Mid-term results of arthroscopically assisted latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears

Waltenspül, Manuel ; Jochum, Benedikt ; Filli, Lukas ; Ernstbrunner, Lukas ; Wieser, Karl ; Meyer, Dominik ; Gerber, Christian

Abstract: BACKGROUND With progress in arthroscopic surgery, latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears (RCTs) has become a reliable all-arthroscopic or arthroscopically assisted procedure. The mid-term results of arthroscopically assisted latissimus dorsi transfer (aLDT) are scarce in the literature. The purpose of this study was to report our clinical and radiographic mid-term results of aLDT for irreparable posterosuperior RCTs. METHODS Thirty-one consecutive patients with a mean age of 55.5 years (range, 38-73 years) at the time of aLDT were evaluated after a mean of 3.5 years (range, 2-5 years). All patients had irreparable, full-thickness tears of at least the complete supraspinatus, with or without infraspinatus tendons, and 12 patients (39%) had undergone previous rotator cuff repair (RCR). A concomitant upper-third subscapularis repair was needed at the time of aLDT in 7 patients (23%). Mid-term results were assessed clinically and radiographically (including magnetic resonance imaging). RESULTS At final follow-up, 4 patients with failure (13%) had undergone revision to reverse total shoulder arthroplasty (RTSA) essentially for untreatable pain. Patients with revision to RTSA had significantly higher preoperative pain levels (Constant pain score, 6 points vs. 11 points; P = .032) and lower Constant activity scores (2 points vs. 5 points, P = .017) than the remaining 27 patients. Patients with failed previous RCRs had significantly inferior results compared with patients without previous repair (mean Subjective Shoulder Value, 67% vs. 88%; P = .035). For the 27 patients without revision, the mean relative Constant score improved from 63% to 76% (P = .032), the Constant pain score, from 10.5 to 12.7 points (P = .012), and the Subjective Shoulder Value, from 43% to 77% (P < .001). Significant progression of glenohumeral arthropathy by 2 or more grades according to the Hamada classification was observed in 13 of the 27 patients (48%), but there was no significant difference in clinical outcomes between the patients with arthropathy (n = 13) and those without it (n = 14, P = .923). CONCLUSIONS The mid-term results of aLDT for irreparable posterosuperior RCTs were associated with significant improvements in objective and subjective outcome measures. The failure rate leading to conversion to RTSA was relatively high in this cohort. The failures were associated with unusually intense pain in low-demand individuals and/or revision of failed RCR. Long-term results of aLDT are needed to evaluate the effect of this procedure on the progression of osteoarthritis.

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Mid-term results of arthroscopically assisted latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears

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Background: With progress in arthroscopic surgery, latissimus dorsi transfer for irreparable posterosuperior rotator cuff tears (RCTs) has become a reliable all-arthroscopic or arthroscopically assisted procedure. The mid-term results of arthroscopically assisted latissimus dorsi transfer (aLDT) are scarce in the literature. The purpose of this study was to report our clinical and radiographic mid-term results of aLDT for irreparable posterosuperior RCTs.

Methods: Thirty-one consecutive patients with a mean age of 55.5 years (range, 38-73 years) at the time of aLDT were evaluated after a mean of 3.5 years (range, 2-5 years). All patients had irreparable, full-thickness tears of at least the complete supraspinatus, with or without infraspinatus tendons, and 12 patients (39%) had undergone previous rotator cuff repair (RCR). A concomitant upper-third subscapularis repair was needed at the time of aLDT in 7 patients (23%). Mid-term results were assessed clinically and radiographically (including magnetic resonance imaging).

Results: At final follow-up, 4 patients with failure (13%) had undergone revision to reverse total shoulder arthroplasty (RTSA) essentially for untreatable pain. Patients with revision to RTSA had significantly higher preoperative pain levels (Constant pain score, 6 points vs. 11 points; P = .032) and lower Constant activity scores (2 points vs. 5 points, P = .017) than the remaining 27 patients. Patients with failed previous RCRs had significantly inferior results compared with patients without previous repair (mean Subjective Shoulder Value, 67% vs. 88%; P = .035). For the 27 patients without revision, the mean relative Constant score improved from 63% to 76% (P = .032), the Constant pain score, from 10.5 to 12.7 points (P = .012), and the Subjective Shoulder Value, from 43% to 77% (P < .001). Significant progression of glenohumeral arthropathy by 2 or more grades according to the Hamada classification was observed in 13 of the 27 patients (48%), but there was no significant difference in clinical outcomes between the patients with arthropathy (n = 13) and those without it (n = 14, P = .923).

Conclusions: The mid-term results of aLDT for irreparable posterosuperior RCTs were associated with significant improvements in objective and subjective outcome measures. The failure rate leading to conversion to RTSA was relatively high in this cohort. The failures were associated with unusually intense pain in low-demand individuals and/or revision of failed RCR. Long-term results of aLDT are needed to evaluate the effect of this procedure on the progression of osteoarthritis.

Ethical approval for this retrospective study was granted by the responsible institutional review board (Ethic Board Zürich Switzerland, BASEC no. 2018-01222), and all included patients gave their written consent.

¹Dominik Meyer, who sadly passed away in December 2019, is a coauthor of this study. He was involved in the introduction of arthroscopic latissimus dorsi transfer at our clinic, and many of the patients included in the study were treated by him. He contributed an important part of the study and is remembered as a dear colleague and an innovative scientist.

