Reverse Shoulder Arthroplasty Combined with a Modified Latissimus Dorsi and Teres Major Tendon Transfer for Shoulder Pseudoparalysis Associated with Dropping Arm

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Abstract Although a reverse shoulder arthroplasty (RSA) can restore active elevation in the cuff deficient shoulder, it cannot restore active external rotation when both the infraspinatus and teres minor muscles are absent or atrophied. We hypothesized that a latissimus dorsi and teres major (LD/TM) transfer with a concomitant RSA would restore shoulder function and activities of daily living (ADLs). We prospectively followed 11 consecutive patients (mean age, 70 years) with a combined loss of active elevation and external rotation (shoulder pseudoparalysis and dropping arm) who underwent this procedure. All had severe cuff tear arthropathy (Hamada Stage 3, 4, or 5) and severe atrophy or fatty infiltration of infraspinatus and teres minor on preoperative MRI or CT-scan. The combined procedure was performed through a single deltopectoral approach in the same session. Postoperatively, mean active elevation increased from 70° to 148° (+78°) and external rotation from -18° to 18° (+36°). The Constant score, subjective assessment and ADLs improved. The combination of a RSA and LD/TM transfer restored both active elevation and external rotation in

this selected subgroup of patients with a cuff deficient shoulder and absent or atrophied infraspinatus and teres minor.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Some patients with a cuff-deficient shoulder report severe shoulder dysfunction with combined loss of active elevation and active external rotation. The loss of active elevation (known as pseudoparalysis) is generally the result of an irreparable superior cuff rupture associated with osteoarthritis of the shoulder (ie, cuff tear arthropathy-CTA) [37]. The loss of active external rotation is a rare but disabling condition that results from posterior extension of the rotator cuff tear to the teres minor, as isolated infraspinatus rupture is generally well-tolerated [26, 29, 36, 45]. This loss is related to atrophy and fatty infiltration of the posterior cuff muscles and is reportedly irreversible [16, 17]. Activities of daily living such as shaking hands, eating, drinking, and brushing teeth or hair become difficult, if not impossible, for patients with pseudoparalysis (active forward elevation < 90°) and an associated loss of active external rotation, since they cannot control the spatial positioning of their upper limb; this deficit becomes worse while raising an object with the hand. Patients voice frustration at their inability to stabilize their arm or prevent it from drifting into internal rotation.

A reverse shoulder arthroplasty (RSA), as originally designed by Paul Grammont [22], has proven effective in treating the arthritic cuff-deficient shoulder and restoring active elevation [8, 42, 44, 48]. However, it does not restore

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active external rotation, specifically when the posterior rotator cuff muscles are absent or deficient, and functional results are considerably less if there is atrophy or fatty infiltration of the teres minor [8–10]. In a previous series of patients with a RSA, we observed that, despite a complete restoration of active elevation, patients with an absent or atrophied teres minor were disappointed with the procedure because they were unable to perform many activities of daily living (ADLs) [6]. Their main complaint was that they could not control the spatial positioning of their arm because of a constant tendency of their forearm to swing toward the trunk in attempting elevation or abduction, specifically when trying to lift an object (Fig. 1). Although external rotation deficit can be successfully treated with a tendon transfer, such a muscle transfer alone may be inadequate to power external rotation and elevation with such

global dysfunction, and is contraindicated when arthritic changes are present [12, 13, 15, 20, 28, 31, 38, 40, 49].

We sought to restore both active elevation and external rotation for this selected population with a single operation through a deltopectoral approach and hypothesized: (1) the combination of a RSA with a muscle transfer would restore both active elevation and external rotation and functional scores; (2) the restoration of external rotation would improve ADLs. We describe this combined surgical procedure, its indications, and report preliminary outcomes for elevation and external rotation and ADLs.

Materials and Methods

We prospectively followed 11 patients (seven women, four men) with a combined loss of active elevation (ie, pseudoparalysis) and active external rotation who underwent the combined procedure. We performed the surgery in a select group of patients with shoulder pseudoparalysis (ie, forward elevation $< 90^\circ$) and loss of active external rotation (ie, active external rotation $< 0^\circ$) with dropping arm (Table 1). All patients had an irreparable massive rotator cuff tear combined with shoulder arthrosis and, on imaging studies, both the infraspinatus and teres minor muscles were absent or atrophied. We excluded patients with functional external

Fig. 1A–E An example of a disappointed patient after RSA because of absence of active external rotation. (A) Although the postoperative radiograph shows a well positioned RSA and (B) consent active forward elevation is restored, the patient is disappointed because of (C) persistent hornblower's sign with inability to control the position of the arm in space. (D) She has negative external rotation with the arm at the side and (E) her preoperative CT scan demonstrated complete fatty infiltration of the teres minor muscle.

