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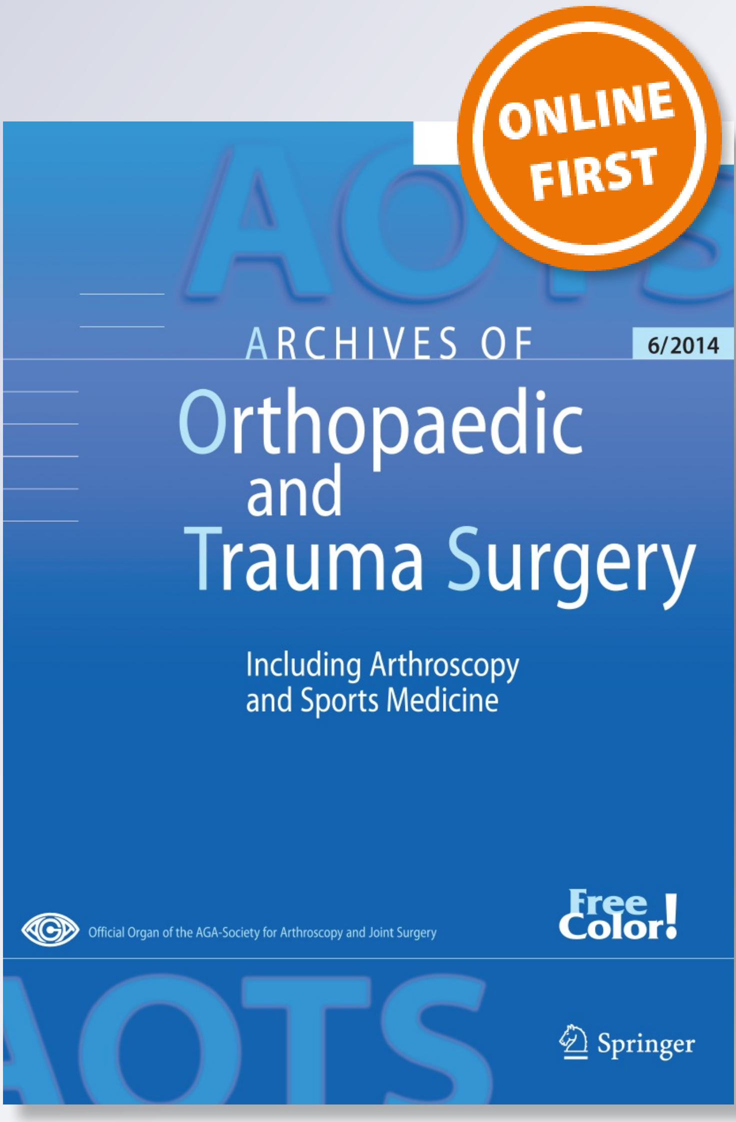

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ARTHROSCOPY AND SPORTS MEDICINE

Fatty degeneration and atrophy of the rotator cuff muscles after arthroscopic repair: does it improve, halt or deteriorate?

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Abstract

Objective The purpose of this study was to evaluate the changes in fatty degeneration and atrophy of rotator cuff muscles after arthroscopic repair. We further assessed the factors affecting the functional outcomes and integrity of the rotator cuff.

Materials and methods One hundred and two prospectively followed patients who underwent single-row arthroscopic repair for full-thickness rotator cuff tears between 2008 and 2010 in our institution were included. All patients underwent shoulder MRI examination before the arthroscopic repair and at the final follow-up at least 2 years after the surgical repair. Supraspinatus muscle atrophy was measured and evaluated according to the Thomazeau classification. The fatty degeneration of the cuff muscles was graded according to the Goutallier classification. Functional outcomes were assessed with the Constant shoulder score. The changes in fatty degeneration and atrophy were analyzed during the treatment period. Correlation coefficients (Pearson *r*) and stepwise, multiple linear regression were used to determine the relationship between the outcome variables (final Constant score and integrity of the cuff), and the predictor variables, age, sex, follow-up duration, initial muscle atrophy, final muscle atrophy, initial fatty degeneration and final fatty degeneration.