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Asymptomatic rotator cuff tears (RCTs) in the elderly population are common. Up to 40% involve ≥2 tendons and are defined as massive RCTs. RCTs may be irreparable, and failed previous rotator cuff repairs (RCRs) may become irreparable in up to 60% of patients. If conservative treatment fails, different surgical options include arthroscopic debridement with biceps tenotomy, partial RCR, superior capsular reconstruction, tendon transfer, and reverse total shoulder arthroplasty (RTSA).

In young and active patients with irreparable posterosuperior RCTs without osteoarthritis (OA), latissimus dorsi transfer (LDT) is an effective treatment with substantial and durable improvement in shoulder function and the potential to alter the progression of OA. Risk factors for poor outcomes are irreparable subscapularis tears, limited passive preoperative range of motion, complete chronic pseudoparalysis, glenohumeral OA, and fatty infiltration of the teres minor, whether a previous failed RCR is a significant risk factor is controversial. There are different modifications of the original open LDT described by Gerber et al. With technical progress of arthroscopic surgery, arthroscopically assisted procedures have been described. Arguments for arthroscopically assisted LDT (aLDT) are protection of the deltoid and specifically its origin, identification and simple repair of subscapularis lesions, smaller incisions, and possibly fewer adhesions. Available short-term studies of aLDT have reported good outcomes and low complication rates, with comparable results to the open technique. There are, however, very few documented mid-term results of aLDT. It was therefore the purpose of this study to report our clinical and radiographic mid-term results of aLDT for irreparable posterosuperior RCTs. We hypothesized that clinical and radiographic mid-term results would be comparable with no more complications than the all-open procedure.

Materials and methods

Patients

From October 2013 until December 2016, a total of 40 consecutive aLDTs (of 645 arthroscopic RCRs during this period) were carried out at our institution. The indications for aLDT were (1) failed conservative management that was initiated for a minimum of 3-6 months; (2) persistent pain and/or subjectively unacceptable shoulder dysfunction; (3) irreparable posterosuperior RCTs with full-thickness tears of at least the complete supraspinatus with/without infraspinatus tendons with more than grade 2 fatty infiltration according to the modification of the Goutallier classification by Fuchs et al. or the inability to achieve refixation of the tendons intraoperatively because of excessive musculotendinous retraction; and (4) an acromiohumeral distance (AChD) ≤ 7 mm on true anteroposterior radiographs of the shoulder with the humerus in neutral rotation (Fig. 1). The exclusion criteria for aLDT were patients with advanced OA (grades 4b and 5) according to the modification of the original Hamada classification irreparable subscapularis tears (grade 3 or 4 fatty infiltration), neurologic disorders of the thoracodorsal and/or axillary nerve, paresis of the deltoid muscle, restriction of passive range of motion, or glenohumeral instability.

A total of 9 patients (23%) were not available for personal clinical follow-up; 4 could be interviewed by telephone: 3 reported a good result (Subjective Shoulder Value [SSV] range, 60%-70%), and 1 reported a fair result (SSV%, 30%). Two patients refused to participate, 2 could not be traced, and 1 died of unrelated causes. According to telephone or chart review, none of the 9 patients had undergone revision surgery.

The personally reviewed cohort thus consisted of 31 shoulders in 31 patients (23 men and 8 women). Their mean age was 55.5 years (range, 38-73 years) at the time of aLDT. Patients were interviewed and examined at a mean follow-up of 3.5 years (range, 2-5 years). Fourteen patients (45%) had previously undergone shoulder surgery, of whom 12 (39%) underwent open or arthroscopic RCR (repairs of the supraspinatus 6; infraspinatus in 1; supraspinatus and infraspinatus in 3; supraspinatus and subscapularis in 1; and supraspinatus, infraspinatus, and subscapularis in 1). In the remaining 17 patients (55%), the aLDT was the primary procedure.

Fatty infiltration of the teres minor was present in 12 shoulders (39%); grade 1 in 5 (16%), grade 2 in 2 (6%), grade 3 in 1 (3%), and grade 4 in 4 (13%). Four shoulders (10%) showed grade 1 fatty infiltration of the subscapularis muscle. Clinically, preoperative subscapularis function, tested by the lift-off test, was intact in all 31 patients.

Surgical technique and postoperative care

All interventions were performed by 2 senior shoulder surgeons (C.G. and D.M.). The patient was placed supine in the beach-chair position, and a hydraulic arm holder (Trimano Fortis Support Arm; Arthrex, Naples, FL, USA) was applied, allowing for free range of motion of the operated shoulder. Shoulder arthroscopy was started with a standard posterior portal. The rotator cuff was evaluated and partially repaired in 12 patients (39%) with double-loaded titanium anchors (6.5 mm; Karl Storz, Tuttingen, Germany): 6 partial repairs of the supraspinatus; 2, infraspinatus; 3, supraspinatus and infraspinatus; and 1, teres minor. A subscapularis tendon lesion limited to the upper third was found in 12 patients. The personally reviewed cohort thus consisted of 31 shoulders in 31 patients (23 men and 8 women). Their mean age was 55.5 years (range, 38-73 years) at the time of aLDT. Patients were interviewed and examined at a mean follow-up of 3.5 years (range, 2-5 years). Fourteen patients (45%) had previously undergone shoulder surgery, of whom 12 (39%) underwent open or arthroscopic RCR (repairs of the supraspinatus 6; infraspinatus in 1; supraspinatus and infraspinatus in 3; supraspinatus and subscapularis in 1; and supraspinatus, infraspinatus, and subscapularis in 1). In the remaining 17 patients (55%), the aLDT was the primary procedure.