Table 1. ADLER score (pre- and postoperative quantification of activities of daily living [ADL] which require active external rotation [ER])

Activities of daily living requiring active external rotation (ADLER)*	Points
1. Comb hair	/3
2. Shave (men) or apply makeup (women)	/3
3. Brush teeth	/3
4. Dress (i.e., put on a shirt or a coat without help)	/3
5. Fill a glass with a full bottle (while sitting at a table)	/3
6. Drink (bring a full glass to the mouth)	/3
7. Eat soup (with a full spoon)	/3
8. Shake someone's hand or open a door	/3
9. Use a phone (at ear level)	/3
10. Write a letter (or sign a paper or use a keyboard or play the piano)	/3
Total :	/30

*All these activities should be performed without the help of flexing the neck or bending the trunk and without the help of first abducting the elbow (i.e., without doing a hornblower sign).

0 = unable to do.

1 = very difficult to do.

2 = somewhat difficult to do.

3 = not difficult at all.

rotator cuff muscles, defined as the ability to maintain a minimum of neutral rotation with the arm at the side (ie, active external rotation $\geq 0^\circ$) and those without arthrosis. Those patients with less than a one year followup or those who had the procedure performed for other indications (prosthetic revision, tumor reconstruction, etc) were also excluded. The average age at surgery was 70 years (range, 60–79 years). Three of the 11 patients had been previously operated on, one for a proximal humerus fracture and two for a rotator cuff tear. All patients presented with positive dropping and hornblower's signs, but negative lift-off sign [45]. The external rotation lag sign was positive in all patients. All patients had lost control of the spatial positioning of their upper limb and were unable to perform most ADLs.

Preoperative rotator cuff muscle status was evaluated with computed tomography or MRI (Fig. 2). The supraspinatus and infraspinatus tendons were torn and retracted to the glenoid level in all cases; the subscapularis was normal in all but two cases with partial tears. All patients had stage 3 or 4 fatty infiltration of the infraspinatus according to the Goutallier classification [21]. In all patients, the teres minor was either atrophic or fatty infiltrated [46]. Shoulder arthrosis was present in all shoulders and classified as Stage 3 (five cases), 4 (five cases), or 5 (one case) according to the radiographic system of Hamada and Fukuda [24]. The long head of the biceps was ruptured in five shoulders, delaminated in two, and hypertrophied (ie, an hourglass biceps) in four [8].

All combined procedures were performed by the senior author (PB) through a single deltopectoral approach with the patient in the “beach chair” position [7]. The

coracoacromial ligament and conjoint tendon were preserved. Next, the arm was placed in adduction and external rotation to identify and tag the subscapularis tendon. Both the anterior axillary vessels and the axillary nerve were identified at the inferior border of the subscapularis. The long head of the biceps (LHB) was identified in its groove and its course traced to the glenohumeral joint; it was tenodesed by suturing the tendon to the transverse humeral ligament, and the intra-articular portion was resected when present. Exploration of the glenohumeral joint confirmed the deficient posterosuperior rotator cuff and arthrosis. The remaining subscapularis tendon was detached from the lesser tuberosity and tagged while the humeral head was dislocated anteriorly allowing the RSA to follow a standard technique according to the manufacturers guidelines (Tornier Inc, Houston, TX) [25].

With a trial prosthesis in place, the LD/TM transfer was performed [7]. We divided the upper half of the pectoralis major tendon at its musculotendinous junction 20 mm from its humeral insertion to keep a stump for reattachment of the transferred tendons (when reattached to the diaphysis) and to repair the pectoralis major tendon at the end of the procedure. Medial reflection of the pectoralis major then exposed the combined insertions of the LD/TM (Fig. 2). With the arm in internal rotation and the LHB protected with a retractor, progressive external rotation of the arm exposed the two tendons, often presenting as a combined tendon, which were then detached from the humerus. Heavy, nonabsorbable sutures of different colors (Ethibond #5; Ethicon Inc, Somerville, NJ, and FiberWire; Arthrex, Naples, FL) were placed in the free ends of the combined tendons using Mason-Allen stitches. The use of different

Fig. 2A–B Principles of the surgical procedure are shown. The reverse prosthesis restores active elevation and the latissimus dorsi and teres major (LD/TM) transfer improves active external rotation. The two tendons that are located at the medial border of the humerus are harvested after partial section of the pectoralis major tendon (A).

