Ten-year clinical and anatomic follow-up after repair of anterosuperior rotator cuff tears: influence of the subscapularis

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Background: Anterosuperior rotator cuff tears are more frequent than expected. We report the results of a 10-year follow-up study after repair. Our hypothesis was that the extent of the subscapularis tear influenced the prognosis.

Materials and methods: The study population consisted of all 138 patients who underwent surgery in 14 participating centers in 2003 for full-thickness tears of the rotator cuff with lesions in the subscapularis and supraspinatus tendons. The patients were divided into 2 groups, depending on whether the subscapularis lesion affected only the superior half of the tendon (group A) or extended into the lower half (group B). Ninety-two patients (56 ± 7 years; 71 in group A and 21 in group B) were available for follow-up after 10 years (127 ± 16 months) with magnetic resonance imaging to evaluate tendon healing and muscle condition.

Results: The mean Constant scores were 59 ± 16 before surgery and 77 ± 14 at follow-up (P = 1.7 × 10−5). The retear rates were 25% for the supraspinatus and 13.5% for the subscapularis tendon. The clinical results for group A patients were better than those for group B. Severe fatty infiltration was observed more frequently in the subscapularis than in the supraspinatus muscle (27% vs. 12% of cases). Supraspinatus healing influenced subscapularis healing and fatty infiltration.

Conclusions: Repair of anterosuperior rotator cuff tears is satisfactory at 10 years, particularly if the subscapularis tear is not extensive. An extensive subscapularis tear is a negative prognosis factor. Postoperatively, fatty infiltration of the subscapularis muscle was frequently observed despite tendon healing.

Level of evidence: Level III; Retrospective Cohort Design; Treatment Study
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Keywords: Shoulder; rotator cuff; anterosuperior; long-term follow-up; repair; supraspinatus; subscapularis; fatty infiltration

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Rotator cuff tears involving isolated lesions in the subscapularis tendon are rare, whereas those associated with superior cuff tears are frequent. Studies of surgical repair for anterosuperior cuff tears report satisfactory clinical outcomes—nonetheless with a residual weakness—at an average follow-up of between 15 months and 6 years. The influence on prognosis of the extent of the lesions, particularly those of the subscapularis, is a matter of debate. Collins et al. have suggested classifying rotator cuff tears into 2 groups, depending on the nature of the anterior lesions. They associated the more severe clinical presentation, when the subscapularis lesion reaches the inferior half of the humeral insertion, with a high risk of pseudoparalytic shoulder. They did not, however, come to any conclusion about the prognosis after tendon repair.

Long-term studies of the outcome of rotator cuff repair, 10 years or more after surgery, are sparse in the literature. Clinical results after open surgery for superior cuff lesions are often reported as satisfactory and stable over time. From an anatomic point of view, Goutallier et al reported intact tendon healing and stable clinical results at a mean follow-up of 9 years. Zumstein et al. found an increased number of iterative tears with no clinical impact after operative repair of massive posterosuperior cuff tears. The results of subscapularis tendon repairs are well documented, but with a mean follow-up of between 29 and 43 months.

Here, we report the clinical and anatomic results of a multicenter retrospective study, with a long-term (10-year) follow-up by magnetic resonance imaging (MRI), of a series of associated lesions in the supraspinatus and subscapularis tendons. Our hypothesis was that the outcome depended on the extent of the subscapularis lesion. According to the classification of Collins et al., patients with larger subscapularis tears (more than half the length of the tendon) have a poorer prognosis than those for whom the tear is confined to the superior half of the tendon.

Materials and methods

Study population

This study involved the follow-up after at least 10 years of rotator cuff repairs performed in 15 surgical centers. The inclusion criteria were that (1) all operations were performed in 2003 for full-thickness tears of the rotator cuff with lesions in the subscapularis and supraspinatus tendons, (2) watertight tendon repair was considered complete by the surgeon regardless of the method employed, and (3) patients were available for a clinical follow-up, with MRI after at least 10 years. Partial lesions of the supraspinatus tendon, partial or incomplete repairs, prior surgery on the same shoulder, and inflammatory conditions were all excluded.

