Relationship between massive chronic rotator cuff tear pattern and loss of active shoulder range of motion

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\textbf{Background:} Management of massive chronic rotator cuff tears remains controversial, with no clearly defined clinical presentation as yet. The purpose of the study was to evaluate the effect of tear size and location on active motion in patients with chronic and massive rotator cuff tears with severe muscle degeneration.

\textbf{Methods:} One hundred patients with massive rotator cuff tears accompanied by muscle fatty infiltration beyond Goutallier stage 3 were prospectively included in this study. All patients were divided into 5 groups on the basis of tear pattern (supraspinatus, superior subscapularis, inferior subscapularis, infraspinatus, and teres minor). Active range of shoulder motion was assessed in each group and differences were analyzed.

\textbf{Results:} Active elevation was significantly decreased in patients with 3 tear patterns involved. Pseudoparalysis was found in 80\% of the cases with supraspinatus and complete subscapularis tears and in 45\% of the cases with tears involving the supraspinatus, infraspinatus, and superior subscapularis. Loss of active external rotation was related to tears involving the infraspinatus and teres minor; loss of active internal rotation was related to tears of the subscapularis.

\textbf{Conclusions:} This study revealed that dysfunction of the entire subscapularis and supraspinatus or 3 rotator cuff muscles is a risk factor for pseudoparalysis. For function to be preserved in patients with massive chronic rotator cuff tears, it may be important to avoid fatty infiltration with anterior extension into the lower subscapularis or involvement of more than 2 rotator cuff muscles.

\textbf{Level of evidence:} Level III, Cross-Sectional Study.

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The Institutional Review Board of the ethical committee of the Hôpital Privé Jean Mermoz and the Centre Orthopédique Santy approved this study.

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Massive chronic rotator cuff tears can often be associated with painful disability, with or without loss of active range of motion. Although massive rotator cuff tears are grouped the same on the basis of size classification, there is substantial variability in clinical symptoms and prognosis. The definition of a massive rotator cuff tear is not universally agreed on. Cofield et al defined a massive tear as being >5 cm in diameter, whereas Gerber et al defined a massive tear as having 2 or more tendons involved. In contrast, the tear pattern is less commonly discussed but may be more important clinically.

The loss of active range of motion seen in some patients with massive rotator cuff tears can markedly restrict activity. Pseudoparalysis with an active forward elevation of less than 90° in association with preserved passive motion commonly occurs in patients with massive rotator cuff tears. Although pseudoparalysis is commonly recognized, the risk factors for its development remain unclear.

The purpose of the study was to evaluate the effect of tear size and location on active motion in patients with chronic massive rotator cuff tears with severe muscle degeneration. The hypothesis was that involvement of the subscapularis would be a risk factor for pseudoparalysis.

Materials and methods

Patient selection

Between March 2008 and April 2011, all patients with a rotator cuff tear evaluated in a shoulder clinic were considered potentially eligible for inclusion in this prospective study. Patients with rotator cuff tears defined as 2 or more tendons, with muscle fatty infiltration beyond grade 3 diagnosed by computed tomography (CT) arthrography according to Goutallier’s criteria, were included in the study. To ensure that the tendon was nonfunctional, fatty infiltration beyond grade 3 was used as an inclusion criterion as it is indicative of complete fatty infiltration of the muscle compartments and proves chronic impairment and a nonfunctional musculotendinous unit. Exclusion criteria were incomplete documentation, limited passive shoulder range of motion, previous shoulder surgery, substantial glenohumeral osteoarthritis (Hamada classification > grade 3), and inadequate CT arthromograms that prevented adequate muscle analysis. The rotator cuff tears were divided into 5 components: supraspinatus, superior subscapularis, inferior subscapularis, infraspinatus, and teres minor (Fig. 1).

Study variables and clinical evaluation

Two shoulder surgeons (P.C. and G.W.) examined all the patients independently. The primary outcome of interest was active range of shoulder motion in relation to rotator cuff tear pattern. Active anterior elevation, external rotation in 0° of abduction, and external rotation in 90° of abduction were assessed with a goniometer in the upright position. Internal rotation behind the back in 0° of abduction was estimated to the nearest spinal level. Range of motion was video recorded in all patients. Pseudoparalysis was defined as the inability to actively elevate the arm beyond 90° with full passive forward flexion. The baseline characteristics assessed were age, sex, and deltoid function. In addition, a visual analog scale pain score graded from 0 (no pain) to 10 points (maximal pain) was recorded.