Results Of the 102 patients reviewed, 87 patients responded and concluded the final clinical follow-up and MRI examination (85.2 % follow-up rate). There were 67 females and 20 males with a mean age of 62.5 ± 8.3 years (range 40–80 years). Mean follow-up period was 30.1 ± 5.8 months (range 24–43 months). At the final follow-up, the mean Constant shoulder score was 94.2 ± 8.2 (range 70–100), and 66 (75.9 %) patients rated as excellent, 14 (16.1 %) as good, and 7 (8.0 %) as fair. No patient had poor results. There was re-rupture in 26 (29.9 %) patients on final MRI examination. No patient had improvement in muscle atrophy and fatty degeneration. The atrophic changes between intact tendon and re-rupture cases were statistically similar ($p = 0.300$). The deterioration of fatty degeneration was significantly higher in the re-rupture group ($p = 0.0001$). The Constant shoulder score was significantly lower in patients with re-rupture (97.4 ± 5.0 versus 86.6 ± 9.3, $p = 0.001$).Multiple stepwise regression analysis showed that the Constant score was dependent on the final integrity of the tendon and the size of the tear (R^2 0.420, p 0.001). The final integrity of the tendon was dependent on the age of the patient, initial and final fatty degeneration of the cuff muscles and the size of the tear (R^2 0.669, p 0.001).

Conclusion Initial muscle atrophy and fatty degeneration did not improve even after a successful rotator cuff repair where the tendon anatomic integrity was maintained for at least 2 years. It may continue to deteriorate, and the best possibility was preservation of the preoperative status. On the other hand, in cases of re-rupture, fatty degeneration and atrophy continued to worsen significantly. The factors affecting tendon integrity were found to be the age of the patient, the size of the tear and the severity of preoperative fatty degeneration in the rotator cuff.

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Introduction

It is well known that following full-thickness rotator cuff tendon tears, retraction, atrophy, fibrosis and fatty degeneration develop within rotator cuff muscles [1–4]. The underlying pathophysiology for these quantitative and qualitative changes has not yet been fully clarified. Research on this subject on a cellular and molecular basis is still ongoing [5–7]. Rotator cuff fatty degeneration was first classified using computerized tomography (CT) scans by Goutallier et al. then modified by Fuchs et al. on magnetic resonance imaging (MRI) [3, 8]. Rotator cuff muscle atrophy, particularly the supraspinatus atrophy, was classified with a quantitative measurement method on MRI which is described by Thomazeu et al. [9]. Both measurement methods are widely accepted and used as the indicators of the qualitative status of the rotator cuff muscles.

Following rotator cuff repair, one of the most important factors determining clinical results and anatomic cuff integrity is accepted as the amount of initial atrophy and the severity of fatty degeneration in the rotator cuff muscles [1–3, 10–12]. When the muscle starts to be used actively after a successful repair, these changes are expected to regress. However, there are conflicting findings and opinions on the subject of how these changes are affected by tendon repair and debate still continues. Some authors claim that there is improvement, while others suggest that it is an irreversible process [3, 9–11].

The purpose of this study was to evaluate the changes in fatty degeneration and atrophy of rotator cuff muscles after arthroscopic repair. We further assessed the several factors affecting the functional outcomes and integrity of the rotator cuff.

Materials and methods

Patients

A retrospective review was performed on 102 prospectively followed patients with degenerative rotator cuff tear who underwent single-row arthroscopic rotator cuff repair between March 2008 and April 2010 in our hospital. All the radiologic imaging files including shoulder (MRI) which were stored in picture archiving and communication system (PACS), patients' charts, medical records, operation notes and notes taken during the follow-up visits were obtained from the institutional patient data base and used to extract the demographic information, clinical findings and imaging findings. Patients with acute traumatic rotator cuff tears, patients who did not comply with the postoperative treatment regimen and rehabilitation, patients with a previous history of ipsilateral shoulder disease or abnormality which would preclude clinical evaluations, and finally patients who were not eligible for MRI were all excluded from the study. This study was carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All patients gave informed consent prior to their inclusion in the study.