In total, 138 patients (41 women, 97 men; mean age at surgery, 56.8 ± 8.5 years; 138 shoulders) underwent surgical repair for torn supraspinatus and subscapularis tendons exclusively, the other tendons in the rotator cuff being unaffected. Eight patients required repeated surgery within 10 years and were excluded from this analysis of tendon repair. The additional operations were to release stiffness (1 case), iterative repair (3 cases), and a reverse shoulder prosthesis (3 cases); in 1 case, the type of operation performed was not specified. Another 38 patients were lost to follow-up because of death (6 patients), unwillingness to return for the follow-up appointment for medical or geographic reasons or other reasons (7 patients), or inability to be located (25 patients), leaving a cohort of 92 patients for analysis (70 men, 22 women; mean age at surgery, 56 ± 7 years).

Following the classification of Collin et al., patients with lesions in only the superior half of the subscapularis tendon were classed in group A (n = 71); those with lesions extending into the lower half of the tendon were classed in group B (n = 21). For 37 cases, the subscapularis lesion was very small and was graded as partial by the surgeon at the time of surgery; 21 of these were not repaired. All patients gave informed written consent.

Functional and radiologic assessments

At follow-up, subjective shoulder values (SSVs) were recorded, with patients asked to assess their shoulder function as a percentage of that of a normal shoulder. Function was also evaluated using the Constant-Murley score, adjusted for the sex and age of the patient and expressed as a percentage. The corresponding preoperative score was available for 67 patients. Preoperative tendon tests are not reported because these differed widely between the participating surgical centers.

Radiographs of the shoulder were taken in anteroposterior view with double-obliquity projections before surgery and at follow-up. The subacromial space—the distance between the inferior cortex of the acromion and the humeral head—was measured in millimeters. The presence of glenohumeral arthritis was assessed using the modified Oxford scale. These radiologic factors were used to grade the tears before surgery and at follow-up using the Hamada-Fukuda classification.

The follow-up MRI examination involved transverse and sagittal T1-weighted sequences focusing on muscle tissue and T2-weighted fat-suppressed sequences in the coronal oblique, sagittal oblique, and transverse planes to analyze the repaired tendons. Follow-up MRI data were available for 77 shoulders, some patients having refused the examination. The MRI studies were interpreted by 4 independent physicians, namely, 1 junior and 2 experienced surgeons and 1 experienced radiologist. The healing of the supraspinatus and infraspinatus tendons was graded according to Sugaya’s classification. In keeping with Sugaya, we classified type I to III tendons as healed, irrespective of their aspect, and types IV and V as either an iterative tear or a failed healing response. Regarding the subscapularis, we classed the tendon as either healed if it appeared continuous in the horizontal cuts or not healed if a discontinuity was observed, regardless of its size or location.

We graded the fatty infiltration of the rotator cuff muscles in Fuchs stages, which are based on Goutallier’s classification. Fuchs stage A corresponds to Goutallier stages 0 (no intramuscular fat) and 1 (some fatty streaks) and is considered normal. Fuchs stage B (Goutallier stage 2) is considered pathologic, with fat evident, but less fat than muscle tissue. Fuchs stage C corresponds to substantial fatty infiltration, with equal amounts of fat and muscle (Goutallier stage 3), or severe (Goutallier stage 4), with more fat than muscle tissue.

The size of the tendon tear was assessed during surgery, in comparison with the preoperative imaging results when available.
(for 6692 patients). All patients had full-thickness tears in the supraspinatus tendon. The lesions in the subscapularis tendon were categorized according to their longitudinal extent, distal, when the tendon stump was at the level of the greater or lesser tuberosities; intermediate, when the tendon was beyond the apex of the humeral head; and severe, when the tendon had retracted to the glenoid. The location (in its sheath or partially/ completely displaced) and state (intact or partially/completely torn) of the tendon of the long head of the biceps brachii were also recorded.

Surgical procedure

Open repair was performed for 57 of 92 patients (62%) through a supraseriferolateral (for 46 patients) or deltopectoral (11 patients) approach. The repair involved transosseous sutures and in some cases subscapularis anchors. Arthroscopic repair was performed for the 35 remaining patients (38%), using anchors. Tenodesis and tenotomy of the tendon of the long head of the biceps brachii was performed in 62 and 8 cases, respectively. Acromioplasty was performed for 90 patients (98%), and an associated procedure on the subscapularis was performed for 8 patients (8.7%).

After surgery, the shoulder was immobilized either in a sling (13 patients [14%]) or on an abduction pillow (79 patients [86%]) for 2-8 weeks (5.8 ± 1.0 weeks on average).

