Reverse shoulder arthroplasty combined with latissimus dorsi transfer using the bone-chip technique

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Abstract

Purpose Reverse shoulder arthroplasty (RSA) can restore active elevation in rotator-cuff-deficient shoulders. However, RSA cannot restore active external rotation. The combination of latissimus dorsi transfer with RSA has been reported to restore both active elevation and external rotation. We hypothesised that in the combined procedure, harvesting the latissimus dorsi with a small piece of bone, leads to good tendon integrity, low rupture rates and good clinical outcome. **Methods** Between 2004 and 2010, 13 patients (13 shoulders) were treated with RSA in combination with latissimus dorsi transfer in a modified manner. The mean follow-up was 65.4 months, and the mean age at index surgery was 71.1 years. All patients had external rotation lag sign and positive hornblower's sign, as well as radiological signs of cuff-tear arthropathy (Hamada 3, 4 or 5) and fatty infiltration grade 3 according to Goutallier et al. on magnetic resonance

imaging (MRI). The outcome measures included the Constant Murley Score, University of California-Los Angeles (UCLA) shoulder score, Simple Shoulder Test (SST), visual analogue scale (VAS) and the Activities of Daily Living Requiring External Rotation (ADLER) score. Tendon integrity was evaluated with dynamic ultrasound. All patients were asked at final follow-up to rate their satisfaction as excellent, good, satisfied or dissatisfied.

Results The overall mean Constant-Murley Shoulder Outcome Score (CMS) improved from 20.4 to 64.3 points ($p < 0.001$). Mean VAS pain score decreased from 6.8 to 1.1 ($p < 0.001$), mean UCLA score improved from 7.9 to 26.4 ($p < 0.001$), mean SST score improved from 2.3 to 7.9 ($p < 0.001$) and mean postoperative ADLER score was 26 points. The average degree of abduction improved from 45° to 129° ($p < 0.001$), the average degree of anterior flexion improved from 55° to 138° ($p < 0.001$) and the average degree of external

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rotation improved from -16° to 21° ($p < 0.001$). Eight patients rated their results as very satisfied, three as satisfied and two as dissatisfied.

Conclusion This modified technique, which avoids cutting the pectoralis major tendon and involves harvesting the tendon together with a small piece of bone, leads to good or even better functional results compared with the results reported in the literature, and also has high patient satisfaction and low failure rates.

Keywords Reverse shoulder arthroplasty · Latissimus dorsi transfer · External rotation · Bone-chip technique

Introduction

In patients with pseudoparalysis and loss of active external rotation due to large, irreparable posterosuperior rotator cuff deficiency and signs of cuff-tear arthropathy, reverse shoulder arthroplasty (RSA) in combination with latissimus dorsi transfer has been reported to restore both active elevation and external rotation [1–5]. Here, we describe our results of a combined procedure using RSA and latissimus dorsi transfer. We used a modified technique of harvesting the tendon with a small piece of bone to achieve bone-to-bone healing, which is proven to reduce the failure rate of a latissimus dorsi tendon (LDT) transfer and is associated with improved clinical results [6]. Clinical failure can be caused by the rupture or poor healing of the transferred tendon. This study investigated the integrity of the transferred tendon, the rupture rate and the clinical outcome after RSA combined with latissimus dorsi in a modified manner. We hypothesised that in the combined procedure, harvesting the latissimus dorsi with a small piece of bone leads to good tendon integrity, low rupture rate and good clinical outcome.

Materials and methods

Between 2004 and 2010, 13 patients (13 shoulders) were treated with RSA in combination with latissimus dorsi transfer. All patients had pseudoparalysis of the affected shoulder, with active elevation $< 90^{\circ}$ and loss of active external rotation due to irreparable, severe posterosuperior rotator cuff tears involving the infraspinatus and teres minor muscle tendons. Of the 13 patients (nine women, four men), two died due to unrelated causes 20 months and 22 months after index procedure. The mean follow-up period was 65.4 (range, 18–92) months, mean age at index surgery was 71.1 (range, 63–79) years and mean age at final follow-up was 76.4 (range, 65–84) years. The dominant side was affected in ten patients (77 %).

Indication for surgery was based on clinical and radiological examinations. Clinical examination criteria included loss of active elevation ($< 90^{\circ}$) and external rotation with positive external rotation lag sign [7] and positive hornblower's sign [8], as well as radiological signs of cuff tear arthropathy (Hamada 3, 4 or 5) on standard radiographs in two planes [9]. Magnetic resonance imaging (MRI) was performed on every patient prior to index surgery. Irreparable rotator cuff tear was defined as large, posterosuperior tears with grade 3 muscle atrophy according to Thomezeau et al. [10] or grade 3 fatty infiltration according to Goutallier et al. [11]. In all patients, delta muscle function was intact prior to surgery. Tears in the partial subscapularis tendon were not considered a contraindication for surgery.

