Does Open Repair of Anterosuperior Rotator Cuff Tear Prevent Muscular Atrophy and Fatty Infiltration?

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Abstract

Background Repair of cuff tears involving rotator interval reportedly improves function. However, it is unclear whether successful repair prevents shoulder degenerative changes.

Questions/purposes Therefore, we (1) documented the minimal 4-year function of patients who underwent open surgical repair for rotator interval tears; (2) evaluated repaired tendon healing with postoperative MRI; and (3) sought to determine the influence of tendon healing on muscular and glenohumeral joint changes.

Methods We retrospectively analyzed 22 patients (23 shoulders) treated by open transosseous reinsertion of supraspinatus and subscapularis tendons. The mean age of the patients was 53 years (range, 37–64 years). The tear

was traumatic in four cases. Repair healing and muscular changes were assessed using MRI. The minimum followup was 46 months (mean, 75 months; range, 46–103 months). **Results** We observed an improvement in the absolute Constant-Murley score from 63 points preoperatively to 76 points postoperatively. With the last followup MRI, the supraspinatus tendon repair had failed in two of the 23 shoulders, whereas the subscapularis tendon repair had healed in all cases. Once healing of the repaired tendon occurred, supraspinatus muscle atrophy never worsened. However, on MRI fatty infiltration of the rotator cuff muscles increased despite successful tendon repair. Glenohumeral arthritis remained stable. Postoperative abduction and internal rotation strengths were better when the standardized supraspinatus muscle area was greater than 0.5 at the final evaluation.

Conclusion Durable functional improvement and limited degenerative articular and muscular changes can be expected in most patients 4 to 10 years after open repair of anterosuperior cuff tears provided that healing of the cuff is obtained.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved or waived approval for the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Rotator cuff tears are a common cause of shoulder pain and dysfunction in adults. Tears typically occur in the supraspinatus tendon and extend posteriorly into the infraspinatus tendon, defining posterolateral rotator cuff tears. The literature shows operative treatment of these tears generally restores a pain-free functional shoulder [4, 7, 19, 28, 31]. Nich et al. [28] suggested that a torn rotator

cuff repair could restore normal glenohumeral joint mechanics and subsequently limit the risk for degenerative changes.

In contrast, tears involving the supraspinatus and subscapularis tendons are much less common. Anterior extension of tears to the subscapularis tendon interrupts the rotator interval and defines anterosuperior rotator cuff tears [29]. Causes are degenerative or traumatic, including anterior glenohumeral dislocation, forced external rotation of the adducted arm, and forced hyperextension of the abducted arm. Combined disorders of the proximal tendon of the long head of the biceps brachii are associated in 31% to 56% cases and result in thickening, medial subluxation or frank dislocation, and rupture [6, 13, 14].

Although preserved shoulder function can be observed in patients with irreparable rotator cuff tears [3, 11, 12], the disruption of natural force balance between the anterior subscapularis muscle and posterior infraspinatus muscle reportedly leads to substantial disability [27, 30, 36]. Therefore, closure of the rotator interval and restoration of the AP force balance appear critical [38]. In a recent experimental study, Hsu et al. [20] reported repairing the balance of anterior and posterior cuff forces was enough to restore shoulder function, even if the supraspinatus tendon remained torn. Pain relief and restoration of internal rotation strength can be expected after surgical repair of isolated tears of the subscapularis tendon [6, 14, 24]. Several authors [2, 36] reported a minimum of 30% increase in the average Constant-Murley scores 2 years after either arthroscopic or surgical technique repair of a combined tear of the supraspinatus and subscapularis tendons. In addition, Flury et al. [8] found rerupture was more likely to occur with severe preoperative fatty degeneration, but did not show whether healing of the repair ultimately influenced postoperative atrophy and fatty muscle infiltration. After our previous study showed that supraspinatus muscle atrophy, but not fatty muscle infiltration, could be stabilized after successful repair of superior and posterosuperior tears [28], we asked whether open repair of anterosuperior rotator cuff tears could prevent muscular changes.