Statistical analysis

Continuous data are reported using the mean or median and the standard deviation (SD) of the distribution. They were compared using a Student t-test if assumed to be normally distributed or a Mann-Whitney U test otherwise. Their paired versions were used to compare preoperative and postoperative data. Categorical data are summarized by the frequency of each category and were compared using an exact Fisher test. Analysis of variance or Kruskal-Wallis tests were used to compare 3 groups or more. To take account of the large number of tests performed in this study, the type I error rate was set to 0.001 (0.1%). All statistical calculations were carried out using R (v. 3.1.2).31

Results

Patient demographics

Table I summarizes the demographic details of the study participants. The states of the supraspinatus and subscapularis tendons in group A and B patients are compared in Tables II and III, respectively. Both groups were similar with regard to age, gender, and other demographic variables, but patients in group B were more likely to undergo open surgery than patients in group A were. The tendon of the long head of the biceps brachii was ruptured in 15 patients and was pathologic in 68 others; it was partially or medially displaced in 60 patients. The gender of the patient, duration of symptoms, cause of the tear (trauma or other), and the involvement of the dominant arm had no effect on the outcome.

Preoperative MRI (41 cases) or computed tomography arthrography (11 cases) data were available for 67 patients (information missing for the 15 remaining patients). The patients in groups A and B had similar lesions and fatty infiltration in the supraspinatus tendon, but the retraction and fatty infiltration of the subscapularis tendon were more marked for those in group B.
Table III  Preoperative data on and properties of the subscapularis tendon in the study population

<table>
<thead>
<tr>
<th>Subscapularis lesion</th>
<th>Group A (n = 71)</th>
<th>Group B (n = 21)</th>
<th>Total (N = 92)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper third</td>
<td>21 (30)</td>
<td>0</td>
<td>21 (23)</td>
<td></td>
</tr>
<tr>
<td>Upper half</td>
<td>50 (70)</td>
<td>0</td>
<td>50 (54)</td>
<td></td>
</tr>
<tr>
<td>Full-length, complete</td>
<td>0 (0)</td>
<td>21 (100)</td>
<td>21 (23)</td>
<td></td>
</tr>
<tr>
<td>Retraction</td>
<td></td>
<td></td>
<td></td>
<td>.002</td>
</tr>
<tr>
<td>Distal</td>
<td>54 (76)</td>
<td>8 (38)</td>
<td>62 (67)</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>13 (19)</td>
<td>7 (33)</td>
<td>20 (22)</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>4 (6)</td>
<td>6 (29)</td>
<td>10 (11)</td>
<td></td>
</tr>
<tr>
<td>Preoperative MRI or arthroscope data available</td>
<td>52</td>
<td>15</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

Fatty infiltration

- Fuchs stage A I: 67 (94), 13 (60), 80 (67)
- Fuchs stage B: 4 (6), 6 (27), 10 (11)
- Fuchs stage C: 0 (0), 2 (13), 2 (2)

MRI, magnetic resonance imaging.

Variables are presented as number (%).

* Fisher exact test.

Patients returned to work 6.2 ± 3.7 months after the operation and attended the follow-up appointment with a mean delay of 129 ± 7.4 months. Follow-up MRI studies were available for 77 patients. There were more reoperations in group B (7) than in group A (1), and likewise for complications, 6 in group B and 1 in group A. The complication reported was stiffness (similar to algodystrophy) in all but 2 cases, in which the type of complication was not specified.

Overall results

The SSV score at follow-up was 85% ± 16%. The preoperative characteristics of the 2 tendons' lesions had no influence on this score, but the healing of the supraspinatus tendon did (P = .02).

The components of the Constant-Murley score are shown in Table IV. The Constant-Murley score was 59 ± 16 (mean ± SD) preoperatively and 77 ± 14 postoperatively (P = 1.7 × 10^-12, paired Mann-Whitney test). The adjusted Constant-Murley scores were 71% ± 19% and 100% ± 18% (P = 2.3 × 10^-14, paired Mann-Whitney test). Larger lesions of the subscapularis and a dislocated biceps tendon were associated with lower Constant scores (P = .03 and P = .01, respectively, linear regression tests). There was no association between the Constant-Murley scores and tendon healing at follow-up.

Using radiographic criteria, 90 (98%) of the shoulders were classified in Hamada-Fukuda stage 1 and 2 were classified in Hadama-Fukuda stage 2 before surgery. At follow-up, 77 of the shoulders were classified in Hamada stage 1, 8 in stage 2, and 7 in stage 4. Samilson grades 1 or 2 were determined for 88 (96%) and 62 (67%) of the patients before surgery and at the follow-up examination, respectively.