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shoulders; 5 underwent débridement, and 7 were directly repaired using the same double-loaded titanium anchor. A biceps tenotomy was routinely performed (n = 15). In the remaining patients, the tendon had previously been ruptured or undergone tenotomy. The anterior supraspinatus footprint was débrided for fixation of the LDT. Then, the passage for the latissimus tendon between the posterior deltoid and the teres minor (if present) was established for the tendon transfer (Fig. 2).

A ribbon of an abdominal sponge was placed at the bottom of the passage and later retrieved to facilitate identification of the passage between the deltoid and teres minor. This was followed by a 5- to 8-cm axillary incision along the anterior border of the latissimus dorsi (LD). The LD was mobilized anteriorly with caution not to injure the thoracodorsal pedicle medially. The muscle-tendon unit was separated of fascial connections to the teres major muscle and the surrounding soft tissue to increase excursion for the transfer. Thereafter, the broad, thin tendon was released at its origin at the humeral shaft. The tendon was loaded twice with crisscross stitches with 2 No. 2 FiberWire sutures (Arthrex) (Fig. 3). The previously positioned ribbon was identified, and the tendon was shuttled between the cuff and the posterior deltoid to the anterior portion of the greater tuberosity through the established passage using a Kocher clamp. A flat onto bone tendon fixation at the anterior portion of the greater tuberosity was performed using the loaded sutures with 2 SuperQuick anchors (Mitek–DePuy Synthes, Raynham, MA, USA).

After surgery, the arm was maintained in 45° of abduction and 30°-45° of external rotation using an abduction brace. Passive range-of-motion exercises and hydrotherapy were started on the first postoperative day with wounds covered using an occlusive dressing. After 6 weeks, the splint was removed and active external and abduction range-of-motion exercises were initiated. Strengthening exercises were not allowed until 3 months after surgery and were continued until 6-9 months postoperatively.

Clinical and radiographic assessment

Clinical outcome parameters included active range of motion, external rotation in 90° of abduction, shoulder scores, work capacity, complications, and reoperations. Clinical examination included measurement of active and passive ranges of motion and assessment of the absolute Constant score (CS), relative Constant score (CS%), and SSV. Patients rated their overall postoperative outcome with respect to their preoperative expectations as “excellent,” “good,” “fair,” or “unsatisfactory.”

The function of the transferred LD tendon was assessed clinically with the external rotation lag in adduction (dropping sign) and by the external rotation lag in 90° of abduction (Hornblower sign), as well as by evaluation of isometric abduction strength and external rotation strength (with the arm in neutral position) (Isobex; Cursor, Bern, Switzerland). Strength was rated as 0 if 90° of abduction or neutral rotation could not be actively reached. Subscapularis function was assessed clinically with the lift-off test.

Radiographic analysis consisted of assessment of the ACHD and the critical shoulder angle (CSA) on true anteroposterior radiographs. The severity of glenohumeral OA was graded according to the Walch modification of the original Hamada classification. All magnetic resonance images were acquired at 3 T using a dedicated 16-channel shoulder coil (MAGNETOM Prisma; Siemens, Erlangen, Germany). The magnetic resonance imaging (MRI) protocol was tailored for metal artifact reduction and included the following sequences: axial and paracoronal proton density Dixon, paracoronal and parasagittal STIR (short tau inversion recovery) with high bandwidth, and parasagittal T1 with high bandwidth. The quality of the rotator cuff muscles was assessed by quantification of fatty infiltration according to the modification of the Goutallier classification by Fuchs et al. The integrity of the aLDT was assessed on postoperative MRI at
final follow-up, by which the tendon transfer integrity was classified as intact, partially torn, or torn (Fig. 4). Magnetic resonance images were studied to follow the whole transfer in the standard planes (axial, parasagittal, and paracoronal) because of its oblique course through all of these planes. At the myotendinous junction of the LD muscle, the axial and parasagittal planes were most helpful to assess the tendon. Along its course posterior to the humeral head, the tendon was best seen on parasagittal images. All images were analyzed by a radiologist (L.F.) trained in the musculoskeletal system and an orthopedic surgeon (M.W.), who were both blinded to the clinical results.

Assessment of risk factors for poor outcome

Assessment of risk factors for clinical and radiographic outcomes included age, preoperative shoulder function and pain, previous RCR, preoperative quality of the subscapularis and teres minor muscles and tendons, CSA, ACHD, and integrity and quality of the aLDT.

Statistical analysis

Normality of the distribution was tested by the Shapiro-Wilk test. Preoperative and postoperative scores were compared by use of the paired \( t \) test (for normal data) or Wilcoxon signed ranks test (for non-normal data). The Mann-Whitney \( U \) test was used for subgroup analyses. The Spearman correlation coefficient was calculated for the strength and size of the LD tendon. The \( \chi^2 \) test and Fisher exact test (if \( n < 5 \)) were used for categorical variables. Significance was set at .05, and all \( P \) values were 2-tailed. Interobserver reliability of the glenohumeral OA grade, fatty infiltration of the rotator cuff, and aLDT integrity was measured with the intraclass correlation coefficient (ICC) for absolute agreement, with 1 indicating perfect reliability.