Therefore, we (1) documented the minimal 4-year function of patients who underwent open surgical repair for a rotator interval tear; (2) evaluated repaired tendon healing with postoperative MRI; and (3) attempted to determine the influence of tendon healing on supraspinatus muscle atrophy, fatty infiltration, and subsequent glenohumeral joint changes.

Patients and Methods

From September 2000 to September 2005, we performed open surgery for a torn rotator cuff tear in 91 patients (94

shoulders). For this review we included patients with (1) an anterosuperior rotator cuff lesion defined by a chronic full-thickness detachment of the supraspinatus tendon retracted on the humeral head apex associated with a tear of at least the superior third of the subscapularis tendon treated with open repair; (2) persistent pain and/or shoulder disability after minimal 6-month nonoperative treatment; (3) an age younger than 65 years and/or the need or desire to improve abduction and internal rotation strengths; and (4) minimum 4-year clinical and radiographic followup after surgery. We excluded patients with (1) a previous attempt at rotator cuff repair; (2) an irreparable tear defined as torn tendon(s) retracted to the glenoid rim and fatty muscle infiltration greater than Stage 2 according to the system of Goutallier et al. [16]; (3) the presence of an infraspinatus tendon complete tear; and (4) osteoarthritis (OA) rated severe according to Samilson and Prieto [32], or rheumatoid disease of the glenohumeral joint. Twenty-two patients (23 shoulders) met the inclusion criteria and were enrolled in the study. None of the 22 patients in this study had been previously reported. Nine patients were men and 13 were women. All patients had chronic shoulder pain that had been treated with medication, physical therapy, and/or subacromial injection of cortisone. The mean duration of symptoms before surgery was 24 months (range, 6–60 months). The ages of the patients at the time of surgery ranged from 37 to 64 years (mean, 53.4 ± 7 years). The right shoulder was treated in 16 patients, the left shoulder was treated in five patients, and a bilateral staged procedure was performed in one patient. The dominant shoulder was involved in 14 cases. Four male patients (four shoulders) could relate the onset of their symptoms to an acute traumatic event with forced external rotation with the arm adducted. In the remaining cases, the current rotator cuff tear could not be related to a traumatic event. Preoperatively, 17 patients were active or were involved in strenuous activity. Five patients were retired or sedentary. One patient (one shoulder) died of an unrelated cause, and two patients (two shoulders) were lost to followup. The 19 remaining patients (20 shoulders) were evaluated clinically by an independent assistant (MDS) and with use of standard radiographs. The minimum followup was 46 months (mean, 74.5 ± 14.5 months; range, 46–103 months). Patients were contacted specifically for the purpose of this study.

As determined with preoperative CT arthrograms and confirmed intraoperatively, a chronic full-thickness tear of the supraspinatus tendon was combined with a tear of the subscapularis tendon, detaching less than 1/2 (but more than 1/3) of its insertion in 17 shoulders. In the three remaining cases, the subscapularis tendon tear involved more than 1/2 of its insertion. Associated rotator cuff lesions included degenerative rupture or dislocation of the

long head of the biceps in 16 cases and delamination tears of the supraspinatus tendon in seven cases. Neither a delamination tear nor full-thickness tear of the infraspinatus tendon was observed.

No detachment of the superior labrum could be observed, but the presence of degenerative fraying was seen in 17 cases. The main stages of the surgical technique have been described in detail [28]. Briefly, a superolateral approach was used routinely with the patient in the lateral position. The deltoid muscle was split between its anterior and lateral portions parallel to its muscle fibers. Antero-inferior acromioplasty, release of the coracoacromial ligament, and release of the subacromial bursa were performed. After examination of the rotator cuff, the degenerative tendon tear border was excised. We made an intraarticular incision at the labrum-capsule junction to release the torn tendon. The free border of the supraspinatus tendon was inserted in a deep osseous proximalized trough and maintained with nonabsorbable transosseous sutures as previously reported [28]. The detached superior border of the subscapularis was reinserted on the lesser tuberosity with two nonabsorbable anchors (Quick Anchor Plus; Mitek; Johnson and Johnson, Norwood, MA, USA) after local débridement. Tenodesis of the long head of the biceps was performed in 15 cases because it either was degenerated or dislocated. In these cases, the biceps tendon was fixed into its groove using a nonabsorbable anchor (Quick Anchor Plus) after local débridement and slight deepening of the groove with a dental burr. We closed the interval between the subscapularis and the supraspinatus with nonabsorbable sutures (Mersuture; Ethicon, Johnson and Johnson, Westwood, MA, USA) to ensure the cuff repair was watertight. Secure deltoid repair was achieved using Number 3 Mersuture (Ethicon), a nonabsorbable transacromial suture. When more than 1/2 of the subscapularis tendon insertion was detached as observed on the preoperative CT arthrogram (three shoulders), exploration and repair of the torn tendons were achieved using a deltopectoral approach with the patient in the supine position. The successive steps of the surgical procedure were completed as described in a previous study [28]. The free border of the subscapularis tendon then was reinserted on the lesser tuberosity with nonabsorbable anchors (Mitek).