MRI protocol and evaluation

All patients underwent shoulder MRI examination before the arthroscopic repair and at the final follow-up at least 2 years after the surgical repair. Both MRI examinations were performed on the same MRI unit (Symphony 1.5T, Siemens, Germany). MRI examinations were performed in the prone position with the affected arm in slight external rotation with a dedicated flexible shoulder coil. The following sequences were used on each patient; axial T2-weighted gradient-echo (TR/TE 622/23 ms, FOV 195 × 240 mm, matrix 290 × 512, 4 mm slice thickness with a 0.2 mm gap); coronal oblique proton density weighted (TR/TE 3,050/46 ms, FOV 200 × 200 mm, matrix 205 × 256, 3 mm slice thickness with 0.3 mm gap); sagittal oblique T1-weighted spin-echo (TR/TE 340/14 ms, FOV 240 × 240 mm, matrix 205 × 256, 5 mm slice thickness with 0.3 mm gap); sagittal oblique T2 weighted with fat saturation (TR/TE 3,380/65 ms, FOV 240 × 240 mm, matrix 154 × 256, 3 mm slice thickness with 0.3 mm gap). The images were then transferred to a workstation (NovaPACS Diagnostic Viewer, Novarad Corporation, USA). The MRI scans were evaluated by two independent radiologists who were specialists in musculoskeletal radiology at separate times and any discrepancy was subsequently resolved by consensus.

Supraspinatus muscle atrophy was measured and evaluated according to the Thomazeau classification [9]. Measurements were performed on oblique sagittal T1-weighted MRI scans at the level of the medial border of the spine of the scapula. The surface of the entire supraspinatus fossa (estimated anatomical area) and the actual surface of the supraspinatus muscle were measured and the occupation ratio was calculated (Fig. 1). According to the occupation ratio, the severity of atrophy was classified into three stages [Stage 1: Normal/slight atrophy occupation ratio (1.00–0.60), Stage 2: moderate atrophy occupation ratio (0.60–0.40), Stage 3: Severe atrophy occupation ratio (<0.40)]. The fatty degeneration of the cuff muscles was graded according to the Goutallier classification (Grade 0, no fatty infiltration; Grade 1, some fatty streaking of the supraspinatus; Grade 2, less fat than muscle; Grade 3, equal

Fig. 1 Measurement of occupation ratio on MRI. The surface of the entire supraspinatus fossa (estimated anatomical area) and the actual surface of the supraspinatus muscle were measured and the occupation ratio was calculated

amounts of fat and muscle; Grade 4, more fat than muscle) [8].

The number of tendons involved in the tear and the size of the tear was identified at the time of arthroscopic surgery and classified according to the Harryman (Type 0, an intact cuff; Type 1A, the mildest identifiable pattern of deficiency; Type 1B, a full-thickness defect of the supraspinatus tendon; Type 2, a full-thickness defect involving the supraspinatus and infraspinatus tendons; Type 3, a full-thickness defect involving the supraspinatus, infraspinatus and subscapularis tendons) and DeOrio classification systems (<1 cm = small, 1–3 cm = medium, 3–5 cm = large, >5 cm = massive) [12, 13].

Surgical technique and postoperative rehabilitation

All patients were operated under scalene block anesthesia in the beach-chair position through standard shoulder arthroscopy portals. After sufficient subacromial bursectomy and decompression, the rotator cuff tear was evaluated both from the bursal and articular side. The size of the tear and the number of tendons involved in the tear were assessed and recorded. In patients who had acromioclavicular osteophytes and Type 3 acromion, acromioplasty was performed (18 patients). Debridement of the tendon stump and soft-tissue release was performed to obtain sufficient mobility of the tendon. Metal suture anchors (5 mm) were used to suture the tendon to its anatomical foot print on the humeral head. An abduction pillow was used for 6 weeks postoperatively. Passive range of motion exercises were started in the second week and active elevation in a sitting position from the adducted position of the shoulder was permitted starting at 10 weeks. Isometric cuff exercises were allowed starting at 12 weeks. Return to work and sporting activities were permitted after 6 months postoperatively, after assessing recovery of the muscle strength and ROM. Postoperative rehabilitation was guided under the supervision of a physiotherapist [11, 14].