Radiographic evaluation and study definitions

A standard set of radiographs, consisting of true anteroposterior, lateral scapular, and axillary views, were obtained for each patient. Glenohumeral arthritis was classified according to Hamada’s criteria. CT arthograms were analyzed for fatty infiltration of the rotator cuff greater than grade 3 as viewed in the sagittal plane. Peripheral fatty tissue surrounding the muscles was viewed as extramuscular and was not taken into account. A training session to review and discuss the Goutallier scoring system was completed by the 2 surgeons before they independently evaluated the images. Each surgeon independently reviewed each set of images once, resulting in 2 separate readings for each patient.

Rotator cuff tear patterns were classified into five types: type A, supraspinatus and superior subscapularis tears; type B, supraspinatus and entire subscapularis tears; type C, supraspinatus, superior subscapularis, and infraspinatus tears; type D, supraspinatus and infraspinatus tears; and type E, supraspinatus, infraspinatus, and teres minor tears (Figs. 2 and 3).

Statistical analysis

In this prospective analysis, baseline characteristic variables were reported as mean ± standard deviation or proportions. The demographic data including differences in pain and active range of motion between the 5 groups were examined by post hoc Mann-Whitney U tests with Bonferroni correction. The significance level was set at .05. The interobserver reliability of the Goutallier scores was determined for each patient by calculating multijudge κ coefficient of agreement.

Results

The study inclusion criteria were met by 112 patients; 12 patients were excluded from the study because of
incomplete documentation, and no patients declined to participate. Thus, 100 patients (50 men and 50 women) with a mean age of 67.7 ± 8.2 years (range, 50-84 years) were available for the analysis. Baseline characteristics are summarized in Table I.

The average $\kappa$ value for interobserver agreement of fatty infiltration evaluation by the Goutallier system was 0.92, representing a good agreement.

No significant difference in subjective pain was observed between the 5 patient groups (Fig. 4). Active anterior elevation was lowest in patients with type B tears (Fig. 5). Of note, active elevation in patients with type B tears ($83^\circ \pm 52^\circ$) was significantly lower than in those with type A ($178^\circ \pm 7^\circ$), D ($176^\circ \pm 21^\circ$), and E ($141^\circ \pm 54^\circ$) tears ($P < .05$). In addition, active elevation in patients with type C tears ($116^\circ \pm 62^\circ$) was significantly lower than in those with type D tears ($P < .01$). Active elevation in patients with type E tears was also significantly lower than in those with type D tears ($P = .01$). Pseudoparalysis was demonstrated in 80% of patients with type B tears and in 45% with type C tears (Fig. 6).

External rotation at 0° of abduction was significantly decreased in patients with type C ($25^\circ \pm 23^\circ$), type D ($26^\circ \pm 21^\circ$), and type E ($1^\circ \pm 3^\circ$) tears compared with those with type A ($60^\circ \pm 17^\circ$) and type B ($52^\circ \pm 21^\circ$) tears ($P < .01$) (Fig. 7). Furthermore, the external rotation at 0° of abduction for patients with type E tears was significantly lower than for patients with type C and type D tears ($P < .01$). In addition, external rotation at 90° of abduction was significantly lower in patients with type E tears ($20^\circ \pm 30^\circ$) compared with those in the other groups (89° ± 4° in A, 80° ± 13° in B, 62° ± 26° in C, and 75° ± 21° in D) ($P < .01$).

External rotation at 90° was also lower in type C compared with type A tears ($P = .04$) (Fig. 8).

Internal rotation was lower in patients with type A (L1 vertebrae), B (L2 vertebrae), and C (L2 vertebrae) tears compared with those with type D (T10 vertebrae) and E (T11 vertebrae) tears (Fig. 9).