Postoperatively, rotator cuff repairs were protected in an abduction (60°), slight flexion, and neutral rotation brace, for 6 weeks. Two to 3 days after surgery, patients were referred to a rehabilitation unit, where passive mobilization of the shoulder above the abduction level of 60° was started once a day. All exercises were performed under the supervision of the physiotherapist. External rotation was not permitted for 6 weeks after surgery. After 6 weeks, progressive decreased abduction was begun in combination with self-assisted pendulum and active shoulder ROM

exercises. The postoperative rehabilitation protocol is detailed (Table 1).

We evaluated patients preoperatively and followed each with clinical examinations 6 weeks, 3 months, 6 months, and 1 year postoperatively according to the method of Constant and Murley [5]. The Constant-Murley score was calculated as an absolute numeric value and as a percentage of an age- and gender-matched normal score (the relative Constant-Murley score). We measured pain using a VAS ranging from 0 (severe pain) to 15 (no pain). At the last followup, assessment of ROM and evaluation of abduction and internal rotation strengths were performed using a digital dynamometer with the arm abducted 90° and with the arm to the side, respectively.

We obtained standardized radiographic examinations (true AP radiographs of the glenohumeral joint with the arm in internal, external, and neutral rotation, and a scapular Y view) under fluoroscopic control for each patient preoperatively and at the latest followup. All images were analyzed by one musculoskeletal radiologist (CM) who was blinded to the clinical data of the patients. OA of the glenohumeral joint was categorized according to the criteria of Samilson and Prieto [32]. This classification system, originally described for dislocation arthropathy of the shoulder, is based on the inferior height of the humeral osteophyte and rates OA as mild (< 3 mm), moderate (3–7 mm), or severe (> 7 mm). One shoulder was considered free of arthritis. OA was classified as mild in 20 shoulders and moderate in two. No shoulder had severe OA. We measured subacromial space height on plain AP radiographs of the glenohumeral joint in neutral rotation. The preoperative subacromial space height ranged from 5 to 13 mm with a mean of 9.3 ± 1.7 mm. Horizontal centering of the humeral head was evaluated on an axillary view at the latest followup and was expressed as the distance between the center of the glenoid rim and the perpendicular projection of the center of the humeral head. All patients had a preoperative CT arthrogram. One patient (one shoulder) was unable to return for postoperative MRI for reasons not related to the results of the surgery. According to the staging system of Goutallier et al. [16], mean preoperative fatty muscle infiltration was 0.65 ± 0.8 (range, 0–1.66). Supraspinatus muscle atrophy was measured on the most lateral image on which the scapular spine was in contact with the scapular body on the oblique and sagittal views (the Y-shaped view), as described by Thomazeau et al. [34]. We digitally measured the cross-sectional areas of the supraspinatus muscle and its fossa using a picture-analyzing system (OsiriX DICOM viewer, open-source software, Pixmeo, Geneva, Switzerland). Results were expressed as the standardized muscle area defined by the cross-sectional area of the muscle to the cross-sectional area of the fossa [33, 39]. At last followup, repaired tendon

