



Comparison of arthroscopically assisted transfer of the latissimus dorsi with or without partial cuff repair for irreparable postero-superior rotator cuff tear

Philippe Valenti¹ · Felipe Reinares¹ · Charbel Maroun¹ · James Choueiry¹ · Jean-David Werthel¹

Received: 18 December 2017 / Accepted: 4 June 2018 / Published online: 15 June 2018
© SICOT aisbl 2018

Abstract

Purpose To evaluate the effect of an additional partial repair in combination with an arthroscopically assisted transfer of the latissimus dorsi (LDT) in massive postero-superior irreparable cuff tear.

Materials and methods Thirty-one patients (mean age 59.2 years) scheduled for arthroscopically assisted LDT either isolated or in combination with a partial cuff repair for a massive posterior-superior cuff tear were prospectively included between January 2011 and December 2013 at our institution. Seventeen had an isolated transfer (Group A) and 14 had a transfer combined with a partial cuff repair (Group B). Outcome measures included visual analogue scale (VAS), range of motion, strength, constant score, and subjective shoulder value (SSV). Potential predictive factors were analyzed.

Results At the last follow-up (mean 22 months), patients in Group B had a significantly higher constant score (64 ± 8 versus 58 ± 4 in Group A), range of motion (33 ± 5 versus 29 ± 5 points in Group A), and strength at 90° of abduction ($2.5 \text{ kg} \pm 1$ in Group B versus $1.9 \text{ kg} \pm 0.9$ in Group A). No significant differences were found between both groups regarding pain scores, SSV, and active external rotation. Thirty-seven variables were analyzed and the only factor which was found to be predictive of a bad result was a preoperative SSV < 40 pts. (RR 0.5).

Conclusion Arthroscopically assisted LDT gives better results when combined with a partial repair of the cuff than when it is performed isolated in the treatment of massive irreparable postero-superior rotator cuff tear.

Level of evidence: Treatment study, Level II

Keywords Latissimus dorsi · Tendon transfer · Massive irreparable cuff tear · Partial repair · Rotator cuff · Arthroscopy · Postero-superior cuff tear

✉ Jean-David Werthel
jdwerthel@gmail.com

Philippe Valenti
philippe.valenti@wanadoo.fr

Felipe Reinares
freinares@gmail.com

Charbel Maroun
charbel.maroun@hotmail.com

James Choueiry
jameschoueiry@hotmail.com

¹ Paris Shoulder Unit, Clinique Bizet, 21, rue Georges Bizet, 75116 Paris, France

Introduction

Management of irreparable postero-superior cuff tears remains controversial. Several surgical options have been proposed to address this condition. These include debridement with subacromial bursectomy and tenotomy or tenodesis of the biceps [1], partial repair of the residual cuff [2], deltoid flap [3], lower trapezius transfer [4], latissimus dorsi transfer (LDT) [5], reverse shoulder arthroplasty [6], and more recently the interposition of a subacromial spacer [7] or superior capsule reconstruction [8]. The LDT has initially been described to restore active elevation and external rotation in patients with sequelae of obstetrical brachial plexus palsies. In 1998, Gerber et al. [9] proposed this tendon transfer to treat irreparable tears of the supra and infraspinatus. Since this first

description, many publications have proven its reliability to improve function and to decrease pain in patients with massive irreparable tears of the postero-superior cuff [10, 11]. Recently, some authors have proposed to fix this transfer arthroscopically on the humeral head. This can be achieved in combination with a mini-invasive axillary approach to harvest the tendon [12] or even more recently fully arthroscopically [13]. Paribelli et al. [14] compared a group of patients undergoing arthroscopically assisted LDT to others undergoing arthroscopic rotator cuff partial repair. Both procedures were found to be effective but the LDT provided a better modified UCLA score improvement and better strength at last follow-up. No study comparing isolated LDT to a LDT in combination with an additional partial repair of the remaining cuff has been published to our knowledge. The purpose of this study was to evaluate the effect of an additional partial repair in combination with an arthroscopically assisted LDT. We hypothesized that combining the LDT to an additional partial repair of the remaining cuff would lead to superior outcomes.

Materials and methods

Patients who were scheduled for arthroscopically assisted LDT either isolated or in combination with a partial cuff repair for a massive irreparable postero-superior cuff tear between January 2011 and December 2013 at our institution were included prospectively. The first step of the surgery was always an arthroscopic exploration of the joint to assess whether partial repair of the cuff was possible. Arthroscopically assisted LDT was then performed and an additional partial repair of the cuff was systematically performed when possible.

