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Functional improvements in active elevation, external rotation, and internal rotation after reverse total shoulder arthroplasty with isolated latissimus dorsi transfer: surgical technique and midterm follow-up

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Hypothesis: This study investigated the hypothesis that reverse total shoulder arthroplasty (RSA) in combination with an isolated latissimus dorsi tendon (LDT) transfer in patients with pseudoparalysis of abduction and external rotation (combined loss of active elevation and external rotation [CLEER] syndrome) would demonstrate improved postoperative functional results.
Methods: This study was a retrospective single-surgeon case series of 13 consecutive patients with CLEER who underwent RSA without subscapularis repair and combined with an isolated LDT transfer. We reviewed 10 patients (77%), at a minimum of 2 years, with 3 cases lost to follow-up. Shoulder function was assessed preoperatively and postoperatively using the Constant score and postoperatively using the Oxford Shoulder Score, University of California–Los Angeles score, American Shoulder and Elbow Surgeons score, ADLEIR (activities of daily living [ADLs] requiring active external and internal rotation) score, and ADLIR (ADLs requiring active internal rotation) score. Force in internal rotation (IR) at 0° of abduction, external rotation (ER) at 0° of abduction, and ER at 90° of abduction, as well as IR in the belly-press position, was measured.
Results: The mean postoperative follow-up period was 57 months (range, 31-85 months). We observed improvement in the Constant score (from 29.8 ± 6.64 preoperatively to 71.9 ± 10.45 postoperatively, P < .05), as well as abduction force, ER, and forward elevation (P < .05). Postoperatively, the mean American Shoulder and Elbow Surgeons score was 95.1 ± 3.38 and the mean Oxford Shoulder Score was 46.6

± 1.57. Mean force in IR at 0° of abduction was 5.45 ± 2.42 kg, and mean force in ER at 90° of abduction was 4 ± 1.20 kg. Mean force in ER at 0° of abduction (3.65 ± 1.24 kg) and IR in the belly-press position (4.5 ± 2.84 kg) demonstrated a positive correlation with ADLs.

Conclusions: The results of this study demonstrate that RSA without subscapularis repair, combined with an isolated LDT transfer, provides improved postoperative functional outcomes for patients with CLEER while maintaining sufficiently balanced force in IR and ER to effectively perform ADLs.

Level of evidence: Level IV; Case Series; Treatment Study

Shoulder function following reverse total shoulder arthroplasty (RSA) relies on a functional deltoid muscle, restoring active overhead elevation and abduction by making use of the mechanical advantage provided by a repositioned center of rotation.[6,13,19,35,36] RSA alone, however, cannot compensate for a combined loss of active elevation and external rotation (CLEER) resulting from a compromised posteroinferior rotator cuff.[4,6,7] The modified L'Episcopo procedure, transferring both the latissimus dorsi and teres major, has been previously described as an adjunct to RSA for addressing CLEER deficits, with multiple follow-up studies demonstrating subjective and objective improvements in shoulder function.[4,5,16,18,33] Despite such reports of functional improvements, a review of the current literature found no published studies describing objective force improvement in external rotation after RSA with the modified L'Episcopo procedure or investigating loss of strength in internal rotation resulting from this transfer.

Throughout the literature, specific scores dedicated to activities of daily living (ADLs) or rotational activities are used for assessing shoulder function after RSA combined with tendon transfers. Commonly used scores are the ADLER (ADLs requiring active external rotation) score proposed by Boileau et al[3] and its modified version described by Levy et al,[27] the ADLEIR (ADLs requiring active external and internal rotation) score (Table I), which includes 2 additional questions regarding function in internal rotation. A new score for assessing activities in internal rotation, the ADLIR (ADLs requiring active internal rotation) score (Supplementary Table S1), was recently developed by Werthel et al[37] for assessing the long-term results of latissimus dorsi transfers in patients with obstetric brachial plexus injuries. These scores may then be appropriately used to reflect the function of the reconfigured force couple around the shoulder in the case of an RSA combined with the modified L'Episcopo transfer: 2 external rotators (latissimus dorsi and teres major) assisted by the posterior fibers of the deltoid muscle vs. 1 or 2 internal rotators (pectoralis major and subscapularis when repairable) assisted by the anterior deltoid muscle fibers.