Table 1. Rehabilitation protocol after rotator cuff repair

Postoperative phase	Goals	Exercise	Immobilization
Phase I: 0–6 weeks	<ol style="list-style-type: none"> 1. Allow repair healing 2. Control pain and inflammation 3. Initiate ROM exercises 4. Patient education 	<p>Immediate postoperative:</p> <p>Cold pack</p> <p>Passive abduction in the plane of the scapula in the supine position</p> <p>Active elbow flexion /extension</p> <p>Gripping exercises for hand</p> <p>Postoperative Weeks 1–6:</p> <p>Continue immediate postoperative exercises</p> <p>Passive abduction in the plane of the scapula in the beach-chair position</p> <p>Deltoid and biceps soft tissue mobilization</p> <p>Active internal rotation and scapular exercises (shoulder shrugs)</p> <p>Static contraction of the infraspinatus and teres minor muscles</p> <p>Active cervical movements</p>	Abduction brace (60°)
Phase II: 6–12 weeks	<ol style="list-style-type: none"> 1. Improve to full ROM 2. Improve neuromuscular control and strength 3. Emphasize normal scapulohumeral rhythm 	<p>Continue Phase I ROM exercises</p> <p>Passive external rotation and initiate active external rotation at 45° with arm supported</p> <p>Manual resistive exercise (internal rotation) with arm supported</p> <p>Phase I strengthening (external rotation, internal rotation, extension)</p> <p>Resisted scapular strengthening (with arms below shoulder height)</p> <p>Pendulums</p>	Abduction pillow (45°) with progressive decreased abduction from postoperative Week 6 to Week 8
Phase III: 12–16 weeks	<ol style="list-style-type: none"> 1. Full ROM 2. Optimize neuromuscular control 3. Improve endurance and strength 4. Initiate return to functional activities 	<p>Continue all ROM and strengthening</p> <p>Progress to Phase II strengthening: abduction, flexion and external rotation</p> <p>Manual resistance for rotator cuff and deltoid</p>	None
Phase IV: 16 weeks–6 months	<ol style="list-style-type: none"> 1. Return to work, sport, or desired activities 2. Continue education 	<p>Gradual return to work or desired activity</p> <p>Work- or sport-specific exercises</p> <p>Avoid repetitive work above shoulder height</p>	

ROM = range of motion.

healing, fatty infiltration of the rotator cuff muscles, subscapularis muscle area, and supraspinatus muscle atrophy were evaluated with standardized MRI using a 1.5-T MR system (Signa; GE Healthcare Technologies, Waukesha, WI, USA) as previously reported [28]. We assessed healing or rerupture of the repaired supraspinatus or subscapularis tendon on oblique coronal fast spin echo fat-saturated T2-weighted sequences. When a fluid-equivalent signal or nonobservation of the supraspinatus or subscapularis tendon was found on at least one section, the diagnosis of a full-thickness rerupture was made. We assessed fatty muscle infiltration according to a classification derived from that of Goutallier et al. [16] as adapted for use with MRI [39] on oblique parasagittal T1-weighted fast spin

echo sequences. Fatty muscle infiltration was expressed as a mean for the supraspinatus, infraspinatus, and subscapularis muscles.

Numerical data were expressed as mean with SD. We determined differences in the Constant-Murley score, pain scores, and strength between the preoperative and postoperative periods using the Wilcoxon nonparametric test (paired groups). We determined whether MRI findings (repaired tendons state, fatty muscle infiltration, and standardized muscle area) correlated with the final function using Fisher's exact test. To determine the influence of postoperative supraspinatus muscle atrophy on function, we compared the Constant-Murley scores for patients according to a standardized muscle area threshold set at 0.5 using

the Mann-Whitney rank sum test [28, 33]. We then determined whether the operative procedure and repair healing, as assessed on the last followup MRI, influenced subacromial space height and glenohumeral arthritis using the Mann-Whitney rank sum test and Fisher's exact test, respectively. All statistical analyses were performed using XLSTAT software (Addinsoft, Paris, France), an add-on for Microsoft Excel (Microsoft Corp, Redmond, WA, USA).