Inclusion/exclusion criteria and patients' demographics

The patients included in the study had pain with irreparable supra and infraspinatus tears after failure of conservative treatment by physical therapy or after failure of a previous surgical treatment. The tear was considered irreparable when during the arthroscopy after complete release we were unable to repair anatomically the cuff. The fatty infiltration was ≥ 2 for at least one of the two torn tendons according to the Goutallier classification [15]. Patients were excluded if they had a subscapularis tear, a cuff tear arthropathy with osteoarthritis ≥ 4 in the Hamada classification [16]), a pseudoparalytic shoulder, a deltoid dysfunction, or an atrophic teres minor (Fig. 1).

Thirty-one consecutive patients (16 men, 15 women) were included. The mean age of the patients was 56 years (range 47–72 years). Seventeen patients had an isolated transfer

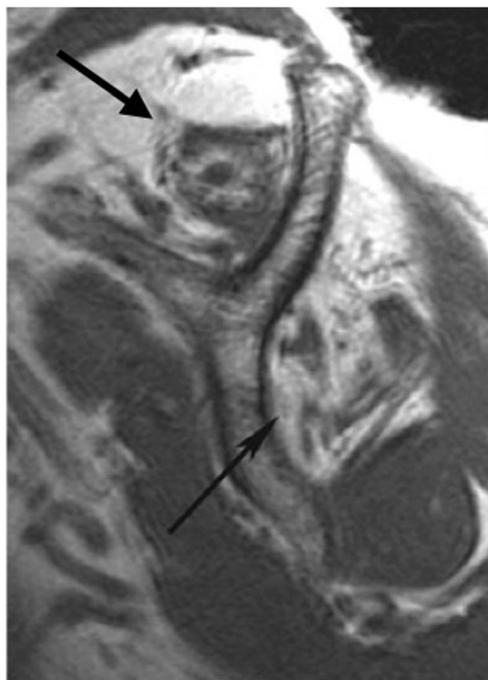


Fig. 1 MRI of a left shoulder. Sagittal view in T1 shows atrophy and fatty infiltration of both the supraspinatus and infraspinatus (black arrows) muscles, with a good subscapularis and teres minor

(Group A) and 14 had a transfer combined with a partial cuff repair (Group B).

Rotator cuff lesions were not significantly different in both groups in terms of number of tendons involved, retraction, and muscle atrophy. However, fatty infiltration of the supraspinatus was significantly higher in Group A (Table 1).

Their activity level was as follows: 54% were involved in heavy load manual working, 31% were sedentary and 15% were retired, 26% received a work compensation procedure, 26% of the patients had comorbidities (Table 2). Average duration of symptoms before the surgical procedure was 37.4 months (range 12–120). For 15 patients, the LDT was the first surgical procedure, for 16 patients it was the second or

Table 1 Comparison of pre-operative lesions in groups A and B

| Pre-op | Tendons involved | SS Stage 3 | FI SS | IS Stage 3 | FI IS |
|-------------------------|------------------|------------|-------------|------------|-------|
| <i>Group A (n = 17)</i> | 2 | 95% | 2.94 | 55% | 2.65 |
| Isolated LDT | | | | | |
| <i>Group B (n = 14)</i> | 2 | 64% | 2.64 | 57% | 2.29 |
| LDT + Cuff repair | | | | | |
| <i>p value</i> | 0.54 | 0.06 | <i>0.04</i> | 1 | 0.53 |

Italicized entries represent statistically significant values

LDT, latissimus dorsi transfer; SS, supraspinatus; IS, infraspinatus; stage 3, retraction according to Patte et al.; FI, fatty infiltration; stage according to Goutallier et al.

Table 2 Characteristics of the study population

| Pre-op | Mean age | Sex (M) | Heavy worker | Worker's compensation | Mean constant |
|-------------------------------------|-------------|-------------|--------------|-----------------------|---------------|
| Group A (n = 17) | 58 | 53% | 2.65 | 55% | 35 |
| Isolated LDT Group B (n = 14) | 53 | 64% | 2.3 | 57.14% | 41 |
| LDT + cuff repair <i>p</i> value | <i>0.14</i> | <i>0.73</i> | <i>0.31</i> | <i>0.23</i> | <i>0.18</i> |

Italicized entries represent statistically significant values. There are no significant differences between both groups
LDT, latissimus dorsi transfer

more; 11 patients had already been operated once, three patients twice, two patients three times. In group A, 11 patients had had previous rotator cuff repair versus 8 patients in group B. Pre-operative clinical evaluation of the two groups is detailed in Table 3.

