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Magnetic Resonance Imaging of Arthroscopic Supraspinatus Tendon Repair

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Background: While a number of studies have documented the very good clinical results of arthroscopic rotator cuff repair, very few authors have specifically assessed cuff integrity, supraspinatus atrophy, and fatty infiltration and their influence on the clinical outcome.

Methods: We evaluated fifty-three consecutive patients (average age, 60.9 years) who had undergone arthroscopic repair of an isolated supraspinatus tendon tear. After an average duration of follow-up of 26.4 months, all patients were evaluated clinically with use of the Constant score and underwent standardized magnetic resonance imaging at our institution. The preoperative and postoperative magnetic resonance images were evaluated by two independent observers who were blinded to the clinical outcome of the patient. Evaluation criteria were cuff integrity; atrophy of the supraspinatus; and fatty infiltration of the supraspinatus, infraspinatus, and subscapularis. These findings were correlated to the clinical outcome.

Results: Regardless of the tendon integrity, every parameter of the Constant score was significantly improved after the repair. The overall average Constant score was improved from 53.5 to 83.4 points ($p < 0.001$). The retear rate in our series was 25% (thirteen of fifty-three). Patients who had a retear had significantly less abduction strength ($p = 0.043$) and a significantly lower total Constant score ($p = 0.012$) than those who had an intact repair. A higher degree of preoperative supraspinatus atrophy and Stage-2 fatty infiltration of the supraspinatus were positive predictors of a retear. Also, an older age was an important predictor of a retear ($p = 0.011$). Progression of structural changes in the rotator cuff was halted when the repair remained intact, but there was no significant reversal of fatty infiltration or muscle atrophy. When the repairs failed, there was significant progression of fatty infiltration and atrophy of the supraspinatus.

Conclusions: The clinical and structural results of arthroscopic repairs of isolated supraspinatus tears are equal to those reported following open repair. Fatty infiltration and muscle atrophy cannot be reversed by successful arthroscopic repair. Higher degrees of muscular atrophy and fatty infiltration preoperatively are associated with recurrence of the tear as well as progression of fatty infiltration and muscular atrophy and an inferior clinical result.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Arthroscopic rotator cuff repair has been reported to produce excellent clinical results and high patient satisfaction comparable with those outcomes following established open and mini-open repair techniques¹⁻⁹. However, regardless of the repair technique, the problem of structural failure of the repair remains, and the question of whether the retear rates after arthroscopic repair are higher than those after open and mini-open repair has been raised¹⁰. This issue has been of special importance because the limited

data available on this subject have indicated that structural failure of rotator cuff repairs could be associated with inferior clinical results^{1,10,11}.

Chronic tears of the rotator cuff are known to induce structural changes such as muscular atrophy and fatty infiltration within the rotator cuff muscles. These changes can be monitored successfully with noninvasive measures such as computed tomography or magnetic resonance imaging. A number of established classification systems are available for

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evaluation of these parameters^{12,13}. Both muscular atrophy and fatty infiltration are known to have a substantial influence on the clinical result of rotator cuff repair.

The importance of these structural changes in the rotator cuff has been the subject of a number of recent reports. However, these reports have focused on open rather than arthroscopic rotator cuff repair^{11,14-18}. The goal of this study was to monitor the clinical and structural results of arthroscopic repairs of isolated supraspinatus tears with a standardized suture anchor technique and to evaluate the influence of tendon integrity, fatty infiltration, and muscle atrophy on the clinical result.

Materials and Methods

Patient Selection

We evaluated fifty-three consecutive patients who had undergone arthroscopic repair of an isolated supraspinatus tear in a standardized fashion at our institution between 2000 and 2001 by one of the two senior surgeons (S.L. and P.H.).

Patients were excluded from the study if they had involvement of rotator cuff tendons other than the supraspinatus, it was not possible to achieve a watertight tension-free repair, a previous operation had been performed on the affected shoulder, or the patient had glenohumeral arthritis or inflammatory arthropathy.

Clinical Evaluation and Operative Technique

The patients were examined clinically on the day before the surgery, and the clinical results were documented with use of the Constant score¹⁹. Both surgeons used an identical operative technique. The operations were performed with the patients in the beach-chair position. After diagnostic arthroscopy and subacromial decompression (in all but one patient), the supraspinatus tear was localized and the tear size was documented according to the Bateman classification²⁰. A modified Mason-Allen technique with a single row of bioabsorbable suture anchors preloaded with two number-2 nonabsorbable braided polyester sutures (Bio-Corkscrew; Arthrex, Naples, Florida) was used to achieve a tension-free repair of the rotator cuff in all patients²¹.