Structural outcome

The overall retear rate was 33% (28/85 patients), including the 6 patients who were reoperated on and excluded from the clinical analysis. The retear rate of the supraspinatus tendon was 25% (19/77 cases). At follow-up, substantial fatty infiltration (Fuchs grade C) was observed in 9 (12%) and 7 (9%) cases for the supraspinatus and infraspinatus muscle, respectively. The retear rate for the subscapularis tendon was 13% (10/77 patients), and Fuchs grade C fatty infiltration of the muscle was observed in 21 (27%) patients. In 7 cases (9% of the cohort), both tendons were retear.

There was no link between the preoperative size of the lesions and the healing of the 2 tendons at follow-up. However, healing of the supraspinatus tendon was associated with healing of the subscapularis tendon (P = .0003, logistic regression test); an unhealed supraspinatus tendon was associated with more advanced fatty infiltration of the subscapularis muscle (P = .01, Fisher exact test).

Table IV  Constant-Murley scores for the study population (N = 92)

<table>
<thead>
<tr>
<th>Score (maximum)</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>P, MW test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain (15)</td>
<td>6 (3)</td>
<td>12 (3)</td>
<td>&lt;2 × 10^-16</td>
</tr>
<tr>
<td>Activity (20)</td>
<td>11 (3)</td>
<td>18 (3)</td>
<td>&lt;2 × 10^-16</td>
</tr>
<tr>
<td>Mobility (40)</td>
<td>32 (9)</td>
<td>35 (6)</td>
<td>0.01</td>
</tr>
<tr>
<td>Strength (25)</td>
<td>10 (7)</td>
<td>13 (7)</td>
<td>0.001</td>
</tr>
<tr>
<td>Total (100)</td>
<td>59 (16)</td>
<td>77 (14)</td>
<td>1.7 × 10^-12</td>
</tr>
<tr>
<td>Adjusted total, %</td>
<td>71 (19)</td>
<td>100 (18)</td>
<td>2.3 × 10^-14</td>
</tr>
</tbody>
</table>

MW, Mann-Whitney.

Data are expressed as mean (standard deviation).

Comparison of the outcomes for patients in groups A and B

Table V shows that the patients in group B have poorer outcomes in terms of all the clinical and anatomic criteria considered here. This indicates that after a full-thickness tear of the supraspinatus, the prognosis is poorer at 10 years when the associated lesions in the subscapularis tendon are extensive. For patients in group A, the type of surgery performed (open or arthroscopic) had no influence on the outcome at 10 years.

Functional outcomes and radiologic assessment

Table VI compares the results obtained for the fatty infiltration of the subscapularis muscle with the clinical and anatomic criteria discussed before. The subscapularis tendon was considered healed in all 26 cases in which there was no fatty infiltration (Fuchs stage A) of the muscle (Fig. 1 A). Similarly, the tendon was considered healed in 89% (38/43) of
Table V  Anatomic and clinical parameters measured for the study population

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant-Murley scores</td>
<td>n = 71</td>
<td>n = 21</td>
<td></td>
</tr>
<tr>
<td>Preoperatively</td>
<td>62 (15)</td>
<td>52 (19)</td>
<td>.06*</td>
</tr>
<tr>
<td>Postoperatively</td>
<td>80 (13)</td>
<td>70 (16)</td>
<td>.02*</td>
</tr>
<tr>
<td>SSV, %</td>
<td>87 (14)</td>
<td>77 (20)</td>
<td>.06*</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>n = 57</td>
<td>n = 20</td>
<td></td>
</tr>
<tr>
<td>Healing</td>
<td>45 (79)</td>
<td>13 (65)</td>
<td>.23</td>
</tr>
<tr>
<td>Fuchs stage C.FI</td>
<td>4 (7)</td>
<td>5 (25)</td>
<td>.048*</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>n = 57</td>
<td>n = 20</td>
<td></td>
</tr>
<tr>
<td>Healing</td>
<td>53 (93)</td>
<td>14 (70)</td>
<td>.02*</td>
</tr>
<tr>
<td>Fuchs stage C.FI</td>
<td>10 (18)</td>
<td>10 (50)</td>
<td>.009*</td>
</tr>
<tr>
<td>Postoperative SAS &lt;7 mm</td>
<td>7 (13)</td>
<td>6 (30)</td>
<td>.16*</td>
</tr>
</tbody>
</table>