Surgical technique (Fig. 2a)

The patients were positioned in the beach chair position with the upper limb completely free and the hemithorax draped. All patients received a pre-operative interscalene block in addition to a general anaesthesia. Arthroscopic exploration of the cuff was performed initially to confirm that the cuff was not repairable anatomically (Fig. 2b). A tenotomy or a tenodesis of the long head of the biceps was performed when it was still present. A tenotomy was performed when the biceps tendon was very degenerative. The integrity of the subscapularis was always assessed. Complete release of the supra- and infraspinatus was systematically performed. An intra-articular release was performed by releasing the deep part of the tendon from the superior capsule anteriorly and posteriorly, and an extra-articular release was performed in the subacromial space until the spine of the scapula posteriorly and until the coracoid process anteriorly. If after this release, mobilization of the tendon was still not possible because of the bad quality of the tendon, partial repair was not performed.

In 14 patients (45% of the series: group B) a partial repair of the remaining postero-superior cuff was performed in combination with the LDT as described by Burkhart et al. [2]. In

23%, a margin convergence was performed with a tendon to tendon suture between the remaining supra- and infraspinatus posteriorly and the remaining tissue of the rotator interval anteriorly and in 77% a superior advancement of the posterior part of the infraspinatus was done.

A mini-invasive axillary approach of 5 to 7 cm was performed along the anterior border of the latissimus dorsi (Fig. 2c). The first key point was to identify the white aponeurotic band of the latissimus dorsi which leads to the insertion of the latissimus dorsi on the humerus and which helps differentiating the latissimus dorsi from the teres major which is more muscular and posterior. Posteriorly, the latissimus dorsi was detached from the teres major and the anterior border of the latissimus dorsi was carefully dissected to release its neurovascular pedicle which penetrates into the deep part of the muscle at 10 cm from the insertion. To obtain a good excursion of the latissimus dorsi, the muscle was released distally from the angle of the scapula and from subcutaneous tissue. The arm was then placed in maximal internal rotation to expose its insertion on the humerus and to keep the radial and axillary nerves at distance. The tendon was then detached from the humeral diaphysis between the tendon of the pectoralis major and of the teres major as close as possible to the bone to provide the maximal length possible for the transfer. The tendon was then intubulated using a large non-absorbable braided suture (Fig. 2d). A passage was made between the posterior deltoid and the remaining posterior cuff using blunt scissors. The tendon of the latissimus dorsi was then retrieved in the shoulder joint using a grasper through a

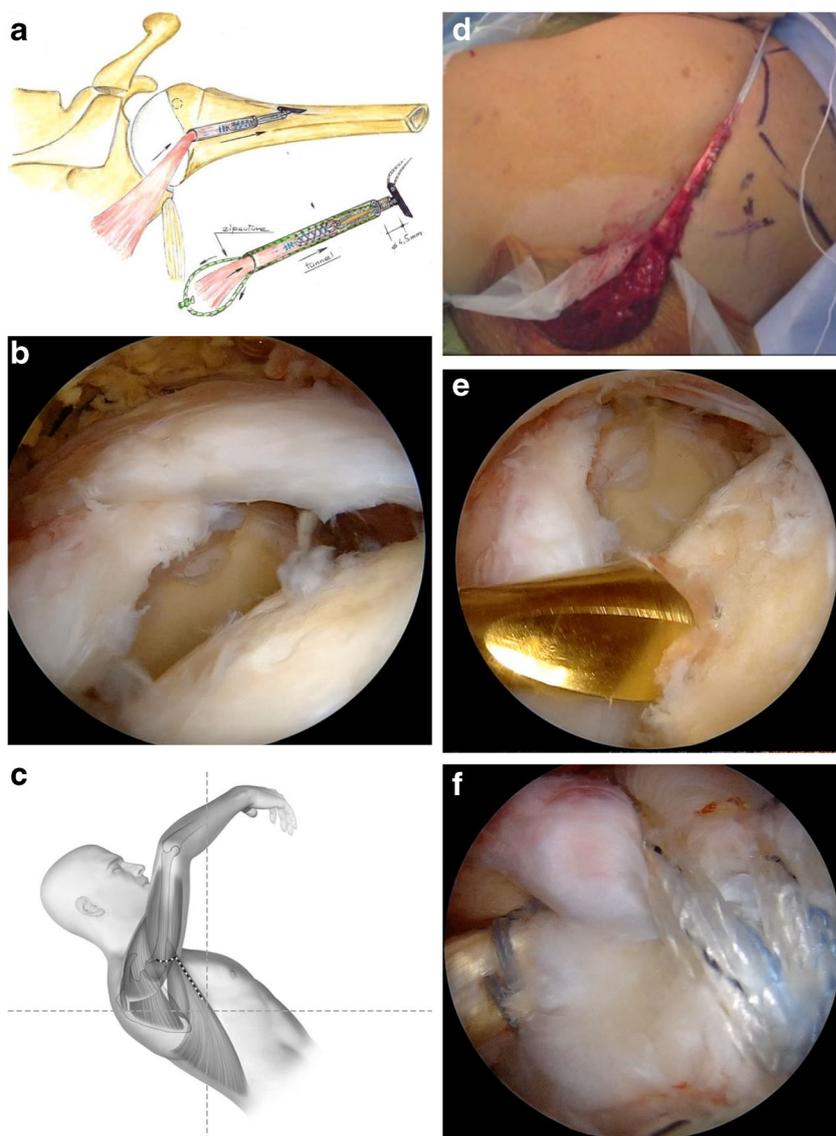
Table 3 Comparison of pre-operative clinical results in groups A and B