Because of the lowered, medialized position of the humerus in front of the glenosphere, the course of the rerouted tendons is short and horizontal, facilitating reattachment to the posterior aspect of the humerus (B).

color sutures (two green, Ethibond; two blue, FiberWire) helps to maintain orientation of the tendon during passage and facilitates suture management.

Both myotendinous units were circumferentially released to gain length while avoiding damage to the neurovascular pedicles. Fascial adhesions were found inferiorly and released bluntly under direct visualization with the arm in adduction and flexion to relax the brachial plexus; dissection did not venture beyond 6 cm medial to the tendon insertions, as anatomic studies have identified the neurovascular pedicles to the latissimus dorsi and teres major at an average of 13.1 and 7.4 cm proximal to the humeral insertions, respectively [3, 39]. When sufficient length was obtained (approximately 3–5 cm), the humerus was dislocated anteriorly and the tendons were transferred around its posterolateral aspect (Fig. 3). The transferred tendons were fixed to the posterolateral aspect of the greater tuberosity (ie, at the teres minor insertion) using transosseous sutures in seven cases. The transosseous sutures were placed before implantation and cementation of the definitive humeral prosthesis, reinforcing the construct by passage of the sutures around the prosthetic neck; and integration into the cement. In four cases, the transferred tendons were fixed at the same level (ie, the diaphysis) to the pectoralis major stump using tendon-to-tendon sutures. The prosthesis was then relocated, and the subscapularis was reattached to the lesser tuberosity with transosseous sutures passed through the bone at the bicipital groove level (also placed before cementation of the final implant). The pectoralis major was repaired, and the wound was closed under suction drainage.

A postoperative radiograph was performed to confirm the alignment, and the shoulder was immobilized in a splint at 30° of abduction and 30° of external rotation for 6 weeks before allowing free motion (Fig. 4).

We encouraged active motion of the elbow, the wrist, and the fingers immediately postoperatively. Six weeks after surgery, the patients began a program of passive

Fig. 4 Postoperative immobilization with 30° of abduction and 30° of external rotation is mandatory after RSA and tendon transfer.

elevation and rotation exercises of the shoulder with a therapist. We additionally recommended water therapy for motion and strengthening. Internal rotation was limited to the greater trochanter for 12 weeks. After 12 weeks, the patient began a program of progressive stretching and strengthening of external rotation. Therapy was continued for 6 to 12 months after surgery to maximize strength and range of motion.

All patients were evaluated by independent observers (CC, YR, RB) using the Constant and Murley score [11] and the Subjective Shoulder Value (SSV) of Gerber et al. [18]. Postoperative active external rotation, internal rotation, and anterior elevation were compared with preoperative values. In addition, one of the evaluators (YR) asked the patients their subjective satisfaction (very satisfied, satisfied, disappointed, unhappy) and willingness to undergo the operation again.

Fig. 3A–B Intraoperative photographs are shown of (A) the two tendons (latissimus dorsi and teres major [LD/TM]) after correct release, ready for transfer; and (B) the tendon transfer around the humerus may be facilitated by dislocation of the reverse prosthesis.

In our early experience with the RSA we observed that patients with an absent or atrophied teres minor were unable to perform many ADLs. Therefore, we developed a list of ten common ADLs that require both active elevation and external rotation [9]. In order to evaluate more objectively the potential effect of our combined procedure on ADLs, we asked patients to answer a questionnaire designed to evaluate their capacity to perform these ten common tasks. A specific scoring system, the ADLER score (Activities of Daily Living [ADL] which require active External Rotation [ER]), was designed with a given number of points according to the severity of the potential handicap: unable (0 points), very difficult (1 points), somewhat difficult (2 points) or not difficult at all (3 points). A maximum score of 30 points indicated the patient was able to easily perform all ten tasks (Table 1).

We described patient demographics using means and standard deviations or medians and ranges for continuous variables, and counts (percent) for categorical variables. We compared the pre- and postoperative items of the Constant and Murley Score, range of mobility and SSV using a paired Wilcoxon test. We performed no posthoc corrections for multiple comparisons. All statistics were computed with InStat for Macintosh software (Graph Pad Software, San Diego, CA, USA).