Postoperatively, the shoulder was immobilized in a sling for forty-eight hours, after which immobilization continued in an abduction pillow for three weeks. During the first six weeks, physiotherapy consisted of passive range-of-motion exercises for the shoulder. Range-of-motion limits were continuously increased from 60° of abduction, 60° of flexion, and 10° of external rotation in the first week to 90° of abduction, 145° of flexion, and 45° of external rotation in the sixth week. At seven weeks, a free passive range of motion was allowed and active mobilization was begun. At nine weeks, carefully performed isometric strengthening exercises, with respect for the patient's pain limit, were started, and the intensity of these exercises was increased to eccentric strengthening and weight training in the twelfth week.

After an average duration of follow-up of 26.4 months (minimum, twenty-four months), all patients were again clin-

ically evaluated with use of the Constant score and underwent a standardized magnetic resonance imaging examination at our institution.

Magnetic Resonance Imaging

Examination

Twenty-nine patients (55%) provided preoperative magnetic resonance images acquired elsewhere, and the other twenty-four (45%) underwent magnetic resonance imaging at our institution, either because the study had not yet been performed or it was considered inadequate or too old.

At the time of follow-up, all patients underwent a standardized magnetic resonance imaging examination at our institution. We used an open low-field (0.2-T) magnetic resonance imaging system with a shoulder coil. The sequences used for the examination included an oblique coronal T1-weighted spin-echo sequence (echo time, 24 msec; repetition time, 770 msec), an oblique coronal T2-weighted turbo-spin-echo sequence (repetition time, 3000 msec; echo time, 80 msec), an oblique sagittal T1-weighted spin-echo sequence (echo time, 24 msec; repetition time, 770 msec), and an axial T1-weighted spin-echo sequence (repetition time, 870 msec; echo time, 24 msec).

Evaluation of Images

The preoperative and postoperative magnetic resonance imaging scans were independently evaluated by each of two observers who were blinded to the clinical outcome of the patient. Eight (15%) of the preoperative scans either were not available for reevaluation or were considered inadequate to analyze all three criteria (described below). This left forty-five preoperative scans to be evaluated. The findings of each observer were documented, and average values were calculated.

The three criteria used for the evaluation were the integrity of the rotator cuff, atrophy of the supraspinatus muscle, and fatty infiltration of the supraspinatus, infraspinatus, and subscapularis muscles. The integrity of the repaired supraspinatus tendon was evaluated with use of established criteria²². The oblique coronal T2-weighted turbo-spin-echo sequence was carefully inspected for fluid-equivalent signal in the tendon or complete nonvisualization of the tendon on at least one sequence. Either finding was considered to represent a retear of the repaired tendon.

Supraspinatus atrophy was evaluated on the most lateral of the oblique sagittal images on which the scapular spine was in contact with the scapular body. The tangent sign introduced by Zanetti et al. was drawn on this image²³. The position of the supraspinatus muscle belly in relation to the tangent sign was graded with a qualitative three-stage system corresponding to the quantitative system introduced by Thomazeau et al.²⁴. Atrophy was considered to be Grade 1 if the muscle was superior to the tangent, it was considered to be Grade 2 if the muscle just touched the tangent, and it was considered to be Grade 3 if the muscle was clearly below the tangent. Since there are no established criteria for qualitative assessment of atrophy of the infraspinatus, teres minor, or

TABLE I Demographic and Intraoperative Data (N = 53)

| | | Influence on Outcome (Constant score) | Influence on Cuff Integrity |
|---|----------------|--|--------------------------------|
| Age at surgery* | 60.9 ± 7.3 yr | p = 0.002† | p = 0.011† |
| Gender‡ | | p = 0.572 | p = 0.641 |
| Male | 34 (64%) | | |
| Female | 19 (36%) | | |
| Duration of symptoms* | 12.6 ± 17.6 mo | p = 0.466 | p = 0.033† |
| Trauma‡ | 20 (38%) | p = 0.717 | p = 0.952 |
| Duration of follow-up* | 26.4 ± 4.8 mo | p = 0.497 | p = 0.716 |
| Tear size (Bateman class)‡ | | p = 0.598 | p = 0.664 |
| 1 | 9 (17%) | | |
| 2 | 38 (72%) | | |
| 3 | 6 (11%) | | |
| Arthroscopic subacromial decompression‡ | 52 (98%) | p = 0.681 | p = 0.574 |
| Acromioclavicular joint resection‡ | 14 (26%) | p = 0.310 | p = 0.689 |
| Biceps procedure‡ | | p = 0.203 | p = 0.454 |
| Tenodesis | 2 (4%) | | |
| Tenotomy | 15 (28%) | | |
| Complications‡ | 0 | | |

*The values are given as the mean and standard deviation. †The values were significant (level of significance, p < 0.05). ‡The values are given as the number of patients with the percentage in parentheses.

subscapularis, only atrophy of the supraspinatus muscle was evaluated.