| | Forward elevation | Ext. rot | Int. rot (points) | Activity (points: CS) | Strength (kg) | VAS | Constant score | SST | SSV |
|------------------|-------------------|-----------|-------------------|-----------------------|---------------|-----------|----------------|-----------|--------------|
| Group A (n = 17) | 110° ± 28° | 23° ± 15° | 6 ± 1.8 | 5.8 ± 1.6 | 0.7 ± 0.7 | 7.6 ± 1.6 | 33 ± 11 | 3.2 ± 1.4 | 28 ± 9.1 |
| Group B (n = 14) | 120° ± 34° | 23° ± 15° | 6 ± 1.8 | 7.4 ± 3.3 | 1.3 ± 1 | 6.4 ± 2.3 | 41 ± 13 | 4.5 ± 2.2 | 41 ± 16 |
| <i>p</i> value | 0.2 | 0.25 | 0.11 | 0.07 | <i>0.036</i> | 0.08 | <i>0.05</i> | 0.06 | <i>0.003</i> |

Italicized entries represent statistically significant values

CS, constant Score; VAS, visual analog scale; SST, simple shoulder test; SSV, subjective shoulder value

Fig. 2 **a** Surgical technique of the transfer. The tendon of the latissimus dorsi was then intubulated using a large non-absorbable braided suture. A bicortical 3.5-mm tunnel was drilled using a canulated drill and the diameter of this tunnel was increased on 3 cm at its entry point with a 4.5-mm canulated drill. The intubulated aponeurotic band of the latissimus dorsi was then introduced into this tunnel and fixed by pulling the strands of a cortical button device (ZipTight, Biomet, Warsaw, IN, USA). **b** Arthroscopic view of a right shoulder: massive irreparable posterosuperior rotator cuff tear. **c** The patients were positioned in the beach chair position with the upper limb completely free and the hemithorax draped. A mini-invasive axillary approach of 5 to 7 cm was performed along the lateral border of the scapula. **d** The tendon of the latissimus dorsi was intubulated using a large non-absorbable braided suture. **e** Arthroscopic view of a right shoulder, a bicortical 3.5-mm tunnel is drilled using a canulated drill to prepare the fixation of the tendon transfer. **f** The intubulated aponeurotic band of the latissimus dorsi is introduced into the tunnel and an additional partial repair of the posterior cuff is performed



posterior portal under arthroscopic visualization through a posterolateral portal.

With the arm placed at 90° of elevation and maximal adduction, a guide (Biomet, Warsaw, IN, USA) was introduced through the posterior portal and positioned over the greater tuberosity close to the cartilage, at the junction between the insertion of the supra- and infraspinatus. A Kirschner wire was then drilled from posterior to anterior to exit just lateral to the intertubercular groove. A bicortical 3.5-mm tunnel was then drilled using a canulated drill (Fig. 2e). The intubulated aponeurotic band of the latissimus dorsi was then introduced into this tunnel (Fig. 2f) and fixed either by an interference screw (Bio-Tenodesis, Arthrex, Naples, FL, USA) in 54% of the cases or by pulling the strands of a cortical button device (ZipTight, Biomet, Warsaw, IN, USA) in 46%. We chose to fix the transfer with an interference screw at the beginning of our experience and decided to switch a cortical button device

as we found that interference screw had a poor purchase in osteoporotic bone. The axillary incision was closed with a drain for 24 h and a compressive bandage was applied for three weeks on the axillary wound to prevent haematoma formation.

The arm was immobilized at 30° of abduction and in neutral rotation for six weeks.

