between the structural integrity of the arthroscopically repaired rotator cuff and the patient’s clinical outcomes.[4,17,19,25] However, the circumstances under which retears occur after arthroscopic rotator cuff repair are still unclear.

The results of this study suggest that retears rarely occur in well-healed tendons that show intact cuff integrity with sufficient mechanical and biological healing within the first 3 postoperative months. In other words, retears occur in the early postoperative period. In addition, as mentioned above in the cases of Sugaya type III tendons, repaired tendons without discontinuity that showed thinning seemed to be healing even after 3 months, demonstrating that complete healing can occur even in incompletely healed tendon if placed in an environment that favors complete healing of the repaired tendon both mechanically and biologically. This leads us to believe that retear can occur due to lack of complete healing during this period. Thus, the healing process could be influenced by several factors, but further research on those factors is needed to make any conclusive assertions.

Two steps are necessary to prevent the occurrence of early retear and increase the survival of repaired tendons. First, it is important that the surgeon achieve firm anatomic restoration of the rotator cuff to the original footprint to enhance healing potential. Second, further studies must be conducted to develop a postoperative rehabilitation protocol that can improve the rate of healing and protect repaired tendon in the first 3 postoperative months.

Our results are consistent with previous studies that evaluated the timing of retears after arthroscopic rotator cuff repair. Miller et al[27] reported that recurrent rotator cuff tears are not uncommon and occur more frequently in the early postoperative period (within the first 3 months) after arthroscopic repair of large and massive tears. Nine of 22 repaired patients (41%) showed retears. Retears from 7 of these 9 patients appeared within 3 months after the surgery. However, the researchers stated that retears had not been observed after 6 months. Our study included small to medium-sized tears and examined patients whose repaired tendon was intact on MRI scans at 3 months. Therefore, the retear rate within 3 months cannot be considered to be definitive. Although it is difficult to directly compare the two studies, they support the same result—that retears tend to be uncommon after 3 months. In a study of 107 patients evaluated by MRI and ultrasound, Kluger et al[22] reported that 74% of patients exhibited repair failure within the first 3 months and that 11% of patients reported retear at 3 to 6 months, although the procedure was arthroscopic assisted mini-open repair. The remaining 15% of patients showed retear related to additional trauma and sports activity. Baring et al[1] reported that patients showed the largest increase in movement of radiostereometric markers during the first 2 to 3 months after surgery, the most intensive period of physical therapy; their study showed the high risk of injury during this period. Recently, McCarron et al[26] reported that only 30% of their patients formed a recurrent defect, and patients who formed a recurrent defect tended to have more tendon retraction during the first 6 weeks after surgery. This study emphasized that repairs should be protected in the early postoperative period.

To explore some important prognostic factors that may influence retears in the late postoperative period, we assigned our subjects to healed and retear groups after 3 months according to the results of their 1-year postoperative image study. The mean ± SD age at the time of surgery was 56.5 ± 10.6 years (range, 32-81 years) in the healed group and 62 ± 8.7 years (range, 49-75 years) in the retear group (P = .14). The mean time to operation was 7.5 ± 10.5 months (range, 0.5-60 months) in the

TABLE 4
Demographics and Surgical Procedures of Healed and Retear Groups

	Healed Group (n = 57)	Retear Group (n = 4)	*P* Value
Age, mean ± SD (range), y	56.5 ± 10.6 (32-81)	62 ± 8.7 (49-75)	.14
Sex, male/female, n	25/27	0/4	.09
Time to operation, mean ± SD (range), mo	7.5 ± 10.5 (0.5-60)	11.5 ± 15.6 (1-36)	.50
Dominant/nondominant side, n	34/18	4/0	.38
Medical history, n			.32
Diabetes mellitus	5	1	
Hypertension	10	1	
Cerebrovascular accident	1	0	
Asthma	0	1	
Injury mechanism, n			.99
Overuse	33	3	
Trauma	12	1	
Sports	8	0	
Concomitant procedures, n			.99
Distal clavicle resection	2	0	
Biceps tenotomy	11	2	
Bankart repair	1	0	
Brisement	2	0	

