Introduction

Irreparable rotator cuff tear is defined as the inability to reattach the cuff tendons on the greater tuberosity despite a release of their deep and superficial layers [1]; it may
be associated with persistent pain and functional disability.

Various methods have been suggested to restore active anterior elevation after irreparable rotator cuff tear, most of which demonstrating uncertain results, such as synthetic implants [2], deltoid muscular flap transfer and upper subscapularis translation [3]. Latissimus dorsi tendon transfer was first introduced by Gerber in 1988 and seems to provide better results [4,5]. The flap stabilizes the humeral head and allows for more effective action of the deltoid muscle, which leads to improved anterior elevation. Furthermore, its posterolateral orientation enhances external rotation.

The purpose of this retrospective study was to assess the outcome of this technique in primary repairs but also in salvage reconstructions for failed prior rotator cuff surgery.

Patients and methods

This retrospective, mono-centric study included 25 consecutive patients who underwent an isolated latissimus dorsi tendon transfer for the treatment of massive irreparable rotator cuff tears with a minimum follow-up of one year. Painful shoulder associated with limited anterior active elevation and significant loss of strength were inclusion criteria. Patients with a trumpet sign and having underwent a latissimus dorsi and teres major transfer according to the L’Episcopo procedure [6] and those sustaining a pseudoparalytic shoulder associated with anterosuperior instability after massive rotator cuff tear, were excluded from the study.

Fourteen males and 11 females of mean age 55.8 years (range, 42 to 64 years) were included in this study group. Seventeen patients underwent a latissimus dorsi tendon transfer as a primary reconstruction (group I) and eight as a salvage procedure for previously failed shoulder surgery (group II). It consisted of arthroscopic debridement in three cases and rotator cuff repair in five cases (open surgery in three cases and arthroscopy in two).

Twenty patients were manual workers and five were sedentary. Symptoms were related to a work-related accident in 15 cases. Only nine patients had sustained trauma. All patients had undergone a rehabilitation protocol of at least 30 sessions therefore enhancing active anterior elevation but with persisting pain and subacromial impingement. Symptoms were often pain with limitation in active anterior elevation (mean 90°) and strength loss.

Clinical examination revealed anterosuperior and posterolateral impingement signs in almost all cases. The Palm-up test was positive in 17 patients showing pain from the long head of the biceps. The Gerber’s lift-off test was positive in one case. None of the patients had a preoperative trumpet sign, which suggested good integrity of the teres minor muscle.

None of the patients had atrophy of the deltoid muscle. We considered integrity of the deltoid muscle as a prerequisite for proper latissimus dorsi tendon transfer.

Standard anteroposterior radiographs taken with the forearm in neutral rotation showed ascension of the humeral head in 20 cases. A persistent subacromial space of at least 2–3 mm was noted. Acromial morphology was of type I in seven cases, type II in 14 cases and type III in four cases according to the Bigliani classification system [7]. Glenohumeral osteoarthritis was observed in a single case.

The CT arthrogram revealed tear of both supra- and infraspinatus tendons in 21 cases, of both supraspinatus and subscapularis tendons in one case and of the three tendons in two cases. Lesions to the subscapularis involved less than half of the tendon in the sagittal plane. Isolated infraspinatus rupture was noted in one case. Group distribution is detailed in Table 1. All torn tendons were retracted to the glenoid (stage 3). The mean preoperative fatty degeneration according to the Goutallier’s classification was 3.28 for both supra and infraspinatus and 0.6 for the subscapularis [8].