FI, fatty infiltration; SAS, subacromial space; SSV, subjective shoulder value.
Categorical variables are presented as number (%). Continuous variables are presented as mean (standard deviation).
* Mann-Whitney test.
† Fisher exact test.

the cases in which Fuchs stage B or C infiltration was observed in the upper third of the subscapularis muscle (Fig. 1, B). However, the subscapularis tendon was considered healed in only 1 of the 6 cases in which substantial fatty infiltration occurred homogeneously throughout the muscle (Fig. 1, C). Note that for the 7 patients whose subscapularis was not repaired, 4 had no fatty infiltration (Fig. 1, A), 2 had Fuchs stage B or C fatty infiltration in the upper third of the muscle (Fig. 1, B), and 1 had substantial fatty infiltration throughout (Fig. 1, C).

Table VI also shows that important fatty infiltration (Fuchs stage B or C) was always associated with poorer clinical and anatomic outcomes, irrespective of its extent (throughout the subscapularis muscle or only in its upper third). Likewise, the observation of substantial subscapularis fatty infiltration was associated with poorer healing of the supraspinatus (P = .01, Fisher exact test) and subscapularis (P = .0003, Fisher exact test) tendons.

Discussion

The long-term outcome of surgical repairs for anterosuperior rotator cuff tears is positive, according to both subjective and objective criteria. With the exception of Borgmästers et al., who reported diminished clinical responses 16 years after open repairs performed in the 1980s, most studies in the literature described satisfactory clinical results at 10 years, particularly in terms of pain levels, even if the anatomic condition of the rotator cuff may degrade over time. According

Table VI  Postoperative anatomic and clinical parameters of the study population as a function of the observed fatty infiltration

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B or C†</th>
<th>B or C†</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>26</td>
<td>43</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Unhealed supraspinatus</td>
<td>0 (0)</td>
<td>5 (12)</td>
<td>5 (83)</td>
<td>.019</td>
</tr>
<tr>
<td>Unhealed subscapularis</td>
<td>2 (8)</td>
<td>12 (28)</td>
<td>4 (67)</td>
<td>.02</td>
</tr>
<tr>
<td>SSV, %</td>
<td>92 (9)</td>
<td>79 (16,5)</td>
<td>83 (23)</td>
<td>.006</td>
</tr>
<tr>
<td>Constant-Murley score</td>
<td>83.9 (9)</td>
<td>73.46 (15)</td>
<td>72.7 (15)</td>
<td>.056</td>
</tr>
</tbody>
</table>

SSV, subjective shoulder value.
Categorical variables are presented as number (%). Continuous variables are presented as mean (standard deviation).
* Graded by Fuchs stage.
† Only in the upper third of the subscapularis muscle.
‡ Throughout the subscapularis muscle.
§ Fisher exact test.

Figure 1  Postoperative magnetic resonance images (sagittal sections through the Y of the scapula) of the subscapularis muscle (A) in its normal condition, Fuchs stage A (26 cases, 35%); (B) with Fuchs stage C fatty infiltration in the upper third (43 cases, 57%); and (C) with Fuchs stage C fatty infiltration throughout (6 cases, 8%).
to Millett et al., the clinical outcome is poorer when the subscapularis tendon is also affected.

The retear rates reported here are not readily put into context, as existing long-term studies of this type of repair seldom report anatomic results. Although repeated tears most often occur soon after surgery, the retear rate seems to increase over time, particularly when the initial tear is large. Zumstein et al reported retear rates of 37% and 57% in the same population, respectively, 3.1 and 9.9 years after open repair of massive rotator cuff tears. Elsewhere, Goutallier et al described stable clinical and anatomic results for tendons healed within 1 year of surgery. In our study, the total retear rate at 10 years was 30% and predominantly involved the supraspinatus (retear rate of 25%) rather than the subscapularis tendon (retear rate of 13.5%), in keeping with most previous studies. Ide et al reported a subscapularis retear rate of 35% at 36 months after surgery, but for initial lesions extending into both halves of the tendon (Collin group B). Note that our study does not allow the time to retear to be determined.

The results at 10 years in our study population are similar to those reported for other anterosuperior repair cohorts with follow-up times varying from 34 to 56 months. In contrast with previous studies, the delay before surgical repair is not predictive of its outcome. In keeping with the literature, we found no association between the size of the lesion, in particular of the subscapularis, and the healing of the tendons, but the severity of the subscapularis tear was correlated with poorer clinical outcomes, in agreement with Namdar et al and Millett et al.