Results

The average absolute and relative Constant-Murley scores improved from 63 ± 8.7 points (range, 47–78 points; mode, 61 points) and $78\% \pm 11.7\%$ (range, 63%–100%; mode, 72%) preoperatively to 76 ± 16 points (range, 39–95 points; mode, 76 points) and $98\% \pm 19.5\%$ (range, 51%–120%; mode, 118%) postoperatively, respectively (Table 2). We noted postoperative improvement in the average score for shoulder pain, average score for activities of daily living, average abduction, and internal rotation strengths. Postoperative functional scores were similar ($p = 0.19$) regardless whether a tenodesis of the long head of the biceps had been performed. Thirteen of 16 active reviewed patients had returned to work at the same level at a mean of 4.2 months.

Supraspinatus tendon repair was considered healed in 17 of the 19 shoulders as assessed by MRI. A full-thickness

retear was noted in only one case, whereas a delamination tear of the tendon was observed in another case. Healing of the subscapularis tendon repair was noted in all shoulders. Preoperative and postoperative standardized supraspinatus muscle areas were comparable ($p = 0.37$) after tendon healing: 0.58 versus 0.61, respectively. For tendon healing failure, the supraspinatus muscle area tended to decrease postoperatively and was lower than the supraspinatus muscle area in healed cuffs. The cross-sectional area of the subscapularis muscle was greater ($p = 0.03$) in shoulders with a supraspinatus muscle area greater than 0.5. Fatty infiltration of the supraspinatus muscle progressed ($p = 0.0001$) with time from 0.7 ± 0.73 preoperatively to 1.16 ± 0.61 postoperatively regardless of repair healing. Fatty infiltration of the subscapularis muscle progressed ($p = 0.02$) with time from 1 ± 0.79 preoperatively to 1.22 ± 0.54 postoperatively. Fatty infiltration of the three muscles progressed ($p = 0.01$) with time from 0.65 ± 0.8 (range, 0–1.66; mode, 1) preoperatively to 1 ± 0.4 (range, 0.33–1.66; mode, 1.33) postoperatively. Neither preoperative CT nor clinical parameters predicted a postoperative retear.

The two shoulders with tendon retears had lower absolute and relative Constant-Murley scores compared with those with healed repairs. Absolute and relative functional scores were consistently higher ($p = 0.009$ and $p = 0.046$, respectively) when postoperative standardized supraspinatus muscle area was greater than 0.5. In this case, abduction

Table 2. Preoperative and postoperative clinical parameters in 20 shoulders

Clinical parameters	Preoperative	Postoperative	p value*
Constant-Murley score			
Absolute (points)	63	76	0.003
Relative [†] (%)	78	98	0.004
Pain score [‡] (points)	9.3	12	0.04
Activities of daily living score (points)	14.6	16.2	0.03
Active motion (degrees)			
Flexion	105	122	0.02
Abduction	110	120	0.03
External rotation	47	43.2	0.09
Internal rotation (thoracic level reached with thumb)	5.2	4.1	0.01
Abduction strength [§]			
Kilograms	5.5	7.7	0.02
Points	11	15.5	0.02
Internal rotation strength [¶]			
Kilograms	5.1	12	0.006

* According to the Wilcoxon signed rank test with $p < 0.05$ as the level of significance; [†]the relative Constant-Murley score is the percentage of an age- and gender-related normal value according to the system of Constant-Murley [5]; [‡]as measured with a VAS on which 15 indicates no pain and 0 indicates intolerable pain; [§]abduction strength was measured with a digital dynamometer with the arm in 90° scapular abduction, the elbow extended, resistance applied at the wrist, and the forearm pronated; ^{||}according to the scoring system of Constant-Murley; patients with active abduction less than 90° are given 0 points for strength; [¶]internal rotation strength was measured with a digital dynamometer with the arm to the side, the elbow in 90° flexion, resistance applied at the wrist, and the forearm in neutral position.

and internal rotation strengths were specifically greater ($p = 0.02$ and $p = 0.017$, respectively). In contrast, postoperative Constant-Murley scores were not related to the degree of fatty muscle infiltration. Glenohumeral arthritis remained stable ($p = 0.55$) with time. Postoperatively, mild glenohumeral OA was noted in 18 shoulders and moderate OA in two. Mean subacromial space height improved ($p = 0.0017$) from 9.3 ± 1.7 mm (range, 5–12 mm) preoperatively to 11.25 ± 1.9 mm (range, 7–15 mm) postoperatively. Limited anterior subluxation of the humeral head was observed in seven cases with a mean eccentricity of 1.7 mm (range, 1–3 mm) in these cases. In 13 other cases (65%), the glenohumeral joint was considered centered on the axillary view.