Results

All 11 patients regained functional active elevation and external rotation. Both subjective and objective functional results improved (Tables 2 and 3). All items of the Constant score improved ($p < 0.05$) with an overall score, at last review, of 63.3 points (range, 42–81), corresponding to a gain of 35.7 points; the mean gain in strength was 5.9 points (Table 2). The mean active anterior elevation was 148° (range, 100° to 170°) corresponding to an increase of 78° ; the mean active external rotation increased from -18° to 18° (range, -10° to 40°) corresponding to a gain of $+36^\circ$, but the mean internal rotation decreased from L1 to S3. The hornblower's sign remained positive in two patients and the dropping sign was positive in two patients; lift-off sign remained negative. The Subjective Shoulder Value improved ($p = 0.004$) from 27% preoperatively to 76% postoperatively.

All patients were satisfied or very satisfied at last review. All patients would undergo the same procedure again if faced with the same handicap. The main reason for their satisfaction was return of ability to control the spatial positioning of their upper limb after surgery, as the transfer counteracted the tendency of the arm to drift into internal rotation. This stability restored independent ADL's for the patients in the study. The ADLER score improved

($p = 0.004$) from 9 ± 5 points preoperatively to 26 ± 4 points postoperatively. This represented a dramatic improvement in quality of life.

There were some complications. One patient had a transient axillary nerve palsy, which resolved a few months after surgery. Another patient had a transient radial nerve palsy of the contralateral upper extremity; this was related to severe concomitant cervical narrowing, which resolved after cervical (C5–C6) spine decompression. Two patients underwent reoperation. One patient with persistent pain related to acromioclavicular joint arthropathy had an arthroscopic acromioclavicular joint resection performed 10 months after the index procedure (with resolution of the symptoms). Another patient presented with a late infection (*Propionibacterium acnes*), which resolved after joint débridement, exchange of the humeral implant, and lavage with antibiotics; the patient remains satisfied.

Discussion

Among shoulder abnormalities, the definitive loss of active elevation and active external rotation is an uncommon but debilitating problem which, until now, has received little or no attention. These patients are severely handicapped because of the combination of shoulder pseudoparalysis and a dropping arm when attempting to elevate or abduct the arm. Simple gestures of daily living such as shaking hands, drinking, brushing teeth or hair becomes difficult, if not impossible. A latissimus dorsi and teres major (LD/TM) transfer, first described by Joseph l'Episcopo, reactivates external rotation [31, 32]. However, such a muscle transfer alone may not restore active elevation and is contraindicated in the case of associated arthrosis. A RSA is an established method to treat an arthritic cuff deficient shoulder and to restore active elevation. However, we have shown that such a RSA cannot restore active external rotation when both the infraspinatus and teres minor muscle are absent or definitively fatty infiltrated [9].

There are several limitations to this study. A randomized, controlled study was not used because we were developing a new surgical technique for a medical condition that has never been addressed previously: the combination of pseudoparalysis of the shoulder with a dropping arm related to the absence of external rotator muscles. Such a complex shoulder problem is rare and the number of patients was too small to consider a randomized study. The evaluators were all members of the department and not blinded to the procedure. Finally, the technique had minor variations throughout the study with the location of the transfer (epiphysis or diaphysis), and the number of cases in each group was too small to allow any comparison. On the other hand, our study has several strengths

Table 2. Patient characteristics and results

Case	Gender/age at surgery (years)	Involved/dominant side (right/left)	Followup (months)	Active forward elevation (degrees) pre/post	Active external rotation (degrees) pre/post	Active internal rotation* (degrees) pre/post	Absolute Constant score (100) pre/post	Subjective shoulder value (%) pre/post	ADLER score (/30) pre/post	Subjective results [†]
1	F/68	R/R	35	40/170	-20/20	4/4	20/77	20/100	5/30	VS
2	F/74	R/R	32	90/140	-20/30	8/4	36/61	40/80	20/25	VS
3	M/77	R/R	27	60/160	-10/20	4/0	40/74	30/80	11/30	VS
4	M/60	R/R	18	70/170	-10/30	8/2	38/81	15/80	4/28	VS
5	F/60	L/R	18	60/150	-20/20	8/0	23/51	20/50	8/16	S
6	F/69	L/R	17	100/120	-10/-10	2/2	16/42	20/60	10/27	S
7	F/61	R/R	16	40/150	-20/10	10/4	20/67	20/80	1/26	VS
8	F/79	R/R	13	80/150	-30/10	8/4	30/68	50/90	3/30	VS
9	F/79	R/R	14	70/100	-10/10	2/2	21/45	25/70	6/23	VS
10	M/69	L/R	13	80/160	-20/40	6/2	31/71	25/75	16/26	S
11	M/74	R/R	12	80/160	-30/20	6/2	29/60	35/75	12/28	VS
Series ($\pm$ SD)	7 F/4 M 70 years (range, 60-79)	8 dominant/ 3 nondominant	19.5 (range, 12-35)	70 $\pm$ 18/ 148 $\pm$ 20	-18 $\pm$ 7/ 18 $\pm$ 12	6/2	28 $\pm$ 8/ 63 $\pm$ 12	27 $\pm$ 10/ 76 $\pm$ 12	9 $\pm$ 5/ 26 $\pm$ 4	M