Surgery was performed under general anaesthesia and interscalenic block in all cases with patient in lateral position. A lateral approach centered over the midsection of the acromion was first performed to make it easier to identify the extent of the rotator cuff tear. The skin incision started posterior to the acromioclavicular joint facing the distal aspect of the trapezius and extending over the midsection of the deltoid without exceeding 4 cm from the lower margin of the acromion to avoid any damage to the axillary nerve. A trapeziodeltoid digastic flap was elevated along with some corticocancellous acromion chips thus reducing the risk of mid-deltoid muscle detachment and facilitating its reinsertion. The coraco-acromial ligament was preserved to prevent any anterosuperior destabilization and the acromion was split in its mid and lateral aspects. The long head of the biceps tendon was present in 19 cases and preserved when intact (six cases) and tenodised (seven cases) in the bicipital groove or tenomised (six cases) in case of subluxation or when damaged. The latissimus dorsi was then harvested through an axillary approach. A 10 cm incision was made along the anterior border of the latissimus dorsi, extending from the scapular angle up to the posterior deltoid and passing through the axillary hollow while respecting the flexion folds (to avoid any retractile scar which could limit elevation movements). It was separated posteriorly from the teres major (not released), anteriorly from the serratus anterior muscle and down the subcutaneous tractus and fibrous attachments of the scapular angle. This release, performed on its vasculonervous pedicle (which was not dissected but only visualized during dissection of the anterior border of the latissimus dorsi), is necessary to allow elevation without traction and fixation of the latissimus dorsi fascia to the greater tuberosity. If not released, the suture is performed with tension resulting in scapular tilt when the arm abucted with a tenodesis effect and a risk of iterative rupture. Proper exposure and release of the aponevrotic fascia of the latissimus dorsi from the humerus requires a thorough knowledge of the radial and axillary nerve path, which location relative to the latissimus dorsi varies according to the arm rotation. These anatomical considerations were reviewed by the anatomical studies conducted by Cleeman [9] and Pearle [10]: the radial nerve is located inferiorly and anteriorly at a mean distance of 2.9 cm, whereas the axillary nerve is situated more proximally at a mean distance of 1.4 cm. No intraoperative damage or postoperative deficiency was observed in our series. The latissimus dorsi’s aponevrotic fascia with its periostium was disinserted from the medial border of the humerus with the arm placed in internal rotation. The harvested fascia was then passed
under the posterior bundle of the deltoid and posteriorly from the teres minor then secured to the greater tuberosity (at the insertion site of the infraspinatus and supraspinatus) with at least four suture anchors to obtain a large contact surface. A suture to the rotator cuff tendon stumps was performed when possible (13 out of 25 cases in our series). Attachment to the greater tuberosity was easier in slender patients: stocky and brachimorphic individuals with bulky but shorter muscle course do not have a suitable anatomy for this type of surgery.

The arm was immobilized at 30° of abduction and 20° of external rotation during a 6-week period. Mobilisation was initiated in the early postoperative phase; passive shoulder motion for the first six weeks after which an active motion program was instituted. The main objective was to achieve a satisfactory external rotation and an active anterior elevation as normal as possible. A 6-month rehabilitation protocol was carried out.

At follow-up, the patient’s degree of satisfaction, shoulder function and pain were assessed subjectively and combined with objective evaluation of active and passive range of motion and muscular strength. The Constant score was used to measure any significant improvement in elevation and external rotation. Patients were divided into three categories according to preoperative active elevation (< 80°; 80–120°; > 120°) [11].

**Statistical analysis**

The student t-test was used for statistical analysis when two groups had to be compared. When comparison involved more than two groups, a variance analysis was applied. The chosen level of significance (p) was set at 0.05.

**Results**

No major postoperative complication (neurologic or infectious) was noted in this series; two patients presented axillaries scars that necessitated extended massage of the scars the results were evaluated at a mean follow-up of 22 months (range, 12 to 60 months).

The mean active anterior elevation increased from 94.4° preoperatively to 151.6° postoperatively, achieving an improvement of 57.2°, that is 60.5%. This increase was significant (p < 0.0001). The improvement was all the more important that the preoperative active anterior elevation value was low. Patients with a preoperative active anterior elevation < 80° reported a mean improvement of 82.5° (123%) versus 18° (12%) in patients with preoperative active anterior elevation > 120° (Table 2). This difference between groups was considered as being significant (p < 0.05).

When comparing the two groups previously defined in Section 1 Patients and methods, the active anterior elevation improvement was higher in group I than in group II (Table 3). However, such difference did not appear as statistically significant.

External rotation achieved a significant improvement of about 50%. The average external rotation value, elbow at the side (ER1) increased from 24.4° preoperatively to 36.4° postoperatively (p < 0.05) and the mean external rotation value, with the arm abducted 90° (ER2), increased from 33.2° to 50.4° (p < 0.0001).

As for active anterior elevation values, the gain of external rotation was higher in patients with preoperative active anterior elevation < 80° (Table 1) and in those from group I (Table 2), however, such differences were not significant.

Strength improvement was poor since it increased from three points preoperatively to 5.12 postoperatively with no significant differences noted between group I and II.