Discussion

The ideal management of massive chronic rotator cuff tears remains controversial. Multiple treatment options have been proposed without any consensus.1,16 Several factors may contribute to this lack of consensus. First, the definition of a “massive” tear has not yet been clearly standardized. Cofield et al6,15 defined massive tears as >5 cm in either the anterior-posterior or medial-lateral dimension, whereas Gerber et al14 defined massive as a complete tear of at least 2 tendons. In the current study, we used the definition of massive tears proposed by Gerber et al. Most past reports have adopted either criterion, which can lead to
very different cohorts of massive tears across clinical studies. Second, many studies do not discuss the pattern of involved muscles. Clinical symptoms are likely to be different on the basis of which tendons are torn, and likewise the management may need to be adjusted on the basis of the tear pattern. To date, however, no correlation has been reported between rotator cuff tear pattern and symptoms. Finally, similarly sized and patterned tears may differ in the quality of rotator cuff muscles. Fatty infiltration is an irreversible condition that negatively influences functional results after repair. In addition, an association has been demonstrated between muscle disease, such as fatty infiltration, and symptoms. Thus, muscle quality should be considered in the management of a massive tear.

In the current study, we focused on muscle status, as tendon status does not reflect musculotendinous unit function. Fatty infiltration in the context of an intact tendon has been described previously. However, severe fatty infiltration of the muscle results in a musculotendinous unit that is nonfunctional, irrespective of whether the tendon is torn. In the current study, cases with rotator cuff tears with severe fatty infiltration of at least 2 rotator cuff muscles were evaluated, and the subscapularis was categorized as 2 components consisting of superior and inferior parts. Therefore, type A tears, which represent a tear of the supraspinatus and superior subscapularis, would be excluded from the category of massive tear according to the criterion of Gerber et al. Subscapularis tears are generally regarded as a single muscle, but anatomy and function support the distinction between the superior and inferior portions of the muscle. Compared with the other 3 rotator cuff muscles, the subscapularis is a substantially larger muscle, and its force-generating capacity is estimated to be equal to that of the other muscles combined. The superior two thirds of the subscapularis coalesce into a tendon and attach to the lesser tuberosity, whereas the inferior third remains muscular in its insertion. This pattern of attachment is similar to the posterior tendinous attachment of the infraspinatus and the muscle attachment of the teres minor. Moreover, in the case of severe fatty infiltration of

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**Table I** Baseline characteristics

<table>
<thead>
<tr>
<th>Type of rotator tears</th>
<th>Number of patients</th>
<th>Mean age ± standard deviation (years)</th>
<th>Patients who were male, n (%)</th>
<th>Dominant/nondominant shoulder, n (%)</th>
<th>Right/left shoulder (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8</td>
<td>63.9 ± 5.4</td>
<td>6 (75%)</td>
<td>6/2</td>
<td>5/3</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>69.5 ± 9.2</td>
<td>8 (40%)</td>
<td>15/5</td>
<td>14/6</td>
</tr>
<tr>
<td>C</td>
<td>22</td>
<td>70.0 ± 8.0</td>
<td>11 (50%)</td>
<td>18/4</td>
<td>19/3</td>
</tr>
<tr>
<td>D</td>
<td>35</td>
<td>66.4 ± 7.8</td>
<td>18 (51%)</td>
<td>19/16</td>
<td>20/15</td>
</tr>
<tr>
<td>E</td>
<td>15</td>
<td>68.2 ± 7.6</td>
<td>7 (47%)</td>
<td>12/3</td>
<td>11/4</td>
</tr>
</tbody>
</table>

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**Figure 3** The cases with rotator cuff tears involving 2 or 3 rotator cuff components with muscle fatty infiltration beyond Goutallier grade 2 were included in this study. Fatty infiltration of the respective muscle compartments could help judgment of the involved area of the rotator cuff tears.
the superior part of the subscapularis, the rounded muscular inferior part of the subscapularis looks like the teres minor in the case of infraspinatus severe fatty infiltration. For these reasons, we have called the inferior part of the muscle the subscapularis minor. The superior and inferior portions of the subscapularis are also innervated by different nerves, the upper and lower subscapular nerves, respectively. Finally, the upper and lower portions of the subscapularis muscle exhibit differential activity in electromyographic and positron emission tomography studies.