Of the 13 patients enrolled in our study, eight had shoulder surgeries prior to the index procedure (Table 1). None had shoulder infection in their past medical history.

Data collection

Pre-operative and intra-operative data were obtained from our institution's database. Pre- and postoperative examination consisted of detailed clinical and radiographic evaluations. Clinical evaluation included pre- and postoperative Constant-Murley Score (CMS), University of California-Los Angeles (UCLA) shoulder score, Simple Shoulder Test (SST) score and visual analogue scale (VAS) [12–15]. Additionally, the postoperative Activities of Daily Living Requiring External Rotation (ADLER) score was evaluated [1].

At the final follow-up, all patients were asked to rate their satisfaction as either excellent, good, satisfied or dissatisfied. A goniometer was used to measure range of motion (ROM) in 5° increments. Clinical examination was performed by an independent examiner who was not part of the surgical team. The radiologic evaluation included standard radiographs in two planes (anteroposterior and axillary), and dynamic ultrasound examination was used to evaluate the integrity and the function of the transferred tendon.

Surgical technique

In all cases, patients were positioned in the beach-chair position and endotracheal intubation in combination with an interscalene block and a deltopectoral approach was used. The subscapularis muscle tendon was at least partly intact in all cases. After ligating the anterior circumflex vessels, the subscapularis tendon was harvested with a bony chip from its humeral insertion using a chisel, and two no. 2 tagging sutures were applied. A reverse prosthetic design (Delta III, DePuy, Warsaw, IN, USA) was used in all patients according to standardised implantation techniques (Fig 1a).

The latissimus dorsi was then identified by lifting the pectoralis major muscle with a Hohmann's hook (Fig. 1b).

Table 1 Patient characteristics

	Patient	Procedures prior to RSA+LDT	Surgeries
RSA Reverse shoulder arthroplasty, LDT latissimus dorsi tendon, SAD subacromial decompression, BT biceps tenodesis, LR labral repair, RCR rotator cuff repair	1	4	SAD, BT, 2 RCR
	2	3	SAD, LR, RCR
	3	3	SAD, RCR
	4	2	SAD, RCR
	5	2	SAD, RCR
	6	2	SAD, RCR
	7	1	RCR
	8	1	RCR

The LDT and teres major tendon were bluntly dissected at their insertion site. The LDT was harvested with a small bone chip (Fig. 1c) using a chisel, as described previously [16]. The bone chip encompassed the entire width of the LDT and had a diameter of approximately 3 mm. Two to three no. 2 nonabsorbable tagging sutures were placed behind the bone chip. Then, the latissimus dorsi was mobilised and the neurovascular bundle identified. A long, curved vascular clamp was inserted laterally around the humeral shaft. The tagging sutures were grasped, and the latissimus dorsi was pulled around the shaft (Fig. 1d). Four to five no. 2 nonabsorbable sutures were used to achieve transosseous bone-to-bone fixation of the bony chip at the posterior aspect of the greater tuberosity at the insertion site of the teres minor muscle (Fig. 1e).

Postoperative protocol

The arm was immobilised with a sling for six weeks. Patients were treated with finger/elbow exercises and isometric exercises during the first four weeks. After sling removal, light active exercises were begun in all planes. After 12 weeks, patients were allowed to return to their normal range of motion and light work and recreational activities.

Statistical analysis

Data were carefully checked for outliers and normality. As the continuous variables severely deviated from normal distributions in some comparisons, dependent bootstrap *t* tests based on 5,000 Monte Carlo simulations were computed. The corresponding 95 % confidence intervals (CI) for means and differences of means were computed using BCa CIs. A *p* value <5 % was considered statistically significant. All analyses were performed by a biostatistician (WH) using NCSS 8 (NCSS, LLC. Kaysville, UT, USA. www.ncss.com) and MATHEMATICA 7 [Wolfram Research, Inc., Mathematica, Version 7.0, Champaign, IL, USA (2008)].

Results

Postoperative functional outcome measurements

The overall mean CMS improved from 20.4 (range, 7–27) points preoperatively to 64.3 (range, 26–81) points postoperatively (*p* < 0.001). Constant pain, activity, mobility, strength and comparison to the opposite side are shown in Table 2. Mean VAS pain score decreased from 6.8 (range, 4–9) to 1.1 (range, 0–7) (*p* < 0.001).