There were two complications in the 19 patients. One patient had paresis of the ulnar nerve through abduction splint compression and underwent surgical neurolysis after an 8-month attempt of nonoperative treatment. One patient had postoperative reflex sympathetic dystrophy and received medical treatment. At the last followup, no surgical revision had been done.

Discussion

Anterior extension of a full-thickness rotator cuff tear to the subscapularis tendon has been identified as a negative factor for global shoulder function, notably after surgical repair [11, 12, 27, 36]. However, the influence of the anatomic location of the tear on the postoperative long-term function and structural characteristics of the rotator cuff is unknown. Therefore, our objectives were to (1) document the minimal 4-year function of patients who underwent open surgical repair for an anterosuperior rotator cuff tear; (2) evaluate repaired tendon healing with postoperative MRI, and (3) determine the influence of tendon healing on supraspinatus muscle atrophy, fatty infiltration, and glenohumeral joint changes.

We recognize some limitations may affect the findings of the current study. First, evaluation of anatomic repair using standard MRI is debated [10, 39]. Although we used fat-suppressed sequences, MRI may have underestimated small and partial-thickness recurrent tears. To circumvent this issue, the diagnosis of rerupture was based on selective criteria applied by an independent radiologist. In addition, MRI provided valuable and accurate data regarding supraspinatus muscle atrophy and fatty muscle infiltration in a noninvasive way, although comparing the latter with preoperative CT parameters may be questionable [10, 39]. Second, enrollment of the patients in the study was based on the anatomic location of the full-thickness tear, not on the mechanism. It is probable that the nature of the tear, traumatic or degenerative, influences functional and

anatomic postoperative parameters. However, we attempted to accurately describe anatomic preoperative features such as torn tendon retraction degree, fatty muscle infiltration, and belly muscle atrophy. Therefore, we believe the population studied here was clearly defined. Third, data should be interpreted with caution given the lack of statistical power as a result of the small patient cohort.

Previous evaluations of surgical repair of anterosuperior rotator cuff tears [27, 36] noted an overall worse functional prognosis than that for the surgical treatment of isolated complete subscapularis and posterosuperior cuff tears [6, 13, 14, 23, 25] (Table 3). Warner et al. [36] reported limited postoperative improvement in active flexion and in pain and a persistent deficiency of the subscapularis and infraspinatus muscles in more than $\frac{1}{2}$ of the shoulders. They found an increase of 31% in the relative Constant-Murley score over the preoperative period in a series of 19 anterosuperior cuff repairs. However, in seven patients, the Constant-Murley score had improved less than 10% “correlating uniformly with a poor subjective result in these cases” [36]. In line with these findings, we noted a slight increase in active shoulder flexion. However, the latter appears limited in comparison to an average 134° flexion obtained after posterosuperior cuff repair as previously observed [28]. Overall, we found a mean increase of 20% in the relative Constant-Murley score can be expected after anterosuperior cuff surgical repairs, leading to satisfying shoulder function. In contrast to other reports [27, 36], we found a delay between onset of symptoms and surgery was not associated with lower postoperative scores. We interpret these differences as the result of careful selection of patients with regard to preoperative arthro-CT parameters such as limited degree of retraction of torn tendons and limited fatty muscle infiltration. Finally, we favor biceps tenodesis versus tenotomy when a tear of the long head of the biceps tendon limits the risk for distal biceps tendon migration and because tenodesis reportedly provides greater load to failure [37].