Results

Complications and reoperations

A total of 6 patients (19%) underwent reoperations. One patient (3%) had an anchor pull out of the aLDT at 5 months postoperatively and underwent arthroscopic débridement and anchor removal. As the aLDT was healed, no further repair was necessary. At final follow-up, the patient reported persistent moderate pain and had fair shoulder function (CS%, 44%) but rated his subjective outcome as good. Another patient needed arthroscopic débridement at 3 months postoperatively because of persisting and unexplained shoulder pain. Microscopic analysis of intraoperative biopsy specimens revealed acute
calcium pyrophosphate arthritis but no microbial growth. The final shoulder function was good (CS%, 79%), and the patient was pain free.

RTSA was performed in 4 patients (13%) after a mean of 29 months (range, 18-39 months); these cases were considered failures. All 4 had a painful shoulder, and 2 showed additional pseudoparesis of active anterior elevation (50° and 70°) after aLDT (Table I). Two of these patients underwent previous rotator cuff re-reconstructions, and one underwent 2 shoulder arthroscopies with débridement and capsulotomy because of frozen shoulder; in none was the subscapularis deficient or repaired during the transfer surgical procedure.

Superficial wound dehiscence of the axillary incision occurred in 1 patient (3%), which healed spontaneously; hydrotherapy, however, was discontinued until wound healing. Postoperative stiffness developed in 2 patients (7%): One recovered completely without surgical intervention (CS%, 84%). The other patient had previously undergone an open supraspinatus reconstruction.

Figure 3  The patient is placed supine in the beach-chair position with the shoulder placed in maximal abduction and internal rotation for further latissimus dorsi (LD) muscle release. (A) A 5- to 8-cm incision is made along the anterior border of the LD muscle. (B, C) The anterior border of the LD muscle is identified. The muscle is separated of fascial connections to the teres major muscle to increase excursion for the transfer. Medially, the thoracodorsal pedicle has to be preserved. (D) The interval between the teres major and posterior deltoid is dissected, and the placed ribbon band for the LD shuttle is identified. (E, F) Loaded LD tendon after shuttling through passage for fixation to greater tubercle.
postoperative rehabilitation was impaired because of long-standing shoulder pain, and after recovery from stiffness, shoulder function remained poor (CS%, 31%) without clinical capability of aLDT activation.

Clinical outcome

The 4 patients who underwent RTSA were not included in the analysis of the final clinical results. At final follow-up, the mean CS% (P = .032), Constant pain score (P = .012), and SSV (P < .001) were significantly improved over the preoperative state. Active external rotation in adduction was not significantly improved but averaged 27° at final follow-up (vs. 24° preoperatively, P = .409). The subjective outcome was rated as excellent by 10 patients (37%), good by 11 (41%), fair by 5 (19%), and unsatisfactory by 1 (3%). However, only 1 patient had no improvement in the SSV with respect to the preoperative value, and only 2 patients had a change inferior to the minimal clinically important difference (MCID) of 10%.

A positive dropping sign was found in 9 patients (33%); their mean active external rotation was 14° at final follow-up. The Hornblower sign was positive in 7 patients (27%); of these, 2 had no fatty infiltration of the teres minor preoperatively, 1 had grade 2, and 4 had grade 4. Postoperatively, there was no fatty infiltration of the teres minor in 2 patients and grade 4 fatty infiltration in 5. Positive lift-off test results were noted in 9 patients (33%) (vs. 0 preoperatively). Of these, only 1 showed a relevant subscapularis lesion with partial rupture of the upper third of the tendon. The patients with positive lift-off test findings, however, had reduced range of motion with mean active anterior elevation of 138° vs. 123° (P = .036) and abduction of 144° vs. 125 (P = .054). Additionally, these patients had reported significantly more previous surgical procedures (6 of 9 vs. 5 of 18, P = .024). Patients with a positive Hornblower sign (n = 7) at final follow-up showed a significantly higher rate of preoperative grade 3 fatty infiltration of the teres minor (57% vs. 5%, P = .003) as well as a significantly higher rate of teres minor atrophy (71% vs. 20%, P = .023) than patients without a positive Hornblower sign (n = 20). It was interesting to see that the mean improvement measured as the gain in the SSV was about the same in patients with teres minor degeneration.

Table I

| No. | Sex | Age, yr* | Findings prior to aLDT (preoperative CS%) | PS, n | Indication for RTSA | Time to RTSA, mo |
|-----|-----|----------|-----------------------------------------|-------|---------------------|-----------------|
| 1   | F   | 60       | Chronic pseudoparesis, chronic shoulder pain (55%) | 3     | Persistent pain, pseudoparesis | 27              |
| 2   | M   | 48       | Chronic shoulder pain (44%)               | 4     | Persistent pain, pseudoparesis | 27              |
| 3   | F   | 44       | Chronic shoulder pain, history of frozen shoulder (40%) | 3     | Persistent pain | 18              |
| 4   | F   | 60       | Chronic shoulder pain (75%)               | 0     | Persistent pain     | 39              |

RTSA, reverse total shoulder arthroplasty; FU, follow-up; aLDT, arthroscopically assisted latissimus dorsi transfer; CS, Constant score; PS, previous surgical procedure; F, female; M, male.

* Age at time of aLDT.
(ΔSSV, 36%) and those without it (ΔSSV, 30%; P = .697). Further details of clinical outcomes are provided in Table II.