Final follow-up and outcome assessments

At the final follow-up, all patients underwent clinical and radiological assessments. Functional outcomes were assessed with the Constant shoulder score [15]. Shoulder MRI evaluation and measurements were repeated as performed before the surgery with the same protocol and MRI unit. Rotator cuff tendon integrity, fatty degeneration, and muscular atrophy were evaluated and graded by the same radiologists who were blinded to their previous assessments, and a consensus agreement was reached. Of the 102 patients reviewed, 87 patients responded and concluded the final clinical follow-up and MRI examination (85.2 % follow-up rate).

Statistical analysis

Continuous variables were stated as mean and standard deviation and categorical variables as percentages and frequency distribution. The comparison of continuous variables between independent groups was performed using Student's *t* test, and the comparison of categorical data was performed using the Chi-square test. Repeated measurements within the same group were analyzed using the Friedman test. The Mann–Whitney *U* test was used to compare the independent samples. Correlation coefficients (Pearson *r*) and stepwise, multiple linear regression were used to determine the relationship between the outcome variables (final Constant score and integrity of the cuff), and the predictor variables, age, sex, follow-up duration, initial muscle atrophy, final muscle atrophy, initial fatty degeneration and final fatty degeneration. A value of $p < 0.05$ was considered statistically significant.

Results

The patients comprised 67 females and 20 males with a mean age of 62.5 ± 8.3 years (range 40–80 years). According to the Harryman classification 65 (74.7 %) patients had Type 1B (full-thickness supraspinatus tear), 14 (16.1 %) patients had Type 2 (full-thickness supraspinatus and infraspinatus tear), and 8 (9.2 %) patients had Type 3 (massive) rotator cuff tears. The size of the tears was measured as small in 31 (35.6 %) patients, medium in 32 (36.8 %) patients, large in 16 (18.4 %) patients and massive in 8 (9.2 %) patients. Patients were followed up for at least 2 years with a mean of 30.1 ± 5.8 months (range 24–43 months).

At the final follow-up, the mean Constant shoulder score was 94.2 ± 8.2 (range 70–100), and 66 (75.9 %) patients rated as excellent, 14 (16.1 %) as good, and 7 (8.0 %) as fair. No patient had poor results. There was re-rupture in 26 (29.9 %) patients.

Of the 61 patients with intact tendon, the rotator cuff muscle atrophy remained the same in 52 (85.2 %) patients and worsened in 9 (14.8 %) patients. Of the 26 patients with re-rupture, rotator muscle atrophy remained the same in 24 (92.3 %) patients and worsened in 2 (7.7 %) patients. The atrophic changes between groups were statistically similar ($p = 0.300$). Of the 61 patients with intact tendon, fatty degeneration remained the same in 52 (85.2.2 %) patients and worsened in 9 (14.8 %) patients. Of the 26 patients with re-rupture, fatty degeneration remained the same in 3 (11.5 %) patients, and worsened in 23 (85.5 %) patients (Fig. 2). No patient had improvement in muscle atrophy and fatty degeneration. The deterioration of fatty degeneration was significantly higher in the re-rupture group ($p = 0.0001$). Summary of results are presented in Table 1. The Constant shoulder score was significantly lower in patients with re-rupture (97.4 ± 5.0 versus 86.6 ± 9.3, $p = 0.001$).

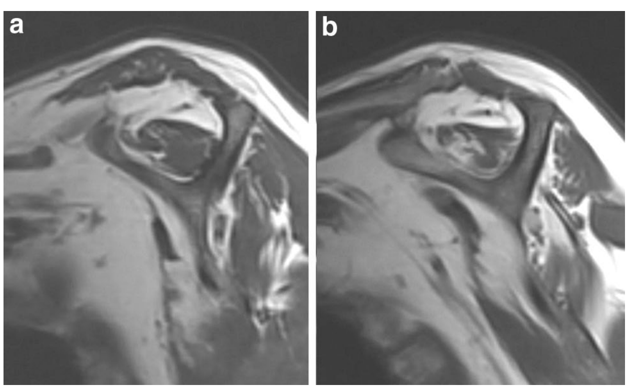

Fig. 2 MRI findings in supraspinatus muscle in a patient with re-rupture. Note the increase in both atrophy and fatty degeneration of the muscle before the operation (**a**) and at the final follow-up (**b**)

Correlation analysis showed that the final Constant shoulder score and the integrity of the cuff were strongly correlated with the age of the patient, the number of torn tendons, the size of the tear, and initial and final atrophy and fatty degeneration of the cuff muscles (Table 2). Multiple stepwise regression analysis showed that the Constant score was dependent on the final integrity of the tendon and the size of the tear (R^2 0.420, p 0.001). The final integrity of the tendon was dependent on the age of the patient, initial and final fatty degeneration of the cuff muscles and the size of the tear (R^2 0.669, p 0.001).