The patient then began passive and active assisted range of motion exercises in every direction after six weeks (from weeks 6–12), then full active range of motion and gentle strengthening was authorized. Patients were allowed to return to unrestricted activities after six months.

Clinical and radiological evaluation (Fig. 3)

Outcome measures included pain (VAS: visual analogue scale), range of motion in degrees, strength, Constant-



Fig. 3 Immediate post-operative anteroposterior radiograph of a left shoulder after latissimus dorsi transfer with partial repair of the cuff. A metallic landmark (surgical stainless steel suture, Ethicon, Somerville, NJ) is located at the entry point of the aponeurotic band to facilitate follow-up of the transfer on standard radiographs

Murley scores, and subjective shoulder value (SSV). These were recorded at the pre-operative visit, at six months post-operatively and at subsequent follow-up visits.

Patients had a pre-operative standard radiological evaluation of the shoulder to analyze the subacromial space and the grade of osteoarthritis according to Hamada et al. [16]. Magnetic resonance imaging (MRI) was performed pre-operatively for all patients to assess atrophy (according to Thomazeau et al. [17] and/or fatty infiltration of subscapularis, supraspinatus, infraspinatus, and teres minor (according to Goutallier et al. [15]). Another MRI was performed at last follow-up to assess the entrance of the aponeurotic band inside the bony tunnel of the humeral head and the position of the fixation device in the humeral head (interference screw) or on the anterior cortex of the humerus (cortical button).

Statistical analysis

This study corresponds to a prospective Cohort Design Model. All variables were presented in average and standard deviation.

The pre- and post-operative patient scores and measurements of shoulder mobility were analyzed for differences between means using a Student's *t* test. Fisher's exact test for small numbers was used to compare categorical data. All tests were considered statistically significant if the *p* values were < 0.05. Potential predictive factors including epidemiologic,

clinical, radiological, intra-operative findings and previous procedures were defined based in relative risk (R.R) analysis, according to the Cohort study design. All statistical analyses were performed with Stata 11 ® for Mac (StataCorp, Texas, USA).

Results

Functional results

All patients were reviewed with a mean follow-up of 22 months (range 18–34) and were all significantly improved. Mean constant score improved from 38 ± 15 to 61 ± 9 ($p < 0.001$). Mean VAS decreased from 7.1 to 1.9 and mean SSV improved from 34 to 67%. Mean active forward flexion improved from 116° to 158° , external rotation with the arm at the side improved from 26° to 37° and external rotation with the arm at 90° of abduction from 40° to 53° . All these changes were statistically significant (p value < 0.001). These results are detailed in Table 4.

Functional results were significantly better in Group B than in Group A regarding constant score (64 ± 8 in Group B versus 57 ± 4 in Group A, $p < 0.03$), range of motion (33 ± 5 versus 29 ± 5 points in Group A, $p < 0.03$), and strength at 90° of abduction ($2.5 \text{ kg} \pm 1$ in Group B versus $1.9 \text{ kg} \pm 0.9$ in Group A, $p < 0.029$). However, pain scores, SSVs, and active external rotation were not significantly different between the two groups. These results are detailed in Table 5.

Complications

Five complications (14.3%) were noted in this series. There was one case of post-operative transient brachial plexus palsy with a complete recovery and a patient satisfied at the last follow-up. Two patients had revision surgery for haematoma localized on the lateral thoracic side. Among these 2 patients, one was infected with *Propionibacterium Acnes* and was treated by open debridement and oral antibiotics. These two patients healed uneventfully and obtained a satisfactory outcome. Two patients (5.7%) had a rupture of the transfer on the MRI control: in one case a migration of the the interference screw was observed. The screw was removed and the transfer was found distally with no more attachment to the humeral bone. The patient was revised with a reverse shoulder arthroplasty with a satisfactory outcome [18]. In the second case, a rupture of the aponeurotic band at the tunnel entrance was diagnosed by MR-imaging. This second patient refused revision.

There were two complications in group A (transient brachial plexus palsy and rupture revised to RSA) and three complications in group B (2 haematomae and the patient with the rupture who refused revision).