External rotation did not demonstrate any significant difference whether suture to the tendon stumps had been performed or not (in 13 out of 25 cases).

The mean Constant score increased from a preoperative value of 35.5 to a postoperative value of 58, thus achieving an improvement of 63.4%. This increase was significant (p < 0.0001). The major improvement was noted in pain values (89%), then activity (86%), strength (70%) and finally mobility (47%). The Constant score improvement was greater in patients demonstrating a preoperative active anterior elevation value < 80°. These patients reported a mean improvement of 30 points, that is 109% against 18.8 points (47.5%) in patients with an active anterior elevation between 80° and 120° and 13.8 points (26.8%) in patients with an active anterior elevation value > 120° (Table 1). However, only the difference in values between patients with preoperative AAE < 80° and those with preoperative AAE > 120° was considered as statistically significant. A higher improvement was reported in patients from group I for whom the Constant score increased from a preoperative value of 35.8 to a postoperative value of 60.8, which is an increase of 25 points or 70% vs 49% in patients from group II; however, this difference was not considered as being statistically significant.

The Constant score gain was better when muscle fatty degeneration was lower than stage 4 with an improvement of 91% vs 49% when muscle fatty degeneration was stage 4, such results were not considered as significant (p < 0.08).

At last follow-up, 84% of patients were very satisfied or satisfied, 8% were quite satisfied and 8% considered surgery as a failure. This subjective outcome was independent from

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**Table 1** Ruptures distribution in both groups (Group 1: primary repair, group II: salvage reconstruction).

<table>
<thead>
<tr>
<th></th>
<th>Supraspinatus and infraspinatus</th>
<th>Supraspinatus and subscapularis</th>
<th>Supraspinatus, infraspinatus and subscapularis</th>
<th>Infraspinatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>14</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Group II</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

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### Table 2  
Results according to preoperative AAE.

<table>
<thead>
<tr>
<th>G</th>
<th>N</th>
<th>preop AAE</th>
<th>postop AAE</th>
<th>AAE gain</th>
<th>ER1 preop</th>
<th>ER1 postop</th>
<th>ER1 gain</th>
<th>ER2 preop</th>
<th>ER2 postop</th>
<th>ER2 gain</th>
<th>CST preop</th>
<th>CST postop</th>
<th>CST gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 80</td>
<td>12</td>
<td>67 (30–80)</td>
<td>149 (80–180)</td>
<td>82*</td>
<td>17 (0–40)</td>
<td>32 (20–60)</td>
<td>15</td>
<td>26 (0–70)</td>
<td>42 (20–80)</td>
<td>16</td>
<td>27 (15–44)</td>
<td>57 (38–69)</td>
<td>30*</td>
</tr>
<tr>
<td>80–120</td>
<td>8</td>
<td>102 (90–120)</td>
<td>146 (120–170)</td>
<td>44</td>
<td>21 (0–40)</td>
<td>31 (20–60)</td>
<td>10</td>
<td>28 (0–60)</td>
<td>45 (20–80)</td>
<td>17</td>
<td>37 (32–46)</td>
<td>54 (43–69)</td>
<td>17</td>
</tr>
<tr>
<td>&gt; 120</td>
<td>5</td>
<td>148 (130–180)</td>
<td>166 (150–180)</td>
<td>18*</td>
<td>48 (10–80)</td>
<td>56 (40–80)</td>
<td>8</td>
<td>58 (40–80)</td>
<td>78 (60–90)</td>
<td>20</td>
<td>51 (46–60)</td>
<td>65 (40–83)</td>
<td>14*</td>
</tr>
</tbody>
</table>

All values are expressed in degree except for Constant score; G: group; AAE: active anterior elevation; preop: preoperative; postop: postoperative; CST: Constant score; ER1: external rotation; elbow at the side; ER2: external rotation in 90° of abduction; N: number of cases.

* Significant gain; p < 0.05.