Collin et al reported that when tendon tears occur with severe fatty infiltration of the muscle (Fuchs stage C), the combination of a full-thickness tear of the supraspinatus with lesions along the full length of the subscapularis often leads to pseudoparalytic shoulder. (Note that only 3.2% of the patients in this study had a pseudoparalytic shoulder before surgery because severe fatty infiltration is generally recognized as a contraindication to surgery). Likewise, the results of this study justify classifying anterosuperior lesions according to the size of the subscapularis tear, in agreement with Barlt. Indeed, patients in group B (lesion extending to both halves of the tendon) had significantly poorer clinical and anatomic outcomes than those in group A (lesion affecting only the upper half of the subscapularis tendon). On average indeed, group B patients had lower Constant scores, higher retear rates, and more frequent arthritic degeneration and were more prone to require additional surgery, both soon after the original operation (to repair a retear) and several years later (to insert a prosthesis). Our results therefore support the prognostic value of the preoperative classification of Collin et al.

The retear rate is higher for the supraspinatus than for the subscapularis tendon, but on the other hand, there is less fatty infiltration increase in the supraspinatus muscle than in the subscapularis. After supraspinatus tendon repair, fatty infiltration is associated with reduced healing responses, but it also occurs when the tendon heals successfully. In this study, fatty infiltration of the upper half of the subscapularis muscle was observed in most (38/43) cases in which the tendon was considered healed. For these patients, the clinical outcomes (SSV, Constant score) were poorer than those of patients with no infiltration and similar to those of patients whose tendon did not heal and had widespread fatty infiltration. This suggests that for the former, contrary to observations, the upper half of the subscapularis tendon was not completely healed. This may be because subscapularis healing is inherently difficult to assess on MRI, in contrast to the supraspinatus tendon, which has a more favorable orientation and for which clear criteria are available. Another possibility is that from a technical and anatomic point of view, the surgical repair of the subscapularis tendon is of lower quality than that of the supraspinatus.

Our results show that healing of the supraspinatus tendon is associated with healing of the subscapularis tendon, whereas an absence of healing was associated with greater fatty infiltration of the subscapularis muscle after surgery. This observation suggests the presence of an anatomic link between the 2 tendons. Whereas the supraspinatus and infraspinatus tendons come together at their insertion in the greater tubercle, the subscapularis tendon may seem anatomically independent because it inserts into the lesser tubercle. However, Lo and Burkhart showed that the supraspinatus and subscapularis tendons are linked by a tendon bridge in the shape of a comma. This comma sign, which can be observed arthroscopically and in cases of retracted tears of the subscapularis, may explain the influence of the supraspinatus tendon on the subscapularis tendon.

The major limitations of this study are its retrospective and multicentric nature, with a variety of repair techniques and rehabilitation protocols that may have evolved during the 10-year follow-up period. Had operative reports been available, it would have been possible to account for the influence of the repair technique, notably whether the rotator interval was released during the operation. We note also that the 2 groups compared do not contain the same number of patients. Furthermore, healing of the subscapularis tendon is difficult to evaluate, and unlike for the supraspinatus tendon, no reference classification exists. The strengths of this study are the number of participants, the long follow-up period, and the availability of postoperative anatomic MRI for 77 patients. To the best of our knowledge, no equivalent study has been published on this frequently occurring injury.

**Conclusion**

The hypothesis of this study, that the size of the subscapularis lesion is predictive of the outcome of surgical repair for torn rotator cuffs, is confirmed. The supraspinatus and subscapularis tendons heal satisfactorily at 10 years, particularly if only the upper half of the subscapularis tendon is torn (group A patients in the classification of Collin et al). Larger lesions in the subscapularis tendon (Collin group B)
are predictive of unfavorable clinical (shoulder function) and anatomic (tendon healing and arthritis) outcomes. Substantial fatty infiltration of the upper subscapularis muscle was often observed at follow-up and was associated with poorer clinical outcomes, similar to those of patients whose tendons did not heal. Our results indicate that the healing of the supraspinatus tendon favors the healing and fatty infiltration of the subscapularis, which we suggest may be an effect of an anatomic link, the comma sign, that connects the 2 tendons. Further studies are required to fully understand the impact of this anatomic link.

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