Pseudoparalysis has been defined as less than 90° of active anterior elevation with full passive range of motion and no neurologic impairment, but its risk factors remain unclear. In the present study, active range of elevation was significantly different between patients with type A (supraspinatus and superior subscapularis) and type B (supraspinatus and complete subscapularis) tears. All patients with type A tears maintained active elevation above shoulder level, whereas 80% of patients with type B tears had pseudoparalysis. This indicates that the other muscles can adequately compensate for tears involving the supraspinatus and superior half of subscapularis but not for tears involving the supraspinatus and entire subscapularis. Conversely, repair of the subscapularis tendon would be critical for reversing pseudoparalysis. The anterior attachment of the rotator cable extends into the subscapularis tendon; thus, extension of a tear into the inferior subscapularis may effectively represent a disruption of the anterior rotator cable attachment. In the current study, a high proportion of patients with group B tears had pseudoparalysis, which was also observed in half of patients with type C tears (superior subscapularis, supraspinatus, infraspinatus) and one third of patients with type E tears (supraspinatus, infraspinatus, teres minor). This demonstrates that dysfunction of 3 rotator cuff muscles is a risk factor for pseudoparalysis. However, the lowest mean active elevation and highest proportion of patients with pseudoparalysis were observed with complete tears of the
subscapularis, suggesting that the subscapularis is more important than the infraspinatus and teres minor in shoulder elevation. This is also supported by positron emission tomography investigation, which has demonstrated that the subscapularis plays an important role during scapular plane elevation in addition to the deltoid and supraspinatus.26

In the management of massive chronic rotator cuff tears, it seems crucial to avoid type B and type C tear pattern situations to preserve shoulder elevation. Both the infraspinatus and teres minor work as external rotators, but the results of the current study highlight the different roles that the 2 muscles play, as previously described.29 In the current study, active external rotation in the abducted position significantly decreased with infraspinatus tears and additionally with extension into the teres minor tear. In addition, external rotation in the abducted position was affected more by a teres minor tear than by an infraspinatus tear alone. Hence, when a massive rotator cuff tear is repairable, rotator cuff repair may be the best option for these patients.1,14

However, there seems to be no consensus for the ideal management of irreparable massive tears.16 Good clinical results have been reported after nonoperative treatment,33 debridement and decompression,12,28 long head of the biceps tenotomy or tenodesis,2,30 and tendon transfer.13,27 These treatment options can relieve pain, but it is questionable whether lost function will recover. Reverse total shoulder arthroplasty has been proposed as an option for treatment of the pseudoparalytic shoulder even without arthritis,3,8,24 with good short-term clinical results being reported with this technique. Although reverse total shoulder arthroplasty is the most reliable treatment in severe cases, it may not be suitable for primary surgery, particularly in younger patients. Furthermore, reverse shoulder arthroplasty may not be indicated without glenohumeral arthritis in patients with group D tears (supraspinatus and infraspinatus). In the current study, group D tear was almost never associated with pseudoparalysis; hence, we suspect that pseudoparalysis reported in cases of supraspinatus and infraspinatus tears only is in reality mistaken for pain inhibition or stiffness. Muscle fatty infiltration, which is irreversible and is dependent on the time after the onset of symptoms, is well known as one of the main factors for poor outcomes in operative repair.15,17,18 Rotator cuff tears with fatty infiltration beyond Goutallier stage 2 are associated with a poorer functional outcome.16 However, the results of the present study support partial rotator cuff repair in select cases.4 Even if a rotator cuff tear is not completely repairable, partial healing may occur and be beneficial. Converting a 3-tendon tear to a 1- or 2-tendon tear may, for instance, help preserve active elevation. Furthermore, with severe fatty infiltration of fewer than 3 muscles, a partial rotator cuff repair may prevent extension of the tear and help maintain critical function.

Strengths and limitations

The current prospective study is only the second detailed report that refers to the relationship between the involved area of massive rotator cuff tear and its clinical symptoms.29 As massive rotator cuff lesions and pseudoparalysis are difficult conditions with considerable debate in treatment, this study provides more information and another way of viewing this important topic. In addition, the large sample size allowed correlation of range of motion and rotator cuff tear pattern. This study was, however, limited by the lack of assessment of biceps disease, which could affect the pain score results. Furthermore, we did not evaluate less severe degrees of fatty infiltration of the rotator cuff muscles. Most important, this study did not examine treatment and the ability of surgical treatment to alter the natural history of disease. The clinical importance is therefore only speculative. Further studies are therefore needed to examine the ability to reverse pseudoparalysis and the relationship to complete or partial tendon healing as
well as the natural history of disease so that more specific recommendations can be made regarding maintenance of function.

Conclusions

This study suggests that dysfunction of the entire subscapularis or 3 rotator cuff muscles is a risk factor for pseudoparalysis. For function to be preserved in patients with massive chronic rotator cuff tears, it may be important to avoid fatty infiltration with anterior extension into the lower subscapularis tendon or involvement of more than 2 rotator cuff muscles.

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