TABLE 5
Comparison of Preoperative Radiological and Intraoperative Findings Between Healed and Retear Groups

	Healed Group (n = 53)[a]	Retear Group (n = 4)	*P* Value
Tear shape, n			.001
Crescent	41	0	
U	6	0	
L	4	3	
Reverse L	2	1	
Delamination, n	10	4	.003
Tear size, mean ± SD (95% CI), cm	2.2 ± 0.9 (0.7-5.5)	3.7 ± 1.2 (2.5-5.5)	.001
Small to medium, n	43	0	
Large to massive, n	10	4	
Extent of retraction, mean ± SD (95% CI), cm	1.9 ± 0.8 (0.7-3.5)	3.4 ± 1.1 (2.0-5.0)	.004
Degree of fat infiltration, n			
Grade I/II/III[b]	39/13/1	0/1/3	<.001

[a]The total number in the healed group was 53 (not including 4 subjects with subscapularis repair).
[b]Goutallier classification.

healed group and 11.5 ± 15.6 months (range, 1-36 months) in the retear group (*P* = .50). Other demographics and surgical procedures of the two groups are presented in Table 4. Statistically significant postoperative clinical improvements were observed in both groups. However, in the comparison of clinical results between both groups, the results were not statistically significant except in internal rotation (see the Appendix, available in the online version of this article at http://ajsm.sagepub.com/supplemental).

The preoperative mean tear size was significantly greater in the retear group (3.7 ± 1.2 cm; range, 2.5-5.5 cm) than in the healed group (2.2 ± 0.9 cm; range, 0.7-5.5 cm) (*P* = .001). The preoperative extent of retraction of the torn tendon was significantly greater in the retear group (3.4 ± 1.1 cm; range, 2.0-5.0 cm) than in the healed group (1.9 ± 0.8 cm; range, 0.7-3.5 cm) (*P* = .004). There was a significant difference in the degree of fat infiltration (Goutallier classification, *P* < .001) and status of delamination (*P* = .003) between the healed group and retear group (Table 5).

The characteristics of patients who showed retear are as follows: (1) large to massive tear, (2) high chronicity, (3) greater extent of retraction, and (4) higher degree of fat infiltration. Even though the number of patients was not sufficient to make a generalization, these 4 characteristics are well-known factors involved in retears. These factors, along with complete tendon fixation, may lead to failure of the healing process. It is technically difficult to firmly fasten a damaged tendon to a footprint if a patient with a large to massive tear has poor tissue quality and severe retraction.[20] Additionally, the extent of retraction of the torn cuff in large to massive tears can reflect the chronicity of the tear, if no recent traumatic events have occurred. Chronically retracted tears can be correlated with severe fatty degeneration and muscle atrophy.[19,35] These factors may contribute to the early mechanical fixation failure and later failure of biological healing of the bone-tendon interface.

From the results described above, we can suggest that surgical strategies should endeavor to augment the repair mechanically and biologically during the early postoperative period. Research related to postoperative rehabilitation to protect the repaired tendon during the early healing period is needed. In addition, it is necessary to further investigate synthetics and scaffolds used to bridge rotator cuff tears and adjuvant biological modalities including growth factors, BMP, and tenocyte-seeded scaffold to augment tendon-to-bone healing.[5,23,31] It is advisable that an orthopaedic surgeon evaluate prognostic factors for retear during preoperative evaluation and design postoperative immobilization and rehabilitation, especially in a large to massive rotator cuff tear, with consideration of retear timing.