Radiographic outcome

The 4 patients with RTSA were not included in the analysis of final radiographic outcomes. The mean glenohumeral OA grade according to the Hamada classification significantly continued to increase from preoperatively (1.7; range, 1-4a) to postoperatively (3.1; range, 1-5; P < .001). Progression by 2 or more Hamada grades was seen in 13 patients (48%), whereas in 9 patients (33%), no progress over the preoperative state was observed. At final follow-up, patients without progression had significantly less atrophy (0 of 9 vs. 6 of 18, P = .001) and less fatty infiltration of the teres minor (0.2 vs. 1.8, P = .011) than patients with progression. However, there was no significant difference in clinical outcomes between the patients with and without progression by 2 or more Hamada grades (CS%, 72% vs. 75%, P = .932). The mean ACHD significantly decreased from 6.7 mm preoperatively (range, 2-13 mm) to 4.7 mm postoperatively (range, 1-9 mm; P < .001).

Analysis of postoperative MRI showed a partial rupture of the aLDT in 5 patients (19%) and a complete rupture in 1 (4%). In the remaining 21 patients (78%), the aLDT was considered intact (Table III).

Functional and subjective outcomes in the group of patients with partial or complete aLDT tears (n = 6, 22%) were inferior to those in the group with intact aLDTs, but the small number of cases did not result in a statistically significant difference (CS%, 74% vs. 82% [P = .666]; SSV, 76% vs. 80% [P = .769]). The glenohumeral OA grade according to the Hamada classification was also not significantly influenced by the integrity of the aLDT (1.8 vs. 1.2, P = .341).

There was no correlation of abduction strength (R = 0.037, P < .289) and external rotation strength (R = 0.161, P = .035) with the width of the LD tendon. Patients with atrophy of the teres minor (n = 6, 22%) showed significantly less mean active external rotation in adduction (0°) compared with patients (n = 21, 78%) with eutrophic or hypertrophic teres minor muscles (34°, P < .001). There was, however, no significant difference in gain of external rotation in adduction from preoperatively to follow-up in both groups (Δ10° vs. Δ0°, P = .334). Patients with preoperative Hamada grades 3 and 4a (n = 6, 22%) showed no significant difference in final clinical outcomes compared with patients with Hamada grades 1 and 2 (n = 21, 78%) (CS%, 75% vs. 76%; P = .77).

Interobserver reliability for glenohumeral OA (ICC, 0.90; 95% confidence interval [CI], 0.78-0.96), fatty infiltration of the rotator cuff (ICC, 0.85; 95% CI, 0.63-0.94), and aLDT integrity (ICC, 0.78; 95% CI, 0.54-0.89) was good or very good.

Assessment of potential risk factors for patients with no postoperative improvement and RTSA

At final follow-up, 7 patients (26%) showed no increase in CS% after aLDT but only 1 showed no improvement in the

Table II: Clinical findings preoperatively and at final follow-up

| Variable            | Preoperative | Follow-up  | Δ          | P value |
|---------------------|--------------|------------|------------|---------|
| Shoulders, n*       | 27           | 27         |            |         |
| CS                  |              |            |            |         |
| Absolute, points    | 56 ± 19      | 67 ± 14    | +11        | .012    |
| Relative, %         | 63 ± 20      | 76 ± 16    | +13        | .032    |
| Pain, points        | 11 ± 3       | 13 ± 3     | +2         | .012    |
| Strength, points    | 6 ± 5        | 7 ± 4      | +1         | .566    |
| AER strength, kg    | 3 ± 2        |            |            |         |
| SSV, %              | 43 ± 16      | 77 ± 19    | +34        | <.001   |
| ROM, °              |              |            |            |         |
| AAE                 | 125 ± 46     | 133 ± 28   | +8         | .485    |
| Abduction           | 117 ± 40     | 138 ± 30   | +21        | .085    |
| External rotation   | 24 ± 28      | 27 ± 18    | +3         | .409    |

Satisfaction, n (%)

| Excellent           | 10 (37)      |            |            |         |
| Good                | 11 (41)      |            |            |         |
| Fair                | 5 (19)       |            |            |         |
| Unsatisfactory      | 1 (3)        |            |            |         |

CS, Constant score; AER, active external rotation; SSV, Subjective Shoulder Value; ROM, range of active motion; AAE, active anterior elevation.

- Results exclude patients with revision to RTSA (n = 4).
- Statistically significant (P < .05).
- Descriptive analysis with absolute and relative values only.
SSV. Ten patients (37%) showed no gain or showed a gain lower than the MCID of 10% whereas 17 patients (63%) showed a gain in CS% over 10%. In the first group, 1 of 10 patients was a heavy manual laborer, and in the second group, 13 of 17 were heavy manual laborers. The gain in CS% was thereby significantly higher in patients who performed heavy manual labor (1 of 10 vs. 13 of 17, \( P = .001 \)). Patients with a history of rotator cuff reconstruction prior to aLDT, however, had a significantly less favorable result (SSV, 67% vs. 88% \( P = .035 \); CS%, 68% vs. 85% \( P = .065 \)). There were 3 patients with a history of open rotator cuff reconstruction, of whom 1 was in the RTSA group, 1 had a less favorable result (SSV, 20%; CS%, 31%), and 1 rated his shoulder as good (SSV, 60%; CS%, 76%). Concomitant subscapularis lesions, aLDT integrity, glenohumeral OA, or CSA had no significant influence when we compared the group with no improvement in CS% vs. the group with an increase in CS% \( (P > .05) \) (Table IV).