Discussion

In this study, it was determined that initial muscle atrophy and fatty degeneration did not improve even after a successful rotator cuff repair where the tendon anatomic integrity was maintained for at least 2 years. It may continue to deteriorate, and the best possibility was preservation of the preoperative status. On the other hand, in cases of re-rupture, fatty degeneration and atrophy continued to worsen significantly. No relationship was determined between atrophic changes and fatty degeneration. In other words, while atrophy remains at the same grade, fatty degeneration may increase, or the reverse may also apply that while atrophy increases, fatty degeneration may stay at the same grade. It is thought that these two processes progress differently. The measurement of muscle atrophy consists of only the volumetric measurement of the muscle, thus it is

Table 1 Changes in fatty degeneration and atrophy within and between groups

Variables		Intact tendon ($n = 61$)	Re-rupture ($n = 21$)	Significance between groups
Muscle atrophy Thomazeau classification	Preoperative	34 Gr I, 26 Gr II, 1 Gr III	7 Gr I, 12 Gr II, 7 Gr III	0.300
	Postoperative	28 Gr I, 31 Gr II, 2 Gr III	5 Gr I, 14 Gr II, 7 Gr III	
	Significance within group	0.052	0.161	
Fatty degeneration Goutallier's classification	Preoperative	11 Gr 0, 25 Gr I, 16 Gr II, 9 Gr III	7 Gr I, 14 Gr II, 5 Gr III	**0.0001***
	Postoperative	10 Gr 0, 21 Gr I, 20 Gr II, 8 Gr III, 2 Gr IV	8 Gr II, 10 Gr III, 8 Gr IV	
	Significance within group	**0.002***	**0.0001***	

* Statistically significant p values (shown as bold)

Table 2 Correlation of variables that affect the final Constant score and the integrity of the tendon

Variables	Constant score	Cuff integrity
Age	**0.010*** (−0.275)	**0.003* (−0.314)**
Sex	0.814 (−0.026)	0.574 **(−0.061)**
Number of torn tendons	**0.0001*** (−0.453)	**0.0001* (−0.552)**
Size of the tear	**0.0001*** (−0.548)	**0.0001* (−0.598)**
Follow-up duration	0.883 (−0.016)	0.203 (0.138)
Initial atrophy grade	**0.0001*** (−0.419)	**0.0001* (−0.382)**
Final atrophy grade	**0.0001*** (−0.414)	**0.001* (−0.361)**
Change in atrophy (Δ grade)	0.449 (−0.082)	0.370 (−0.097)
Initial fatty degeneration	**0.006*** (−0.290)	**0.010* (−0.276)**
Final fatty degeneration	**0.0001*** (−0.458)	**0.0001* (−0.578)**
Change in fatty degeneration (Δ grade)	**0.0001*** (−0.531)	**0.0001* (−0.700)**
Constant score	–	**0.0001* (0.605)**

* Statistically significant *p* values (shown as bold). Values in parenthesis are Pearson correlation coefficients (rho)

a quantitative evaluation. However, fatty degeneration is evaluated from the muscle quality. While atrophy is not a predictive factor of clinical results and tendon integrity, an increase in fatty degeneration has been found to negatively affect functional results.

There have been many experimental and clinical studies on the changes from preoperative to postoperative atrophy and fatty degeneration in the current literature. However, these studies have reported conflicting findings.