The strength of this study is that it investigates the structural status of repaired tendons based on imaging studies that targeted patients without retear in the early postoperative period. As well, our study has some limitations. First, this was a retrospective study. However, patients' data were collected preoperatively in an effort to overcome this limitation. Second, due to the relatively small number of patients, inadequate statistical power was achieved, but by examining the timing of retears in only patients who had an intact tendon on 3-months postoperative MRI, this study significantly demonstrated that retears were uncommon in the late postoperative period (after 3 months). The third limitation is that we used 2 different imaging methods for evaluation. Ultrasonography results are somewhat dependent on the examiner; MRI is more accurate, but ultrasonography was used in some patients due to financial reasons. To increase accuracy, a single radiologist who specialized in musculoskeletal injury evaluated the tendon integrity. Fourth, there was a possibility of selection bias. Sixty-nine patients did not undergo postoperative imaging studies twice. This might significantly bias our conclusion, as these patients might be very satisfied and have lower rates of retears than those who were willing to undertake MRI or ultrasound evaluations. For the purpose of the study, we included only those patients whose postoperative 3-month MRI and 1-year MRI or ultrasound evaluation were both available. Fifth, retear was evaluated at a mean of 12 months after surgery, which may be a relatively short time to verify the course of repaired tendons and clinical results. Therefore, further long-term studies are needed that investigate retear rates of healed tendon at an even later postoperative period.

CONCLUSION

Retears occur infrequently in the late postoperative period (after 3 months) in well-healed tendons that show intact cuff integrity with sufficient mechanical and biological healing within the first 3 postoperative months. Therefore, rotator cuff repair strategies should focus on both mechanical and biological aspects during the early postoperative period, especially in repairs of large to massive tears.

REFERENCES

1. Baring TK, Cashman PP, Reilly P, Emery RJ, Amis AA. Rotator cuff repair failure in vivo: a radiostereometric measurement study. *J Shoulder Elbow Surg*. 2011;20(8):1194-1199.
2. Bianchi S, Martinoli C, Abdelwahab IF. Ultrasound of tendon tears, part 1: general considerations and upper extremity. *Skeletal Radiol*. 2005;34(9):500-512.
3. Bishop J, Klepps S, Lo IK, Bird J, Gladstone JN, Flatow EL. Cuff integrity after arthroscopic versus open rotator cuff repair: a prospective study. *J Shoulder Elbow Surg*. 2006;15(3):290-299.
4. Boileau P, Brassart N, Watkinson DJ, Carles M, Hatzidakis AM, Krishnan SG. Arthroscopic repair of full-thickness tears of the supraspinatus: does the tendon really heal? *J Bone Joint Surg Am*. 2005;87(6):1229-1240.
5. Chen JM, Willers C, Xu J, Wang A, Zheng MH. Autologous tenocyte therapy using porcine-derived bioscaffolds for massive rotator cuff defect in rabbits. *Tissue Eng*. 2007;13(7):1479-1491.
6. Constant CR, Gerber C, Emery RJ, Sojbjerg JO, Gohlke F, Boileau P. A review of the Constant score: modifications and guidelines for its use. *J Shoulder Elbow Surg*. 2008;17(2):355-361.
7. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res*. 1987;214:160-164.
8. 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(12):1428.
9. Fotiadou AN, Vlychou M, Papadopoulos P, Karataglis DS, Palladas P, Fezoulidis IV. Ultrasonography of symptomatic rotator cuff tears compared with MR imaging and surgery. *Eur J Radiol*. 2008; 68(1):174-179.
10. Franceschi F, Ruzzini L, Longo UG, et al. Equivalent clinical results of arthroscopic single-row and double-row suture anchor repair for rotator cuff tears: a randomized controlled trial. *Am J Sports Med*. 2007;35(8):1254-1260.
11. Galatz LM, Ball CM, Teefey 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(2):219-224.
12. Gazielly DF, Gleyze P, Montagnon C. Functional and anatomical results after rotator cuff repair. *Clin Orthop Relat Res*. 1994;304:43-53.
13. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. *J Bone Joint Surg Am*. 2000;82(4):505-515.
14. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. 1994;304:78-83.
15. Goutallier D, Postel JM, Gleyze P, Leguilloux P, Van Driessche S. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. *J Shoulder Elbow Surg*. 2003;12(6):550-554.
16. Ianotti JP, Deutsch A, Green A, et al. Time to failure after rotator cuff repair: a prospective imaging study. *J Bone Joint Surg Am*. 2013;95(11):965-971.
17. Jost B, Pfirrmann CW, Gerber C, Switzerland Z. Clinical outcome after structural failure of rotator cuff repairs. *J Bone Joint Surg Am*. 2000;82(3):304-314.
18. Keener JD, Galatz LM, Stobbs-Cucchi G, Patton R, Yamaguchi K. Rehabilitation following arthroscopic rotator cuff repair: a prospective randomized trial of immobilization compared with early motion. *J Bone Joint Surg Am*. 2014;96(1):11-19.
19. Kim JR, Cho YS, Ryu KJ, Kim JH. 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(4):786-793.
20. Kim KC, Shin HD, Cha SM, Kim JH. Repair integrity and functional outcomes for arthroscopic margin convergence of rotator cuff tears. *J Bone Joint Surg Am*. 2013;95(6):536-541.
21. Kim YS, Chung SW, Kim JY, Ok JH, Park I, Oh J. Is early passive motion exercise necessary after arthroscopic rotator cuff repair? *Am J Sports Med*. 2012;40(4):815-821.