Some studies reported short-term rerupture rates of 13% [8] and 35% [21] in anterosuperior rotator cuff tendon repairs using surgical and arthroscopic techniques. Our observations compare with those from these studies. MRI showed two retears of the supraspinatus tendon repairs in 19 cases, with only one full-thickness lesion at a mean of 6 years. Subscapularis tendon repairs were considered healed in all cases. Because most recurrences reportedly develop within the first 6 postoperative months [22], our findings suggest open transosseous reinsertion of torn tendons, including proximalization of the supraspinatus tendon, provided durable stabilization of bone-tendon healing. Consistent with previous findings [28, 34], we observed stabilization of supraspinatus muscular volume between the preoperative and postoperative periods

Table 3. Comparison of literature reporting results for anterosuperior rotator cuff surgical repairs

Study	Followup (months)	Number of cases	Surgical technique	Biceps tenodesis (% cases)	Postoperative imaging assessment	Improved parameters (% cases)	Retear rate	Main findings
Warner et al. [36]	40	n = 19	Transosseous reinsertion	100%	–	Flexion (active), external rotation (passive), pain, lift-off test (25%), Constant-Murley score	–	Correlations between: preoperative FMI and tendon quality, preoperative muscle atrophy and abduction strength, Constant-Murley score and preoperative FMI, Constant-Murley score and duration of symptoms
Flury et al. [8]	35	n = 32*	Transosseous reinsertion	57%	US	Abduction and internal rotation (active), pain, strength (internal rotation), lift-off test (73%), Constant-Murley score	13%	Correlations between: preoperative FMI and rerupture rate, prerupture rate and duration of symptoms, Constant-Murley score and repair failure, Glenohumeral osteoarthritis: stable
Namdari et al. [27]	56	n = 30	Transosseous reinsertion	40%	–	Flexion (active), internal rotation (passive), pain, strength (internal rotation, flexion), lift-off test (56%), DASH, SST, Constant-Murley score	–	Correlations between: Constant-Murley score and duration of symptoms
Current study	74.5	n = 23	Transosseous reinsertion	75%	MRI	Flexion, abduction and internal rotation (active), pain, strength (abduction, internal rotation), Constant-Murley score	10%	Correlations between: postoperative muscle atrophy and repair healing, postoperative muscle atrophy and abduction and internal rotation strengths, Constant-Murley score and repair failure, FMI progression independent of repair healing, Glenohumeral osteoarthritis: stable

* of a larger series including infraspinatus tendon tears; US - ultrasound; FMI: fatty muscle infiltration; DASH = disabilities of the arm, shoulder and hand; SST = simple shoulder test.

provided that repair healing occurred. In contrast, atrophy of the supraspinatus muscle tended to worsen after repair failure. Globally, the degree of fatty muscle infiltration increased in all cases independent of cuff healing. Interestingly, the consequence of the latter on shoulder strength appeared limited, because internal rotation and abduction strengths were consistently improved at last followup. This inevitable progression of the fatty muscle infiltration has been observed by others [9, 15, 16, 26, 28, 35]. From our data, however, it cannot be excluded that increased fatty muscle infiltration at last followup was also a function of patient aging.

Several studies have shown that function tends to be better in patients with healed rotator cuffs [1, 9, 16, 18]. We similarly observed lower absolute and relative Constant-Murley scores when a retear occurred. Our observations suggest patients with repairs that healed had better improvement in pain and activities of daily living. Confirming previous observations [28, 33], a standardized muscle area greater than 0.5 was associated with higher Constant-Murley scores. We believe the supraspinatus muscle area is a determining factor influencing function of the rotator cuff after surgical repair.

Habermeyer et al. [17] suggested combined full-thickness tears of the supraspinatus and subscapularis tendons led to progressive anterior and superior migration of the humeral head resulting in glenohumeral arthritis. Although there is a lack of preoperative axillary views in our study, we noted an absence of anterosuperior eccentricity of the humeral head in the majority of shoulders at last followup. In combination with the finding of an improved subacromial space height, we assume the current surgical procedure provided effective stabilization of the humeral head. As a result, glenohumeral arthritis remained limited at a mean of 6 years.

We believe open repair of the supraspinatus and subscapularis tendons with a transosseous technique combined with a biceps tenodesis is a reasonable option for patients with anterosuperior rotator cuff tears. For our patients, this technique led to durable functional improvement, with limited degenerative changes of the glenohumeral joint and a high rate of repair healing after 4 to 10 years. Although successful repairs were associated with limited muscular atrophy, we did not observe a benefit of repair healing on fatty muscle infiltration. Further investigation is needed to fully understand the consequences of fatty muscle infiltration on shoulder function and to explore new pathways to prevent it.

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