Mean UCLA score improved from 7.9 (range, 3–10) preoperatively to 26.4 (range, 6–33) (*p* < 0.001) postoperatively; mean SST score improved from 2.3 (range, 0–3) to 7.9 (range, 3–10) (*p* < 0.001); mean postoperative ADLER score was 26 (range, 9–30) points. The average degree of abduction improved from 45° (range, 20–90) to 129° (range, 90–170) (*p* < 0.001), and the average degree of anterior flexion improved from 55° (range, 20–90) to 138° (range, 90–170) (*p* < 0.001). The average external rotation improved from −16° (range, −10 to −30) to 21° (range, −10 to 40) (*p* < 0.001). Eight patients rated their results as very satisfied, three as satisfied and two as dissatisfied. In the ten patients with dominant-side injury, integrity of the transferred tendon was good, which was verified by ultrasonography at the final follow-up.

Complications

One patient sustained an anterior dislocation three months after index surgery, with rupture of the transferred tendon. The patient had to undergo revision surgery, and an inlay exchange was performed. The patient showed a low postoperative CMS of 26 points, no strength (0 kg) and a low ADLER score of 14 points; active abduction and elevation were 90°, and external rotation was −10°. The patient identified revision surgery and severe restriction of activities of daily living as the main reasons for dissatisfaction. Two patients sustained a deep infection after 12 and 18 months, respectively. Both patients were treated with two-stage revision and had a low Constant score of 47.1 and 49, respectively. External rotation was 0° in both patients: one was dissatisfied and one satisfied with the results.

Discussion

The combined loss of active elevation and external rotation (CLEER), as described by Boileau et al. [1], is a rare but devastating situation for patients and severely affects their ability to carry out activities of daily living [1]. Here, we report that treating patients according to the procedure described by L'Episcopo [1–5], which consists of RSA in combination with latissimus dorsi transfer or combined latissimus dorsi–teres major (LD/TM) transfer, yields good results. In

Fig. 1 **a–e** Principles of the surgical technique: Shoulder from anterior after implantation of reverse shoulder arthroplasty (RSA) (**a**). The latissimus dorsi tendon (LDT, red dotted line, ●) is displayed by retracting the pectoralis major muscle cranially. Therefore, a Hohmann's hook is inserted under the pectoralis major muscle (■) at the cranial and lateral aspect of the humerus (**b**). The LDT and teres major tendons are

dissected bluntly using a raspatorium. The LDT is then harvested, together with a small piece of cortical bone, using a chisel (**c**). Tagging sutures are placed behind the bone chip (black arrows), and a long vascular clamp is inserted from the lateral aspect behind the humerus to grasp the latissimus dorsi tendon (**d**). Then, the latissimus dorsi tendon is fixed with transosseous sutures at the insertion site of the teres major muscle (**e**)

cases of irreparable infraspinatus muscle deficiency, RSA addresses the lack of active elevation in cuff-deficient, pseudoparalytic shoulders, and latissimus dorsi transfer addresses the lack of active external rotation due to biomechanical principles [17–20].

Here, we present our results of combining RSA and latissimus dorsi transfer using a modified technique in which the LDT is exposed without cutting the pectoralis major tendon and harvested with a small piece of cortical bone.

Using this bone-chip method in an isolated procedure, Moursy et al. [6] showed improved functional results [16].

We hypothesised that this harvesting method leads to proper tendon integrity, good functional results and low failure rate when used in a combined procedure with RSA, and this hypothesis was proven by our results. We achieved excellent gains in active external rotation of $+37^\circ$ and high postoperative ADLER scores of 26/30, which indicates high ability to carry out activities of daily living. This ability likely corresponds to

Table 2 Outcomes according to Constant Murley Score compared to the opposite shoulder

CMS	Preop	Postop	Improvement	95% CI	P value	Opposite side	Difference	95% CI ^a	P value ^a
Pain	4.6±1	13.7±1.25	9.1±1.4	(8.4–9.8)	<i>p</i> <0.001	14.4±0.90	0.7±1.50	–	0.15
Activity	5.6±1.6	15.9±3.1	10.3±3.0	(8.5–12.1)	<i>p</i> <0.001	16.9±4.4	1.0±4.3	–	0.42
Mobility	11.1±2.8	30.8±6.3	19.8±6.5	(15.9–23.7)	<i>p</i> <0.001	32.2±7.1	1.3±8.7	–	0.59
Strength (kg)	0.31±0.48	3.7±1.9	3.4±1.9	(2.5–4.3)	<i>p</i> <0.001	6.1±2.0	2.4±2.4	(1.2–3.8)	0.003
Absolute	20.4±5.2	64.3±15.7	44.0±12.9	(36.7–50.2)	<i>p</i> <0.001	76.1±14.0	11.8±27.3	–	<i>p</i> =0.08

Data given as value±standard deviation

CMS Constant-Murley Score, Preop preoperative, Postop postoperative, CI confidence interval

^a

the high patient satisfaction rate observed in our group; the only rationale for the excellent improvement of +37° in external rotation is due to the high tendon integrity resulting from bone-to-bone healing.