Goutallier et al. reported that fatty degeneration within the infraspinatus did not change after repair, but some improvement was determined in the fatty degeneration in the supraspinatus tendon in patients where the tendon remained healthy after tendon repair [3, 10]. Similarly, Thomazeau et al. reported an improvement in fatty degeneration at the rate of 10 % in patients who did not experience postoperative re-rupture [9]. Yamaguchi et al. determined even higher rates of improvement, 50 % for atrophy and 25 % for fatty degeneration, in patients with intact tendon [14]. They claimed that follow-up period should be sufficient enough to demonstrate these improvements. In a study by Seok won Chung et al., atrophy of the rotator cuff muscles quantified with the occupation ratio was seen to have increased in patients with preserved tendon integrity [16]. These improvements were also shown in animal experiments. Coleman et al. reported that improvement in fatty degeneration can be seen in the early period following repair [17]. In the current study, the follow-up period was at least of 24 months, which was a sufficient period to detect any improvement in fatty degeneration or atrophy, but in contrast to previous studies, fatty degeneration and atrophy in patients with intact tendon were not seen to improve.

On the other hand, there are other studies which report opposite findings in the literature. Liu, Grupta and Gerber carried out separate animal studies and reported that fatty degeneration started from the 6th month after the experimental rotator cuff tear and even if tendon integrity was ensured, fatty degeneration did not improve [18–20]. Lee et al. determined an increase in fatty degeneration and atrophy in all the patients in their series followed up over a period of mean 12.7 months [21]. Bartl et al. followed patients with only massive tears, and again all patients were determined to have continued fatty degeneration [22]. Gladstone et al. have shown the progression of fatty degeneration in all patients they followed and noticed that the rate of fatty degeneration was significantly higher in patients with re-rupture [11]. The findings of the current study conform to these results. In our opinion, even if tendon integrity is preserved, both atrophy and fatty degeneration are irreversible processes.

The postoperative tendon integrity, whether it is intact or re-ruptured, is the most important predictor of the progression of fatty degeneration and atrophy. However, there are also opinions that the age of the patient and the preoperative size of the tear have an effect. While Goutallier reported that the age of the patient did not affect the amount of fatty degeneration, Harryman et al. reported an increase in fatty degeneration with increasing age [10, 12]. According to Harryman and Thomazeau, the size of the preoperative tendon tear did not affect preoperative or postoperative fatty degeneration, the tendon integrity and postoperative functional score, but the rate of re-rupture was influenced by the amount of fatty degeneration [9, 12]. In studies by Sugaya, Gladstone and Rebuzzi, it was determined that as the size of the tear increased, so preoperative fatty degeneration increased and this affected the rate of re-rupture [11, 23, 24]. Deorio examined patients who had undergone revision surgery for re-ruptured cuff and reported that the factors affecting re-rupture were the preoperative size of the tear and insufficient postoperative immobilization [13]. In the current study, the factors affecting tendon integrity were found to be the age of the patient, the size of the tear and the severity of preoperative fatty degeneration in the rotator cuff.

There are some strengths and limitations of this study. All patients were followed at least 2 years to respite the changes to occur. The follow-up period was sufficient for the determination of these changes. Both the preoperative and postoperative MRI examinations were performed with the same MRI unit and evaluated by the same radiologists. Thus, any discrepancy due to different MRI units and radiologists were minimized. In addition, all the operations were performed by the same surgeon, and the effect of different surgical techniques on the rate of re-rupture could be avoided. However, small number of patients was followed, many of whom were over 60 years of age. We examined the factors that we could measure and identify in our series. On the other hand, there may be other factors which may influence the rate of fatty degeneration and atrophy such as diabetes mellitus and cigarette smoking.

In conclusion, arthroscopic rotator cuff repair is an effective treatment method which provides excellent and good results even if the tendon re-rupture occurs. The preoperative fatty degeneration and atrophy of the RC muscles do not improve even after a successful surgery and intact tendon, and the best possibility is preservation of the initial status. However, in re-rupture cases, the process continues and deterioration takes place. The age of the patient, the size of the tear and initial fatty degeneration negatively affect functional results and tendon integrity. Therefore, in patients diagnosed with full-thickness rotator cuff tear, timing of surgical intervention is important, repairing the cuff before the development of these changes may be a more proper approach. During decision making, choosing the optimal treatment for a particular patient, and realizing the goals of treatment, all these identifiable factors should be carefully considered.

Conflict of interest The authors have no conflict of interest to disclose.

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