### Table 3  
Results according to surgical indication: primary (group I) or salvage procedure (group II).

<table>
<thead>
<tr>
<th>G</th>
<th>N</th>
<th>Preop AAE</th>
<th>Postop AAE</th>
<th>AAE gain</th>
<th>ER1 preop</th>
<th>ER1 postop</th>
<th>ER1 gain</th>
<th>ER2 preop</th>
<th>ER2 postop</th>
<th>ER2 gain</th>
<th>CST preop</th>
<th>CST postop</th>
<th>CST gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>17</td>
<td>96 (30–180)</td>
<td>159 (120–180)</td>
<td>63*</td>
<td>24 (0–80)</td>
<td>39 (20–80)</td>
<td>15*</td>
<td>31 (0–80)</td>
<td>52 (20–80)</td>
<td>21*</td>
<td>36 (15–60)</td>
<td>61 (40–75)</td>
<td>25*</td>
</tr>
<tr>
<td>II</td>
<td>8</td>
<td>91 (60–110)</td>
<td>135 (80–160)</td>
<td>44*</td>
<td>25 (0–40)</td>
<td>30 (20–50)</td>
<td>5</td>
<td>37 (0–70)</td>
<td>46 (20–80)</td>
<td>9</td>
<td>35 (20–52)</td>
<td>52 (38–69)</td>
<td>17*</td>
</tr>
</tbody>
</table>

All values are expressed in degree except for Constant score; G: group; AAE: active anterior elevation; preop: preoperative; postop: postoperative; CST: Constant score; ER1: external rotation; elbow at the side; ER2: external rotation in 90° of abduction; N: number of cases.

* Significant gain; p < 0.05.
age, gender and work-related injury. On the other hand, 50% of the patients who underwent latissimus dorsi tendon transfer as a salvage procedure (Group II) reported a fair or poor subjective outcome. No significant differences were observed within group II according to the type of previous surgeries.

Injury to the subscapularis tendon, only involving its upper half (confirmed intraoperatively) was present in three patients of our study and did not significantly influenced the objective and subjective outcome. These patients reported improvement in active range of motion values (AAE: from 82.5° to 157.5°; external rotation 1: from 25° to 42.5°; external rotation 2: from 35° to 60°) and Constant score values (from 30 to 58.5).

Discussion

The management of irreparable rotator cuff’s tears, especially in young patients, is therapeutically challenging with a limited number of available treatment options. The good results achieved with latissimus dorsi tendon transfer for proper restoration of elevation and external rotation in the management of obstetrical brachial plexus palsy have encouraged Gerber, in 1988, to use this technique in the treatment of irreparable supra- and infraspinatus tendon tears [12–14]. Due to the successful results reported in 1992 with regards to pain, anterior elevation and external rotation after latissimus dorsi tendon transfer in the treatment of posterosuperior cuff tears with intact subscapularis, the use of this technique was expanded. Since then, many studies [15–17] were published and reported similar results with use of this technique thus demonstrating its reproducibility and biomechanical fundament. The use of the latissimus dorsi tendon transfer has two benefits: it acts as a depressor and external rotator of the humeral head and stabilizes it while centering it and enhancing the elevation and abduction potential of the deltoid. Intact deltoid was a prerequisite to the achievement of the tendon transfer. This requirement has been frequently suggested by various authors such as Codsi and Warner who consider deltoid amyotrophy as a contraindication to latissimus dorsi transfer [16,18]. However, Miniaci did not found any difference in the outcome with regards to the presence or absence of deltoid dysfunction and concludes that deltoid integrity is not a prerequisite to the achievement of tendon transfer [15].

In our series, the mean postoperative AAE was 151.6° demonstrating an average improvement of 57.2°. These findings correlate with those reported by Gerber et al. [5] with an increase of 52°, and are slightly higher than the 36° improvement reported by Aoki et al. [17].

In his series, Warner and Parsons [16] compared the outcome of latissimus dorsi transfer for primary and salvage reconstructions of irreparable rotator cuff tears: the postoperative AAE was 122° with a mean improvement of 60° in the first group and 105° with a mean improvement of 43° in the second group. These findings correlate with those reported in our series. However, Miniaci [15] reports an increase of 57.8°, significantly higher in salvage reconstructions. In 2006, Gerber moderates these two observations by demonstrating that pain relief and functional improvement are similar in both groups except if the reoperated patient presents with a long history of deficient shoulder.

In our series, external rotation in ER1 improved from 24.4° to 36.4° with an overall increase of 12°. These results are in agreement with those reported in the Miniaci study. However, the difference between the improvements seen in group I and II (15.3° and 5°) did not appear as significant and correlates with the outcome reported in the series of Warner in which no significant difference was noted between the two groups regarding external rotation.