Table 4 Clinical results of the global series

| | Forward elevation | Abduction | Ext. rot | Int. rot (points) | Strength (kg) | VAS | Constant | SST | SSV |
|----------------|-------------------|---------------|---------------|-------------------|---------------|---------------|---------------|---------------|---------------|
| Preop | 113° ± 30° | 97° ± 32° | 25° ± 15° | 6 ± 1.8 | 0.9 ± 0.9 | 7 ± 2 | 35 ± 15 | 3 ± 1 | 32 ± 13 |
| Postop | 158° ± 18° | 125° ± 27° | 37° ± 17° | 7 ± 1.3 | 2.1 ± 1 | 2 ± 1 | 61 ± 9 | 7 ± 1 | 67 ± 12 |
| <i>p</i> value | <i>0.0001</i> | <i>0.0001</i> | <i>0.0018</i> | 0.09 | <i>0.001</i> | <i>0.0001</i> | <i>0.0001</i> | <i>0.0001</i> | <i>0.0001</i> |
| Gain | 45° | 28° | 12° | 1 | 1.3 | −5 | 26 | 4 | 35 |

Italicized entries represent statistically significant values

Predictive factors

Four variables were found to be predictive of a good functional result: pre-operative active forward flexion > 120° (RR: 2), pre-operative active abduction > 120° (RR 1.9), pre-operative strength > 2 kg (RR 1.9) and concomitant partial repair of the remaining tendons (RR, 2.07). The only factor which was found to be predictive of a bad result was a pre-operative SSV < 40 pts. (RR: 0.5). Seven patients (26%) were very satisfied, 23 (73%) patients were satisfied and 3% (1 patient) were disappointed by the surgical procedure.

Discussion

This study shows that arthroscopically assisted LDT gives satisfactory functional results in the treatment of irreparable postero-superior cuff tears and that these results can be improved by combining a partial repair of the infraspinatus with that tendon transfer.

These results are in agreement with previous studies that have shown that both the isolated LDT [19, 20] and isolated partial repair [21] of the cuff give good functional results in these patients.

In 2015, Paribelli et al. [14] analyzed results of transfers versus partial repairs in a study of 40 patients, and recommended the transfer in high demand younger patients with no or mild osteoarthritis, since it better restores shoulder strength compared with partial repair. Partial repair procedures were found to mostly decrease pain and were recommended

for low demand patients with poor preoperative status [14]. Therefore, combining systematically partial repairs with an associated transfer of the latissimus dorsi could improve the results of both an isolated transfer or an isolated partial repair. Indeed, it appears necessary to repair the cuff even partially to restore the “suspension bridge” described by Burkhart et al. [21]. However, when only a partial repair is possible, the rotator cuff muscles are often found to be atrophic and with a high degree of fatty infiltration. Therefore, although the restoration of Burkhart’s cable is important to relieve pain, it is probably insufficient to restore normal kinematics of the shoulder. An additional transfer allows to add a dynamic effect to the partial repair as it appears that the transfer does not only have an interposition effect but also a true active effect of the muscle which has learned to contract synergistically in its new location [22]. Electromyographic studies have shown electric activity of the transferred latissimus dorsi in abduction and external rotation [23]. In addition, a synchronous electromyographic signal of the latissimus dorsi was found to be associated with a higher rate of success and Constant score [23]. This proves that the tenodesis or interposition is not solely responsible for the improvement of post-operative pain and function. In fact, a biomechanical study showed that the tenodesis effect is mostly responsible for shoulder abduction, whereas the active function of the muscle improved both external rotation and flexion of the shoulder [24]. Other options described more recently in similar indications such as the subacromial spacer [7] or superior capsule reconstruction [8] provide only passive stabilization of the humeral head which might not be sufficient in younger active patients.

Table 5 Comparison of postoperative clinical results in groups A and B

| | Forward elevation | Ext. rot | Int. Rot (points) | Activity (points: CS) | Strength (kg) | VAS | Constant score | SST | SSV |
|------------------|-------------------|-----------|-------------------|-----------------------|---------------|-----------|----------------|-------|---------|
| Group A (n = 17) | 154° ± 22° | 35° ± 14° | 6 ± 1.3 | 12 ± 2 | 1.9 ± 0.9 | 2.7 ± 1.9 | 58 ± 9 | 7 ± 2 | 66 ± 11 |
| Group B (n = 14) | 160° ± 21° | 40° ± 21° | 7 ± 1.5 | 13 ± 2 | 2.5 ± 1 | 1.5 ± 1 | 64 ± 8 | 8 ± 1 | 68 ± 11 |
| <i>p</i> value | 0.13 | 0.17 | 0.1 | 0.16 | <i>0.029</i> | 0.35 | <i>0.03</i> | 0.24 | 0.32 |

Italicized entries represent statistically significant values

CS, constant score; VAS, visual analog scale; SST, simple shoulder test; SSV, subjective shoulder value

One of the main drawbacks of the LDT is its supposed morbidity. However, the association of mini-invasive techniques described to harvest the transfer combined with an arthroscopic fixation or fully arthroscopic [25] which does not impair the deltoid muscle make this surgery far less aggressive.