The 4 patients who underwent RTSA for a failed aLDT had significantly higher mean preoperative pain levels and lower Constant activity scores than the patients without RTSA \( (n = 27) \) (6 points vs. 11 points \( P = .032 \) and 2 points vs. 5 points \( P = .017 \)) (Table V). Two of the patients requiring revision to RTSA had undergone a failed RCR prior to LDT.

### Table III Radiographic findings preoperatively and at final follow-up

| Variable                     | Preoperative | Follow-up | \( \Delta \) | \( P \) value |
|------------------------------|--------------|-----------|--------------|--------------|
| Shoulders, n*                | 27           | 27        |              |              |
| Fatty infiltration\(^1\)    |              |           |              |              |
| SSP                         | 1.6 ± 0.8    | 1.9 ± 0.8 | +0.3         | .005\(^1\)   |
| ISP                         | 2.4 ± 1.1    | 2.9 ± 1.1 | +0.5         | .01\(^1\)    |
| TM                          | 1.0 ± 1.5    | 1.3 ± 1.5 | +0.3         | .52          |
| SSC                         | 0.1 ± 0.5    | 0.4 ± 0.6 | +0.4         | .014\(^1\)   |
| LDT on MRI, n (%)           |              |           |              |              |
| Intact                      | 21 (78)      |           |              |              |
| Partial rupture             | 5 (18.5)     |           |              |              |
| Transmural rupture          | 1 (3.5)      |           |              |              |
| OA                          |              |           |              |              |
| Hamada grade\(^2\)          | 1.7 ± 0.8    | 3.1 ± 1.3 | +1.4         | <.001\(^1\)  |
| Grade 3 or higher, n (%)    | 6 (22)       | 18 (67)   | +12          | .001\(^1\)   |
| ACHD, mm                    | 6.7 ± 2.3    | 4.7 ± 1.9 | -2           | <.001\(^1\)  |
| CSA, °                      | 35 ± 4       | 34 ± 4    | -1           | .12          |

SSP, supraspinatus; ISP, infraspinatus; TM, teres minor; SSC, subscapularis; LDT, latissimus dorsi transfer; MRI, magnetic resonance imaging; OA, osteoarthritis; ACHD, acromiohumeral distance; CSA, critical shoulder angle.

Data are presented as mean ± standard deviation unless otherwise indicated.

* Results exclude patients with RTSA \( (n = 4) \).

\(^1\) Fatty infiltration according to modification of Goutallier classification by Fuchs et al.\(^{15,27}\)

\(^2\) Statistically significant \( (P < .05) \).

\(^1\) Descriptive analysis with absolute and relative values only.

\(^1\) Cuff tear arthropathy was graded from 1 (no degeneration) to 5 (cuff tear arthropathy) according to the Walch modification of the original Hamada classification.\(^{34,57}\)

### Discussion

Similarly to open LDT, aLDT is associated with substantial improvement in the SSV and moderate improvement in shoulder function as measured by the Constant score after a mean of 4 years if used for the treatment of irreparable posterosuperior RCTs. Range of motion and abduction strength did not improve significantly in these patients, a fact that also represents the deselection of patients with pseudoparalysis and especially those with acute pseudoparalysis. Three of four patients report that their overall subjective results are good or excellent; postoperative complications including disinsertion, failure of the transferred LDT, and rupture are rare. The ultimate CS% is roughly 75% and the SSV is between 75% and 80% of a normal shoulder, comparable to the reported results of open LDT; for the SSV, only 2 of 27 patients had an improvement inferior to the MCID of 10%. As in all previous studies concerning open LDT, the SSV was lower preoperatively and higher postoperatively than the CS%, resulting in a substantially greater improvement in the SSV, suggesting that the subjective disability caused by posterosuperior tears is underestimated by the CS. Therefore, we confirm that the effect of LDT on shoulder function is not well recognized by the CS. In particular, the strength of
external rotation and fatigability of the arm in abduction are not well represented by the CS.

Nonetheless, this series shows 2 distinctly different features compared with the open series previously reported: The failure rate is 13%—mostly related to failure to relieve pain, which led to revision with RTSA. This is substantially higher than the rates observed in open series, which reported conversion rates of only 0%-4%.\(^2\,7,\,21\) In addition, with an increase of ≥2 Hamada grades in 48% of the patients at relatively short follow-up, the increase in OA is more pronounced than in the previous studies.

The failure rate is mainly because of failure to relieve pain and less so because of failure to correct dysfunction. Three of the four patients who required revision to RTSA had undergone previous surgical procedures, as opposed to only 41% of the successfully treated patients, and had more painful shoulders than the non-revision cohort. This finding is compatible with the mid-term results after open LDT for