The Constant score values increased by 73% in Gerber’s series [19] and by 63.3% in our series. In the study of Warner, the postoperative Constant score was 69 in group I with an improvement of 33% [20] and 52 in group II with an improvement of 16% [21]. A better improvement was noted in our series for each group but the Constant scores remain lower than those reported by Warner. These findings might be explained by a higher preoperative score in Warner’s series [16] compared with our series.

The overall Constant score slightly exceeds 60 points. This score is lower than that obtained after conventional rotator cuff repair (open or arthroscopic surgery). Patient should be advised that latissimus dorsi tendon transfer achieves a less favourable functional recovery than with conventional rotator cuff repair. According to Warner, the lack of information is responsible for most iterative tendon ruptures, especially in the case of early significant improvement. After one-year follow-up, the clinical result had not decreased (for older patients), which could suggest the absence of iterative tendon rupture in our series. However, no postoperative electromyogram was carried out to confirm any contraction of the harvested tendon and no MRI did evaluate the presence of the fascia on the greater tuberosity in our series.

In our study, 84% of the patients were very satisfied or satisfied. These results correlate those reported by Gerber, Aoki and Miniaci with 80, 75 and 82% respectively of excellent and good results. In the series of Warner, similar results were only achieved in group I (83% of the cases). In group II, 50% of the patients from our series and that of Warner demonstrated fair or poor results.

The influence of the subscapularis integrity on the results remains controversial. According to a biomechanical study conducted by Werner et al. [22], the subscapularis plays a key role in stabilizing the humeral head in the transverse plane. Its absence of deficiency could be responsible for anterior subluxation of the humeral head. In the initial series of Gerber, the overall Constant score at last follow-up was 73 and evolved to 83 after excluding patients with subscapularis deficiencies. According to Warner and Codsi, subscapularis rupture is a contraindication to transfer, whereas Miniaci believes it does not constitute a bad predictive factor.

The small number of subscapularis tears (three cases), involving the upper half, does not suggest subscapularis dysfunction is a contraindication to latissimus dorsi transfer. However, combined teres minor transfer secured to the lower portion of the lesser tubercle could compensate for the absence of the subscapularis and therefore enhance the latissimus dorsi action (we performed this procedure successfully twice, outside this study).

Gerber et al. have demonstrated that latissimus dorsi transfer reported better results when teres minor fatty infl-
tation was lower than grade 2 according to the Goutallier classification. In our series, even if no patient had a preoperative trumpet sign which suggested an efficient teres minor, teres minor muscular trophicity and degree of fatty infiltration were not assessed with scan in all patients therefore preventing any significant correlation with the outcome of latissimus dorsi transfer, which is a limitation of our study.

Due to the short follow-up period of our series (12–60 months), we could not conclude about the evolution of the subacromial impingement and glenohumeral joint osteoarthritis, as demonstrated by Gerber et al.

The lower results achieved with salvage reconstruction compared with primary repair could have various explanations.

Fatty degeneration has been proved by Warner to play a key role in the outcome of latissimus dorsi tendon transfer since the obtained results were poorer when the degree of preoperative fatty degeneration was high. In our series, the degree of fatty degeneration did not significantly affect the overall result.

The influence of deltoid deficiency is under debate. Even if most authors insist on the bad influence of these lesions commonly induced by surgeries performed prior to transfer, Miniacci did not evidence any objective difference in the final outcome whether these lesions were observed or not.

In our study, prognosis was even better when preoperative AAE was diminished. On the contrary, according to Codsi, a significant decrease in preoperative mobility, particularly in AAE, would constitute a bad predictive factor, and a preoperative AAE lower than 80° would represent a relative contraindication.

Latissimus dorsi tendon transfer is a useful surgical technique if conventional repair of the rotator cuff defect is not possible, particularly as the available therapeutic options are limited in such situation. This tendon transfer is performed to reduce pain and enhance active anterior elevation and external rotation. These benefits are all the more significant given that the preoperative deficit was high. However, this is considered a salvage procedure and patients should be informed that it demonstrates less favourable results than those obtained after conventional rotator cuff repair, particularly if tendon transfer is performed following a failed rotator cuff repair.

Predictors of postoperative success are difficult to identify but we believe that deltoid integrity is essential to achieve satisfactory AAE. Salvage procedure could be a bad prognosis factor. Moreover, the role of subscapularis, fatty degeneration and possible suture of the tendon stumps remain controversial. A prospective study could better define these factors.

Conflicts of interest
None.

References