There are several limitations of this study: retrospective design, small number of patients and lack of a control group limit its validity. Additionally, we did not use electromyographic investigation to prove functional activity of the transferred tendon. However, we used dynamic ultrasonography to verify tendon integrity and muscle function.

In all patients, we used a single deltopectoral approach for the combined procedure. We found that the LDT, together with its neurovascular pedicle, could be identified easily and safely through a single incision. Specifically, this can be achieved by following the anterior portion of the humerus distally until the insertion of the pectoralis major muscle, under which the LDT directly lies. As such, we feel that there is no rationale for using a two-incision technique, such as that described by Gerber et al. [2]. Additionally, two-incision techniques are associated with adhesion, scarring and transient or permanent nerve palsies [21]. Notably, we had no extensive scarring, adhesions or nerve palsies in our population. Once the pectoralis major tendon was identified, instead of cutting the tendon to display the latissimus tendon, we lifted the pectoralis major tendon by inserting a Hohmann's retractor in between the pectoralis major tendon and the latissimus tendon and retracted the pectoralis major tendon cranially. This approach leaves the pectoralis tendon intact and may prevent pectoralis major weakness after reinsertion. With regard to postoperative loss of internal rotation, this may be of even higher importance in cases in which the subscapularis muscle is absent or with combined LD/TM transfer.

Boileau et al. [1, 3] observed a postoperative decrease in internal rotation after using a combined LD/TM transfer. They inserted the transferred tendons to the pectoralis major stump and suggested that insertion as a possible reason for the loss of internal rotation. Therefore, in a later study, the authors changed the insertion point to diametrically opposite the original LD/TM insertion. They found no decrease in postoperative

internal rotation [4]. However, we think that the reduced internal rotation may have been due to pectoralis major weakness after cutting and reinserting and/or the transfer of both LD/TM, which left only the subscapularis and pectoralis major muscles for internal rotation.

We inserted the transferred tendon at the posterior site of the greater tuberosity adjacent to the insertion site of the teres minor tendon. This insertion was advocated by Favre et al. [22], who found in a biomechanical study that inserting the transferred LDT in a combined procedure with RSA produced greater external rotation in the arm than when using other insertion sites. Boileau et al. [1, 3] transferred the LD/TM tendon to the stump of the divided pectoralis major and reported good results for external rotation of +28.3° and +36°, respectively, but found deficits in internal rotation [1, 3]. They modified their technique and brought the tendon diametrically opposite the original LD/TM insertion and achieved a gain in external rotation of +34° [4]. Boughebre et al. [5] inserted the LD/TM tendons near the lateral aspect of the bicipital groove and reported a mean gain of external rotation of +36°, without restrictions in internal rotation. Some studies report that transferring the LDT alone results in a small gain in external rotation [7]. Gerber et al. [18] reported a gain of only 7° in ten patients after a combined procedure of RSA and LDT alone.

In our patients, we found comparable or even better results in gains of external rotation compared with authors using both LD/TM tendons [1, 3–5]. These results are likely due to preservation of proper tendon integrity at its insertion site. Although some authors report the LDT to be thin and weak and have advised the use of fascia lata grafts, Achilles tendon grafts or Teflon reinforcement, our technique of harvesting the tendon with a small bone chip showed no need for such augmentation techniques [23, 24].

As shown by Moursy et al. [6] in an isolated procedure, harvesting the latissimus tendon with a small cortical bone chip causes bone-to-bone healing and results in improved tendon integrity, better clinical results and reduced failure rates. We therefore postulated that the same harvesting technique may

also lead to good or even better results in a combined procedure with RSA compared with results previously reported in the literature. We used ultrasonography to verify tendon integrity in every patient. Although we could not evaluate fatty infiltration or atrophy of the transferred muscle by ultrasonographic investigation, in 10 patients, tendons were intact at their insertion site. Of the three patients in whom the tendon was not intact, two had a deep infection with destruction of the transferred tendon, and one had an anterior dislocation with rupture of the transferred tendon. MRI was not helpful because of severe artifacts caused by the prostheses.

Reported negative predictive factors after an isolated latissimus dorsi transfer include female sex, age, revision surgery and integrity of the subscapularis tendon and fatty infiltration of the teres minor muscle (> 2 according to Gutallier et al. [11]) [18, 20, 25–27]. In our series, even though the majority of patients were women (69 %), in ten patients (77 %), the subscapularis tendon was at least partly intact and the teres minor muscle showed no signs of high-grade atrophy (< 2 according to Gutallier et al. [11]). Eight patients (62 %) had rotator cuff repair prior to index surgery.

Conclusion

Our technique of displaying the LDT without cutting the pectoralis major tendon, and harvesting the LDT together with a small piece of bone leads to good tendon integrity, low rupture rate, good or even better functional results compared with results reported in the literature, high patient satisfaction and a low failure rate.

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