Fatty infiltration of the supraspinatus, infraspinatus, and subscapularis was assessed on the same oblique sagittal image, with use of the classification system described by Goutallier et al.¹³ With this system, Stage 0 indicates no fatty infiltration of the muscle; Stage 1, some fatty streaks; Stage 2, less fat than muscle; Stage 3, equal muscle and fat contents; and Stage 4, more fat than muscle. This system was originally designed for use in computed tomography examinations but was later correlated for magnetic resonance imaging¹².

Statistical Analysis

Statistical analysis was performed with use of SPSS statistical

software (version 13.0; SPSS, Chicago, Illinois). The level of significance was set at 0.05. Preoperative and postoperative nonparametric data were analyzed with use of the Wilcoxon signed-rank test. Comparisons between two groups were performed with use of the Mann-Whitney U test.

Results

Patient Demographics and Clinical Outcome

Fifty-three consecutive patients met the above-mentioned criteria and were included in this study. The average age (and standard deviation) of our cohort was 60.9 ± 7.3 years, and the average duration of follow-up was 26.4 months (minimum, twenty-four months). The study group consisted of thirty-four men and nineteen women. The domi-

TABLE II Preoperative and Postoperative Constant Scores

| | Retear Group (N = 13) | | | Intact-Repair Group (N = 40) | | |
|----------------------------|-----------------------|----------|----------|------------------------------|----------|----------|
| | Preop.* | Postop.* | P Value† | Preop.* | Postop.* | P Value† |
| Pain | 7.2 | 14.6 | 0.0001 | 6.1 | 14.3 | <0.0001 |
| Activities of daily living | 10.7 | 18.7 | 0.0001 | 10.4 | 19.3 | <0.0001 |
| Range of motion | 30.0 | 37.2 | 0.0016 | 30.5 | 38.6 | <0.0001 |
| Strength | 4.9 | 8.4 | 0.0003 | 6.9 | 13.9 | <0.0001 |
| Overall Constant score | 52.8 | 78.9 | 0.0001 | 53.9 | 86.1 | <0.0001 |

*The values are given as the mean number of points on the Constant scale. †Level of significance, p < 0.05.

TABLE III Fatty Infiltration and Supraspinatus Atrophy

| | Preop. | Postop. | P Value* |
|--|--------|---------|----------|
| Fatty infiltration of supraspinatus (<i>Stage</i>) | | | |
| Retear group | 1.30 | 2.23 | 0.014 |
| Intact-tendon group | 1.00 | 1.15 | 0.225 |
| Overall | 1.06 | 1.42 | 0.015 |
| Fatty infiltration of infraspinatus (<i>Stage</i>) | | | |
| Retear group | 0.50 | 1.69 | 0.016 |
| Intact-tendon group | 0.40 | 0.88 | 0.001 |
| Overall | 0.42 | 1.07 | 0.001 |
| Fatty infiltration of subscapularis (<i>Stage</i>) | | | |
| Retear group | 0.10 | 0.69 | 0.059 |
| Intact-tendon group | 0.31 | 0.35 | 0.366 |
| Overall | 0.27 | 0.43 | 0.059 |
| Atrophy of supraspinatus (<i>Grade</i>) | | | |
| Retear group | 1.50 | 2.38 | 0.011 |
| Intact-tendon group | 1.14 | 1.12 | 0.655 |
| Overall | 1.22 | 1.43 | 0.071 |

* Level of significance, $p < 0.05$.

nant side was affected in thirty-seven patients, and the nondominant side was affected in sixteen. The influence of the demographics on the clinical outcome is outlined in Table I. The only factor with significant influence on the clinical outcome was the patient's age ($p = 0.002$). The integrity of the repair was also significantly influenced by the patient's age ($p = 0.011$) as well as by the duration of symptoms preoperatively ($p = 0.033$).

Preoperatively, the average overall Constant score was 53.5 points (range, 23 to 80.8 points). At the time of follow-up, the score was significantly improved to 83.4 points (range, 62.5 to 99.3 points) ($p < 0.001$). All single parameters of the Constant score (pain, activities of daily living, range of motion, and abduction strength) were also significantly improved compared with the preoperative scores (Table II).