*Internal rotation has been evaluated in points according to Constant and Murley [11]: dorsum of hand to lateral thigh = 0, buttock = 2, sacrum = 4, L3 = 6, T12 = 8, T7 = 10; [†]VS = very satisfied, S = satisfied, D = disappointed, U = unhappy; F = female; M = male; R = right; L = left; SD = standard deviation.

Table 3. Functional results according to the score of Constant and Murley [11]

Parameters	Preoperative score		Followup score	Gain	p Value*
Pain (15 points)	5 ± 3.7	⇒	13.4 ± 2.6	+8.4	< 0.05
Activity (20 points)	6.5 ± 1.9	⇒	15.3 ± 3.5	+8.8	< 0.05
Mobility (40 points)	15.2 ± 6.2	⇒	28 ± 5.9	+12.8	< 0.05
Strength (25 points)	0.8 ± 1.5	⇒	6.7 ± 3.8	+5.9	< 0.05
Absolute Constant score	27.6 ± 7.8	⇒	63.3 ± 12.3	+35.7	< 0.05
Adjusted Constant score	37 ± 9.6	⇒	85.3 ± 15.6	+48.3	< 0.05

Scores are mean ± standard deviation; *Wilcoxon paired t-test.

including all procedures having been performed by the same experienced shoulder surgeon; examination by independent observers; no patient lost to followup (despite advanced patient age); and detailed radiological analysis both of the state of the cuff preoperatively, and the prosthesis postoperatively. Moreover, a real effort has been made to objectively compare the pre- and postoperative handicap in ADLs. For this purpose, we designed a specific score: the ADLER score is a 30 point score designed to quantify some of the ADLs requiring combined active elevation and external rotation (Table 1). Furthermore, we

have evaluated the benefits of this technique, not only in terms of quantity of movement (degrees of active external rotation/elevation) but also in terms of quality of life (tasks that could not be done before and that are possible afterward).

We confirm that a surgical procedure combining a RSA with a LD/TM transfer can restore both active elevation and external rotation in patients with a cuff deficient shoulder and absent or atrophied infraspinatus and teres minor (Fig. 5). The gain in active elevation is high (+70°) while the gain in active external rotation (+36°) is similar

Fig. 5A–F A patient with a combined loss of active elevation and external rotation (A) and associated cuff tear arthritis, Hamada and Fukuda [24] stage 3 (B); a reverse prosthesis associated with LD/TM transfer (C) allows restoration of both active elevation (D) and external rotation with the arm at the side (E) and in abduction (negative hornblower's sign) (F).

or superior to that reported with the standard two-incision procedure [1, 2, 11, 18, 23, 30, 35, 47]. As observed in our early experience with the RSA, without the tendon transfer patients would remain disabled, because in the absence of external rotator cuff muscles (infraspinatus and teres minor) there is no counterbalance to the strong functional internal rotators (pectoralis major, latissimus dorsi, teres major and subscapularis). The transferred muscles compensate for the absent and fatty infiltrated infraspinatus and teres minor, stabilizing the arm to allow performance of ADLs. The major contributor to patient satisfaction after our procedure is the capacity to regain control of the spatial positioning of the arm, eliminating the tendency of the forearm to swing in toward the trunk with attempted elevation or abduction [4, 49]. All patients regained the ability to perform ADLs, particularly those that require a coordination of elevation and external rotation: eating, drinking, shaving, dressing, combing hair, and holding a phone.