In our series, pre-operative active forward flexion > 120° was found to be predictive of good functional results. This shows that latissimus dorsi transfer and partial repair must be proposed mainly to patients with a painful shoulder but who still have a good function.

In addition, our study showed that a pre-operative SSV of less than 40 was linked to poor results. This correlates with Iannotti et al. [26], who stated that patients and especially females with poor general musculature and very weak shoulder function are more susceptible to suboptimal post-operative outcome. Furthermore, Codsi et al. [27] stated that an active anterior elevation angle of less than 80° was associated with a poor result.

Our study has several limitations. Firstly, the relatively small number of patients and a short mean follow-up period which did not enable us to analyze progression of osteoarthritis. Secondly and most importantly, the first group (Group A) had a worse pre-operative constant score and SSV. Finally, the fixation technique of the LD transfer we used at the time of this study has changed to a more laminar technique of fixation. However, it is the first prospective study comparing these two techniques performed by a single surgeon.

Conclusion

This study confirms that arthroscopically assisted LDT improves the constant score, range of motion, strength, pain scores, and SSV score for irreparable postero-superior rotator cuff tears. Results were significantly better for range of motion and strength when the LDT was combined with a partial repair of the infraspinatus.

Compliance with ethical standards

Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

Conflict of interest Philippe Valenti and Jean-David Werthel receive royalties for shoulder prosthesis design from FH Orthopedics. The other authors, their immediate families, and any research foundations with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

- Boileau P, Baque F, Valerio L, Ahrens P, Chuinard C, Trojani C (2007) Isolated arthroscopic biceps tenotomy or tenodesis improves symptoms in patients with massive irreparable rotator cuff tears. *J Bone Joint Surg Am* 89(4):747–757. <https://doi.org/10.2106/JBJS.E.01097>
- Burkhart SS, Nottage WM, Ogilvie-Harris DJ, Kohn HS, Pachelli A (1994) Partial repair of irreparable rotator cuff tears. *Arthroscopy* 10(4):363–370
- Glanzmann MC, Goldhahn J, Flury M, Schwyzer HK, Simmen BR (2010) Deltoid flap reconstruction for massive rotator cuff tears: mid- and long-term functional and structural results. *J Shoulder Elb Surg* 19(3):439–445. <https://doi.org/10.1016/j.jse.2009.06.005>
- Elhassan BT, Wagner ER, Werthel JD (2016) Outcome of lower trapezius transfer to reconstruct massive irreparable posterior-superior rotator cuff tear. *J Shoulder Elb Surg* 25(8):1346–1353. <https://doi.org/10.1016/j.jse.2015.12.006>
- Gerber C, Rahm SA, Catanzaro S, Farshad M, Moor BK (2013) Latissimus dorsi tendon transfer for treatment of irreparable posterolateral rotator cuff tears: long-term results at a minimum follow-up of ten years. *J Bone Joint Surg Am* 95(21):1920–1926. <https://doi.org/10.2106/JBJS.M.00122>
- Mulieri P, Dunning P, Klein S, Pupello D, Frankle M (2010) Reverse shoulder arthroplasty for the treatment of irreparable rotator cuff tear without glenohumeral arthritis. *J Bone Joint Surg* 92(15):2544–2556. <https://doi.org/10.2106/jbjs.i.00912>
- Deranlot J, Herisson O, Nourissat G, Zbili D, Werthel JD, Vigan M, Bruchou F (2017) Arthroscopic subacromial spacer implantation in patients with massive irreparable rotator cuff tears: clinical and radiographic results of 39 retrospective cases. *Arthroscopy*. <https://doi.org/10.1016/j.arthro.2017.03.029>
- Mihata T, Lee TQ, Watanabe C, Fukunishi K, Ohue M, Tsujimura T, Kinoshita M (2013) Clinical results of arthroscopic superior capsule reconstruction for irreparable rotator cuff tears. *Arthroscopy* 29(3):459–470. <https://doi.org/10.1016/j.arthro.2012.10.022>
- Gerber C, Vinh TS, Hertel R, Hess CW (1988) Latissimus dorsi transfer for the treatment of massive tears of the rotator cuff. A preliminary report. *Clin Orthop Relat Res* 232:51–61
- Nove-Josserand L, Costa P, Liotard JP, Safar JF, Walch G, Zilber S (2009) Results of latissimus dorsi tendon transfer for irreparable cuff tears. *Orthop Traumatol Surg Res* 95(2):108–113. <https://doi.org/10.1016/j.otsr.2008.10.002>
- Valenti P, Kalouche I, Diaz LC, Kaouar A, Kilinc A (2010) Results of latissimus dorsi tendon transfer in primary or salvage reconstruction of irreparable rotator cuff tears. *Orthop Traumatol Surg Res* 96(2):133–138. <https://doi.org/10.1016/j.rcot.2010.02.018>
- Goldstein Y, Grimberg J, Valenti P, Chechik O, Drexler M, Kany J (2013) Arthroscopic fixation with a minimally invasive axillary approach for latissimus dorsi transfer using an endobutton in massive and irreparable postero-superior cuff tears. *Int J Shoulder Surg* 7(2):79–82. <https://doi.org/10.4103/0973-6042.114223>
- Cutbush K, Peter NA, Hirpara K (2016) All-arthroscopic latissimus dorsi transfer. *Arthrosc Tech* 5(3):e607–e613. <https://doi.org/10.1016/j.eats.2016.02.007>
- Paribelli G, Boschi S, Randelli P, Compagnoni R, Leonardi F, Cassarino AM (2015) Clinical outcome of latissimus dorsi tendon transfer and partial cuff repair in irreparable postero-superior rotator cuff tear. *Musculoskelet Surg* 99(2):127–132. <https://doi.org/10.1007/s12306-015-0353-4>
- Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC (1994) Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res* 304:78–83