Tendon Integrity

Evaluation of standardized postoperative magnetic resonance imaging scans revealed thirteen retears (25%). Preoperatively, no single parameter of the Constant score, nor the overall Constant score, differed significantly between the group with a re-tear and the group with an intact tendon. Postoperatively, tendon integrity had a significant influence only on the abduction strength, which was significantly lower ($p = 0.043$) in the re-tear group (8.4 points) than in the intact-tendon group (13.9 points). The parameters of pain, activities of daily living, and range of motion were not significantly influenced by tendon integrity. However, the overall Constant score was still significantly lower ($p = 0.012$) in the re-tear group (78.9 points) than in the intact-tendon group (86.1 points). The only demographic parameter that had a significant influence on the clinical result was the patient's age ($p =$

0.002). Patients with a structural failure of the repair were significantly older (65.3 years) than those with an intact tendon (59.5 years) ($p = 0.011$).

Supraspinatus Atrophy

Atrophy of the supraspinatus muscle measured on the preoperative magnetic resonance imaging scan was a positive predictor of the integrity of the repair and therefore of the clinical outcome. There was significantly greater preoperative atrophy of the supraspinatus muscle in the re-tear group than in the intact-repair group ($p = 0.014$). The re-tear rate associated with Grade-2 atrophy of the supraspinatus muscle was significantly higher than that associated with Grade-1 atrophy ($p = 0.018$). There was also a significantly higher degree of postoperative supraspinatus atrophy in the re-tear group ($p < 0.001$). When we compared preoperative and postoperative magnetic resonance imaging scans it was evident that atrophy of the supraspinatus was stabilized in shoulders with a successful repair; however, there was no evidence of reversal. In the re-tear group, the amount of postoperative supraspinatus atrophy had increased significantly compared with the preoperative state ($p = 0.011$) (Table III).

Fatty Infiltration

Overall, regardless of tendon integrity, there was a significant increase in fatty infiltration in the supraspinatus ($p = 0.015$) and the infraspinatus ($p = 0.001$) from the preoperative to the postoperative examinations. Fatty infiltration of the subscapularis did not increase significantly ($p = 0.059$). Analysis of the available forty-five preoperative magnetic resonance imaging scans showed differences in the extent of fatty infiltration of

TABLE IV Retear Rate for the Different Stages of Preoperative Fatty Infiltration and Grades of Supraspinatus Atrophy

| | Retears (%) | P Value |
|-----------------------|-------------|----------------------------------|
| Fatty infiltration | | Stage 0 and 1 vs. Stage 2: 0.021 |
| Stage 0 (n = 7) | 1 (14%) | |
| Stage 1 (n = 28) | 5 (18%) | |
| Stage 2 (n = 10) | 4 (40%) | |
| Supraspinatus-atrophy | | Grade 1 vs. 2: 0.018 |
| Grade 1 (n = 35) | 5 (14%) | |
| Grade 2 (n = 10) | 5 (50%) | |

the supraspinatus, infraspinatus, or subscapularis between the retear group and the intact-tendon group, but these differences did not reach significance with the small number of patients evaluated in this study. However, the retear rate was significantly higher for patients with Stage-2 fatty infiltration of the supraspinatus on the preoperative magnetic resonance imaging scans than it was for those with Stage-0 or 1 fatty infiltration ($p = 0.021$) (Table IV).

Postoperatively, fatty infiltration of the supraspinatus ($p < 0.001$) and infraspinatus ($p = 0.001$) was significantly greater in the retear group than in the group with an intact repair. Fatty infiltration of the subscapularis did not differ significantly between the groups ($p = 0.067$).

Comparison of preoperative and postoperative magnetic resonance imaging scans revealed no decrease in fatty infiltration in either the intact-repair group or the retear group. The retear group had a significant increase in fatty infiltration of the supraspinatus ($p = 0.014$) and the infraspinatus ($p = 0.016$) but not of the subscapularis. In the intact-repair group, fatty infiltration of the infraspinatus increased significantly ($p = 0.001$) but the supraspinatus and subscapularis showed no significant difference in fatty infiltration between the preoperative and postoperative magnetic resonance imaging examinations (Table III).

Discussion

The clinical results of arthroscopic rotator cuff repair have been good to excellent and comparable with those reported following open or mini-open rotator cuff repair²⁵⁻³⁰. While the clinical outcomes and patient satisfaction have been shown to be equal to those following established open techniques, structural changes associated with arthroscopic repairs of the rotator cuff and the integrity of these repairs are not well known. Failure has not been exclusive to arthroscopic repairs, as numerous studies of open rotator cuff repairs have also shown failures^{11,14-16,18,31,32}. The retear rates reported in those studies varied considerably, although some reports have suggested that there are more retears after arthroscopic rotator cuff repairs than after open repairs¹⁰.