22. Kluger R, Bock P, Mittlbock M, Krampla W, Engel A. Long-term survivorship of rotator cuff repairs using ultrasound and magnetic resonance imaging analysis. *Am J Sports Med*. 2011;39(10):2071-2081.
23. Kovacevic D, Rodeo SA. Biological augmentation of rotator cuff tendon repair. *Clin Orthop Relat Res*. 2008;466(3):622-633.
24. Levy O, Venkateswaran B, Even T, Ravenscroft M, Copeland S. Mid-term clinical and sonographic outcome of arthroscopic repair of the rotator cuff. *J Bone Joint Surg Br*. 2008;90(10):1341-1347.
25. Liu SH, Baker CL. Arthroscopically assisted rotator cuff repair: correlation of functional results with integrity of the cuff. *Arthroscopy*. 1994;10(1):54-60.
26. McCarron JA, Derwin KA, Bey MJ, et al. Failure with continuity in rotator cuff repair ''healing.'' *Am J Sports Med*. 2013;41(1):134-141.
27. Miller BS, Downie BK, Kohen RB, et al. When do rotator cuff repairs fail? Serial ultrasound examination after arthroscopic repair of large and massive rotator cuff tears. *Am J Sports Med*. 2011;39(10):2064-2070.
28. Park JY, Lhee SH, Oh KS, Moon SG, Hwang JT. Clinical and ultrasonographic outcomes of arthroscopic suture bridge repair for massive rotator cuff tear. *Arthroscopy*. 2013;29(2):280-289.
29. Richards DP, Burkhart SS, Lo IK. Subscapularis tears: arthroscopic repair techniques. *Orthop Clin North Am*. 2003;34(4):485-498.
30. Richards RR, An KN, Bigliani LU, et al. A standardized method for the assessment of shoulder function. *J Shoulder Elbow Surg*. 1994;3(6):347-352.
31. Rodeo SA, Potter HG, Kawamura S, Turner AS, Kim HJ, Atkinson BL. Biologic augmentation of rotator cuff tendon-healing with use of a mixture of osteoinductive growth factors. *J Bone Joint Surg Am*. 2007;89(11):2485-2497.
32. Sonnabend DH, Howlett CR, Young AA. Histological evaluation of repair of the rotator cuff in a primate model. *J Bone Joint Surg Br*. 2010;92(4):586-594.
33. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: single-row versus dual-row fixation. *Arthroscopy*. 2005;21(11):1307-1316.
34. Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F. Prediction of rotator cuff repair results by magnetic resonance imaging. *Clin Orthop Relat Res*. 1997;344:275-283.
35. Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F. Atrophy of the supraspinatus belly: assessment by MRI in 55 patients with rotator cuff pathology. *Acta Orthop Scand*. 1996;67(3):264-268.
36. Yen CH, Chiou HJ, Chou YH, et al. Six surgery-correlated sonographic signs for rotator cuff tears: emphasis on partial-thickness tear. *Clin Imaging*. 2004;28(1):69-76.