The combined RSA and tendon transfer is performed in the same operative session through a single deltopectoral approach with the patient in the beach chair position, obviating the need to place the patient in the lateral position and another posterior approach to harvest the tendons [12, 13, 15, 28, 31, 38, 40, 49]. The deltopectoral approach makes the identification, dissection, and transfer of the LD/TM tendons relatively simple and safe, because the tendons are located at the medial border of the humerus immediately behind the pectoralis major tendon. A posterior incision is not needed, and through this approach, the transfer can be performed with no stretching or angulation of the neurovascular pedicle and the axillary and radial nerves can be identified and protected [3, 34, 39, 43]. By both lowering and medializing the humerus, the reverse prosthesis facilitates the tendon reattachment at the epiphysis level. Moreover, the passage of the LD/TM tendons around the posterior aspect of the humerus is facilitated by its dislocation when performing the RSA; the course of the rerouted LD/TM tendon is short and horizontal, facilitating reattachment to the posterolateral aspect of the humerus, providing an ideal vector for external rotation (Figs. 3, 4) [27, 41]. Our preference is to reattach both tendons at the teres minor insertion with transosseous sutures passing around the stem prosthesis, as this offers the best mechanical advantage to restore external rotation [26, 40]. However, postoperative immobilization is still an important factor for success of the procedure; noncompliance and early internal rotation may overstretch or disrupt the transferred tendons.

Although a technical alternative, we did not transfer the latissimus dorsi (LD) tendon alone. The main reason is that the reported gain in active external rotation has been small after an isolated LD transfer [26]. It seemed to us that such a limited gain in active external rotation was not sufficient

to restore active external rotation of the arm in our patients who all had preoperative external rotation $< 0^\circ$. None of our patients could control the spatial positioning of their arm, as demonstrated by positive preoperative dropping, lag, and hornblower signs. Review of the literature suggests the reported gain in active external rotation after an isolated transfer of the LD is modest, but patient satisfaction remains high because the arm is stabilized by the transfer [1, 2, 18, 23, 30, 35, 47]. Gerber [19] has recently reported a similar series of patients treated with a LD transfer and reverse shoulder arthroplasty; his preliminary results suggested similar promise but demonstrated a lower gain in external rotation. In addition, the isolated LD tendon is often thin and fragile while harvesting of both LD/TM tendons provides a strong tendon unit, improving the ease and strength of the reattachment on the posterolateral part of the humerus.

The indications of our combined procedure must be limited to patients presenting clinically with negative external rotation associated with a positive dropping, lag and hornblower signs. These clinical symptoms, previously described by Walch et al. [45], are associated with infraspinatus and teres minor complete rupture or fatty infiltration on imagine [16]. Patients presenting with positive active external rotation, even if limited, should be excluded because in these cases, the external rotator cuff muscles are still functional. Only 17 of 112 (15%) RSAs performed during the study period received a LD/TM transfer.

There is a clear rationale behind our combined procedure that has been designed for patients with severe cuff-deficient shoulders and absent or atrophied teres minor. After an isolated RSA, those patients remained disabled because the nonfunctional external rotator cuff muscles (ie, infraspinatus and teres minor) provided no counterforce to the strong functional internal rotator muscles (ie, pectoralis major, latissimus dorsi, teres major and subscapularis). While the RSA could solve the problem of vertical muscle imbalance by providing a fixed center of rotation and increasing the deltoid muscle power to overcome the weak rotator cuff muscles, it could not rebalance the shoulder in the horizontal plane. Therefore the associated muscle transfer is needed. In contrast to others, we do not believe a modified prosthetic design, increasing lateralization or retroversion, is sufficient to restore active external rotation [14, 22]. Such technical or technologic modifications can work to improve active external rotation, but only if some posterior rotator cuff muscles are still present, healthy, and functional. Only transferred healthy muscles can serve as a substitute for definitively damaged muscles [9]. In the present series, all patients had atrophic or absent infraspinatus and teres minor muscles, and fatty infiltration was irreversible. In our experience, the posterior portion of the

deltoid muscle alone is not strong enough to restore active external rotation, even with a lateralized reverse design, when there are no functional external rotator cuff muscles [9, 10]. Moreover, lateralization of the center of rotation (outside the scapula) is mechanically risky because it increases the torque and shear forces at the glenoid and may lead to prosthetic loosening [8].

Our technique combining a RSA and a LD/TM transfer through a single deltopectoral approach is effective in restoring active elevation and external rotation in patients with shoulder pseudoparalysis and a dropping arm. In this combined procedure, the RSA rebalances the shoulder in the vertical plane while the associated LD/TM transfer allows rebalancing of the shoulder in the horizontal plane. This procedure is also an attractive reconstructive option for tumor patients who require resection of the proximal humerus and sacrifice of the cuff muscles. Three additional tumor patients (not reported here) have undergone the same procedure and have had an excellent functional result. Owing to the good and reproducible results obtained with this preliminary study, further evaluation with a larger series of patients and longer followup is underway.

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