16. Hamada K, Fukuda H, Mikasa M, Kobayashi Y (1990) Roentgenographic findings in massive rotator cuff tears. A long-term observation. *Clin Orthop Relat Res* 254:92–96
17. Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F (1996) Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. *Acta Orthop Scand* 67(3):264–268
18. Valenti P, Maqdes A, Werthel JD (2017) Clinical and radiological outcomes after reverse shoulder arthroplasty in patients with failed deltoid or latissimus dorsi transfers. A review of ten cases. *Int Orthop*. <https://doi.org/10.1007/s00264-017-3520-4>
19. El-Azab HM, Rott O, Irlenbusch U (2015) Long-term follow-up after latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears. *J Bone Joint Surg Am* 97(6):462–469. <https://doi.org/10.2106/JBJS.M.00235>
20. Grimberg J, Kany J, Valenti P, Amaravathi R, Ramalingam AT (2015) Arthroscopic-assisted latissimus dorsi tendon transfer for irreparable posterosuperior cuff tears. *Arthroscopy* 31(4):599–607.e591. <https://doi.org/10.1016/j.arthro.2014.10.005>
21. Burkhart SS, Danaceau SM, Pearce CE Jr (2001) Arthroscopic rotator cuff repair: analysis of results by tear size and by repair technique-margin convergence versus direct tendon-to-bone repair. *Arthroscopy* 17(9):905–912. <https://doi.org/10.1053/jars.2001.26821>
22. Aoki M, Okamura K, Fukushima S, Takahashi T, Ogino T (1996) Transfer of latissimus dorsi for irreparable rotator-cuff tears. *J Bone Joint Surg Br* 78(5):761–766
23. Irlenbusch U, Bernsdorf M, Born S, Gansen HK, Lorenz U (2008) Electromyographic analysis of muscle function after latissimus dorsi tendon transfer. *J Shoulder Elb Surg* 17(3):492–499. <https://doi.org/10.1016/j.jse.2007.11.012>
24. Ling HY, Angeles JG, Horodyski MB (2009) Biomechanics of latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears. *Clin Biomech (Bristol, Avon)* 24(3):261–266. <https://doi.org/10.1016/j.clinbiomech.2008.12.002>
25. Gervasi E, Causeo A, Parodi PC, Raimondo D, Tancredi G (2007) Arthroscopic latissimus dorsi transfer. *Arthroscopy* 23(11):1243 e1241–1243 e1244. <https://doi.org/10.1016/j.arthro.2006.12.021>
26. Iannotti JP, Hennigan S, Herzog R, Kella S, Kelley M, Leggin B, Williams GR (2006) Latissimus dorsi tendon transfer for irreparable posterosuperior rotator cuff tears. Factors affecting outcome. *J Bone Joint Surg Am* 88(2):342–348. <https://doi.org/10.2106/JBJS.D.02996>
27. Codsi MJ, Hennigan S, Herzog R, Kella S, Kelley M, Leggin B, Williams GR, Iannotti JP (2007) Latissimus dorsi tendon transfer for irreparable posterosuperior rotator cuff tears. Surgical technique. *J Bone Joint Surg Am* 89(Suppl 2):Pt.1:1–Pt.1:9. <https://doi.org/10.2106/JBJS.F.01160>