When different studies are analyzed, it is important to consider the extent of the tears. When used for isolated tears

of the supraspinatus, arthroscopic repairs are associated with retear rates comparable with those reported after open repair. In our study, the retear rate following use of a standardized technique involving a single row of suture anchors with Mason-Allen stitches was 25% (thirteen of fifty-three). This percentage is in agreement with the 25% rate of retears (sixteen of sixty-five) recently found by Boileau et al. after treatment of isolated supraspinatus tears with the tension-band suture technique¹. Retear rates have been considerably higher after repairs of massive tears of the rotator cuff^{10,15}.

Muscle atrophy of the supraspinatus was shown to be an important prognostic factor in our study group. More severe atrophy seen on preoperative magnetic resonance imaging was associated with a higher percentage of failed repairs. Furthermore, patients with a retear showed postoperative progression of the muscular atrophy accompanied by an inferior clinical result. Preoperative fatty infiltration exceeding Stage 1 was also a prognostic factor for a recurrent tear. In this regard, our results after use of the arthroscopic technique are in agreement with the findings following open repair. Goutallier himself identified Stage-1 fatty infiltration as a cutoff between tendon integrity and failure following open repair¹⁷. These findings were confirmed recently by Mellado et al., who reported a higher prevalence of recurrent defects following open rotator cuff repair if preoperative fatty infiltration had exceeded Stage 1¹⁵.

The question of whether fatty infiltration can be reversed by successful rotator cuff repair is controversial. We found no evidence that this was the case. Neither muscle atrophy nor fatty infiltration decreased after a successful repair, but both parameters significantly worsened in patients with a retear. This finding is in agreement with those of recent studies of open rotator cuff repair¹⁴, but to our knowledge this issue has not been previously examined following arthroscopic rotator cuff repair. It should be noted that there was a significant increase in fatty infiltration of the infraspinatus in our study group, regardless of the integrity of the repair. In a recent study addressing open repair of an isolated tear of the supraspinatus or subscapularis, Fuchs et al. also found a significant increase ($p = 0.018$) in fatty infiltration of the infraspinatus when the supraspinatus had been repaired but not when the subscapularis had been repaired¹⁴. As there was no clinical correlation with these magnetic resonance imaging findings in either the study by Fuchs et al. or our study, no sufficient explanation can be given. Additional studies examining possible neurologic damage to the suprascapular nerve during mobilization of the supraspinatus could improve our knowledge regarding these findings.

The clinical implication of the results of our study is that only a successful repair can halt the atrophy of the muscle and lead to an optimal clinical result regarding strength. Because strength accounts for 25% of the Constant score, which was chosen as the outcome measure in our study, the retear group had a significantly lower overall Constant score. This finding was reported by other investigators following open and arthroscopic repair¹. It should be noted that a recurrent

defect of the rotator cuff had no impact on the other parameters measured by the Constant score (pain, activities of daily living, and range of motion). It will be interesting to see whether the difference in the clinical outcome between the re-tears and intact repairs will become more evident with longer follow-up. Recently, there has been evidence that the clinical results associated with structural failures of rotator cuff repairs do not deteriorate over time³¹. An important finding of our study was the fact that higher age was associated with a higher prevalence of re-tears and inferior clinical outcomes. This concurs with the findings of the recent study on arthroscopic rotator cuff repair by Boileau et al.¹

Limitations of this study include the fact that we were not able to analyze all of the preoperative magnetic resonance imaging scans. This could obviously have altered our results with regard to associations with preoperative findings. Also, whether low-field magnetic resonance imaging systems have the same sensitivity for evaluating the rotator cuff as established high-field magnetic resonance imaging has been debated³³⁻³⁵. We found no study comparing low-field and high-field magnetic resonance imaging for postoperative evaluation of the rotator cuff in the literature. We believe that the magnetic resonance images that we acquired were sufficient to evaluate the above-mentioned three criteria, as these criteria are clearly defined in the literature and safely reproducible. A

known limitation of measuring supraspinatus atrophy is the fact that retraction of a tear can alter comparability among different magnetic resonance imaging scans. This variable could not be eliminated in our study.

In conclusion, the clinical and structural results of arthroscopic repair of isolated supraspinatus tears were comparable with the previously reported good and excellent results of open and mini-open repair. Structural changes such as fatty infiltration and muscle atrophy cannot be reversed by successful arthroscopic repair. A higher degree of muscular atrophy and fatty infiltration preoperatively as well as the patient's age are prognostic factors for a recurrent tear. Finally, a recurrent tear leads to progression of fatty infiltration and muscular atrophy and to an inferior clinical result. ■

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