| Table IV  | Clinical and radiographic findings preoperatively and at final follow-up |
|-----------|-----------------------------------------------------------------------|
| Variable  | Improvement in CS% (≥10%) | No improvement in CS% (<10%) or RTSA | Δ | P value |
| Preoperative | | | | |
| Shoulders, n | 17 | 14 | | |
| Age, yr\(^*\) | 57 ± 6 | 54 ± 10 | 3 | .279 |
| Smoking, n (%) | 7 (41) | 5 (36) | | |
| Previous RCR, n (%) | 7 (41) | 6 (42) | | |
| CS | | |
| Absolute, points | 49 ± 19 | 62 ± 14 | 13 | .028\(^†\) |
| Relative, % | 56 ± 21 | 68 ± 16 | 13 | .088 |
| Pain, points | 10 ± 3 | 10 ± 4 | 0.7 | .423 |
| Strength, points | 6 ± 6 | 5 ± 4 | 0.8 | .936 |
| ROM, ° | | | | |
| AAE | 111 ± 49 | 145 ± 27 | 34 | .040\(^†\) |
| Abduction | 100 ± 41 | 134 ± 44 | 34 | .064 |
| External rotation | 27 ± 29 | 26 ± 30 | 1 | .689 |
| SSV, % | 41 ± 18 | 45 ± 12 | 4 | .422 |
| SSC lesion, n (%) | 4 (24) | 7 (50) | | .153 |
| Follow-up | | | | |
| Shoulders, n | 17 | 10 | | |
| CS | | |
| Absolute, points | 72 ± 9 | 54 ± 16 | 18 | .012\(^†\) |
| Relative, % | 82 ± 9 | 61 ± 20 | 21 | .022\(^†\) |
| Pain, points | 13 ± 3 | 12 ± 3 | 1 | .375 |
| Strength, points | 8 ± 4 | 6 ± 4 | 2 | .055 |
| ROM, ° | | | | |
| AAE | 143 ± 15 | 116 ± 36 | 27 | .022\(^†\) |
| Abduction | 147 ± 20 | 121 ± 37 | 26 | .045\(^†\) |
| External rotation | 31 ± 14 | 22 ± 23 | 9 | .643 |
| SSV, % | 83 ± 17 | 69 ± 20 | 14 | .117 |
| Functional test, n (%) | | | | |
| Hornblower | 3 (18) | 4 (40) | | .365 |
| Dropping arm | 3 (18) | 6 (60) | | .039\(^†\) |
| Radiographic findings | | | | |
| LDT intact on MRI, n (%) | 11 (65) | 10 (100) | | .057 |
| Hamada grade | 3.4 ± 1.3 | 2.5 ± 1.3 | 0.9 | .183 |
| ACHD, mm | 4.9 ± 2.0 | 5.3 ± 3.1 | 0.4 | .608 |
| CSA, ° | 33 ± 3 | 36 ± 5 | 3 | .173 |

CS, Constant score; RTSA, reverse total shoulder arthroplasty; RCR, rotator cuff repair; ROM, range of motion; AAE, active anterior elevation; SSV, Subjective Shoulder Value; SSC, subscapularis; LDT, latissimus dorsi tendon; MRI, magnetic resonance imaging; ACHD, acromiohumeral distance; CSA, critical shoulder angle.

Data are presented as mean ± standard deviation unless otherwise indicated.

* Age at time of arthroscopically assisted LDT.

† Statistically significant (P < .05).

\(^\) Results exclude patients with RTSA (n = 4).

\(^\) Cuff tear arthropathy was graded from 1 (no degeneration) to 5 (cuff tear arthropathy) according to the Walch modification of the original Hamada classification.\(^34,\,57\)
Arthroscopically assisted latissimus dorsi transfer

Table V  Patient characteristics, shoulder function (scores), and subjective scores prior to arthroscopically assisted latissimus dorsi transfer in RTSA group vs. non-RTSA group

| Variable                  | RTSA  | Non-RTSA | Δ     | P value |
|---------------------------|-------|----------|-------|---------|
| Shoulders, n              | 4     | 27       |       |         |
| Age, yr†                  | 53 ± 8| 56 ± 8   | 3     | .497    |
| Smoking, n (%)            | 3 (75)| 9 (33)   |       | .272    |
| Previous surgery, n (%)   | 3 (75)| 11 (41)  |       | .304    |
| CS Absolute, points       | 49 ± 14| 56 ± 19  | 7     | .377    |
| CS Relative, %            | 54 ± 15| 63 ± 20  | 9     | .030    |
| CS Pain, points           | 6 ± 4 | 11 ± 3   | 5     | .032†   |
| CS Strength, points       | 3 ± 6 | 6 ± 5    | 3     | .189    |
| CS Activity, points       | 2 ± 2 | 5 ± 2    | 3     | .017†   |
| CS Mobility, points       | 31 ± 6| 27 ± 11  | 4     | .767    |
| SSV, %                    | 38 ± 10| 44 ± 16  | 6     | .388    |
| ROM, °                    | 136 ± 26| 125 ± 46 | 11    | .859    |
| AAE                       | 100 ± 43| 118 ± 50| 18    | .477    |
| Abduction                 | 40 ± 9 | 24 ± 28  | 14    | .389    |
| Fatty infiltration        |       |          |       |         |
| SSC                       | 0.3 ± 0.5| 0.1 ± 0.5|       | .513    |
| TM                        | 0.3 ± 0.5| 1 ± 1    |       | .712    |
| OA Grade                  | 1 ± 0 | 1.8 ± 1.1|       | .173    |
| Grade 3 or higher, n (%)  | 0 (0) | 6 (22)   |       | .561    |

RTSA, reverse total shoulder arthroplasty; CS, Constant score; SSV, Subjective Shoulder Value; ROM, range of motion; AAE, active anterior elevation; SSC, subscapularis; TM, teres minor; OA, osteoarthritis.

Data are presented as mean ± standard deviation unless otherwise indicated.

† Age at time of arthroscopically assisted latissimus dorsi transfer.

Statistically significant (P < .05).

Cuff tear arthropathy was graded from 1 (no degeneration) to 5 (cuff tear arthropathy) according to the Walch modification of the original Hamada classification.34,57

Revision of massive RCTs, in which a failure rate of 41% and a conversion rate to RTSA of 14% were reported.47

Two of the patients were opioid users at the time of aLDT, and one of these patients had previously been treated for very painful frozen shoulder syndrome. There were no other particular risk factors that could be identified in these patients; specifically, they did not have more advanced OA.

Therefore, the indications for aLDT should be applied with caution in patients with pain syndromes, and patients have to be informed about the possibility of persistent postoperative pain.

Revision of a failed rotator cuff as opposed to a primary procedure constituted an additional substantial risk factor for an inferior outcome of aLDT. In the literature, it is controversial whether a previous RCR is a risk factor for an inferior outcome: some studies found inferior results of open LDT after failed RCR,35,49,54,58 whereas others did not.8,10,45,51 Our results confirm other published data on aLDT2,29 with poorer outcomes after failed previous RCR.

Less favorable functional results can be anticipated in patients with a preoperatively positive Hornblower or dropping sign, and fatty infiltration or atrophy of the teres minor muscle has also been observed in previous studies.8,21 However, the gain in the SSV is the same in the 2 groups; thus, the inferior results are not related to a poor effect of the transfer but are related to the fact that the transfer can bring about a certain improvement over the preoperative state that is somewhat independent of the state of the teres minor. It is interesting to note that a reparable subscapularis lesion did not significantly affect postoperative shoulder function and is therefore not considered a contraindication for aLDT. Furthermore, low-demand individuals who perform no heavy manual labor seem to benefit less than patients who are heavy laborers.

Although the LDT is an effective treatment for the irreparable posterosuperior rotator cuff, the postoperative shoulder function of the patients in our study improved less compared with patients who underwent the open technique.22 The preoperative shoulder function, however, was lower in the study of open LDT, but final outcomes were comparable. One reason could be the extension of the indication for “minimally invasive” aLDT also in patients with less severe shoulder function impairment.
As observed in long-term studies of open LDT, the progression of OA might be slowed down but cannot be stopped by tendon transfer surgery. Several short-term studies of aLDT reported no progression of OA. Our mid-term results of aLDT revealed progression of ≥2 grades in almost half of the included patients. On the other side, in one-third of the included patients, OA did not progress over the preoperative state, which could be an indicator that the natural progression of OA may be altered in certain cases after aLDT. The status of the teres minor is of tremendous importance not only for postoperative shoulder function but also in the context of the progression of OA, as our patients without progression of OA showed significantly less atrophy and fatty infiltration of the teres minor than those with progression of OA. Even though previous studies demonstrated that advanced glenohumeral arthropathy is associated with inferior clinical outcomes, our results did not confirm this observation. It should be noted, however, that there were no cases of Hamada grade 4b or 5. An interesting finding was that patients with pre-existing Hamada grade 3 or 4a had no inferior outcomes. A reason for this could be the minor surgical trauma of dissection during arthroscopy compared with open dissection and, therefore, reduced destabilization of an injured shoulder.

The tendon-to-bone fixation in aLDT can be difficult. The reported postoperative rupture rate of aLDT is as high as 40%. There are, however, different techniques of tendon fixation that have been rapidly evolving since the first report of an arthroscopic technique. In our study, only 1 technique-related complication required revision surgery, and this complication is known to be related to the design of the anchor used in our early time performing aLDT. On the other side, we observed only 1 complete rupture of the LDT and 5 patients showed partial tears on final MRI. Patients with lesions of the aLDT showed a tendency toward inferior clinical outcomes, but the small number of cases did not result in a statistically significant difference. In addition to the muscle traction force of the LD on the humeral head, the tendon acts as a stabilizer with a tenodesis effect that leads to better stability of the joint during abduction and flexion. This explains the fact that patients still improve despite lesions of the tendon on MRI. Additionally, evaluation of the LD tendon quality (particularly tendon healing) on MRI seems difficult because of postoperative scarring and the occurrence of the magic-angle artifact (high signal intensity on T1 and proton density sequences).

To improve the outcome after LDT, intraoperative reduction of a pathologically high CSA could reduce the vertical thrust of the deltoid, which theoretically should lead to a better abduction moment for the deltoid with more biomechanical synergism with the residual rotator cuff and the transferred LD muscle. The feasibility and safety of arthroscopic lateral acromioplasty have been proved previously. There are limitations associated with this study, including the retrospective design with its associated bias. Another limitation is the number of patients lost to follow-up (23%), as well as the limited power to perform a meaningful subgroup analysis. As this is one of a very limited number of available reports on the mid-term results of aLDT, the current study is an important contribution to the knowledge about the outcomes of minimally invasive tendon transfers for irreparable posterosuperior RCTs.

**Conclusion**

Arthroscopically assisted LDT for irreparable posterosuperior RCTs is associated with statistically significant improvements in objective and subjective shoulder function but statistically nonsignificant gains in range of motion and abduction strength at mid-term follow-up. The failure rate with conversion to RTSA, however, was relatively high and related to unsatisfactory pain relief in low-demand patients with unusually intense pain, often with prior failed RCR. Long-term results of aLDT are needed to evaluate the effect of this procedure on the progression of OA and to identify optimal indications.

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