As reported by Edwards et al,[14] in up to 55% of RSA cases, the subscapularis may be irreparably torn. Moreover, not all RSA designs allow a functional repair of this tendon owing to the modified line of pull, which renders the subscapularis less an internal rotator and more an adductor within the first 70° of arm abduction and may even cause limitation of external rotation.[1,2,9,10,14,17,21] This factor must be considered when planning an RSA with a concomitant modified L'Episcopo transfer because an irreparable or nonfunctioning subscapularis has a direct impact on the new force configuration (latissimus dorsi and teres major as external rotators vs. pectoralis major as the sole remaining internal rotator). Nevertheless, in a comparative study of a large group of patients, Friedman et al[17] demonstrated that postoperative outcomes after RSA, with or without subscapularis repair, resulted in comparable range of motion and outcome scores, with no clinically significant difference noted between the 2 groups. Particularly given these findings, the decision to repair the subscapularis (when possible) or not in RSA is the subject of much ongoing debate and remains at the discretion of the individual surgeon.[17]

In the case of a nonfunctional subscapularis in RSA, with a modified L'Episcopo transfer, the pectoralis major with its short line of pull acts as the sole remaining internal rotator.[1] This raises concern over the potential for reduced residual internal rotation strength postoperatively and the impact this may have on ADLs following RSA. In light of this, we developed a further modification of the original L'Episcopo procedure,[27,28] transferring the latissimus dorsi in isolation to restore external rotation, thus keeping the teres major as an internal rotator of the shoulder.

The aim of this study was to investigate the hypothesis that in patients with CLEER, RSA without subscapularis repair, combined with an isolated latissimus dorsi tendon (LDT) transfer, will result in good postoperative functional outcomes, specifically in rotational activities owing to optimized opposing muscle force couples.

Table I Preoperative and postoperative quantification of ADLEIR score*

	Possible score, points
1. Comb hair	0-3
2. Shave (men) or apply makeup (women)	0-3
3. Brush teeth	0-3
4. Dress (ie, put on shirt or coat without help)	0-3
5. Fill glass with full bottle (while sitting at table)	0-3
6. Drink (bring full glass to mouth)	0-3
7. Eat soup (with full spoon)	0-3
8. Shake someone's hand or open door	0-3
9. Use phone (at ear level)	0-3
10. Write letter (or sign paper, use keyboard, or play piano)	0-3
11. Remove object from the opposite back pocket	0-3
12. Wash the back of the opposite shoulder	0-3

ADLEIR, activities of daily living requiring active external and internal rotation.

All activities should be performed without flexing the neck or trunk and without first abducting the elbow (ie, without the Hornblower sign). A total of 36 points is possible: 0 points, unable to do; 1 point, very difficult to do; 2 points, somewhat difficult to do; and 3 points, not difficult at all to do.

* Adapted from modified version of ADLER (activities of daily living requiring active external rotation) score[3] described by Levy et al.[26]

Materials and methods

Study population

RSAs combined with an isolated LDT transfer were performed in 13 patients with CLEER between January 2010 and December 2015. The inclusion criteria were severe cuff arthropathy with pseudoparalysis of elevation and external rotation, a positive lag sign in external rotation at 0° and 90° of abduction, and preoperative magnetic resonance imaging or computed tomography confirmation of muscular atrophy and fatty infiltration of the teres minor and infraspinatus (Goutallier grade 3 or 4 [or equivalent]). An intact posterior rotator cuff was considered a criterion for exclusion. Shoulder function according to the Constant score[11] was documented at 1 day preoperatively. The senior author performed all procedures in a single center, using a consistent technique, involving subscapularis excision without repair in all cases.

Surgical technique

The procedure is performed in the beach-chair position with the patient under general anesthesia with an interscalene block. A lateralized skin incision and deltopectoral approach are used, with retraction of the cephalic vein laterally or medially depending on its branches. The deltopectoral interval is opened, and the long head of the biceps is tenotomized in the rotator interval.

If not already absent, the subscapularis tendon is detached and excised with the anterior and inferior glenohumeral ligaments for optimal surgical exposure. The superior third of the pectoralis major insertion is released from the humerus and tagged with sutures for later repair. The axillary neurovascular bundle and radial nerve are identified and protected. The plane between the teres major tendon and LDT is identified and developed with subsequent release and harvest of the latter from its humeral insertion in isolation. Krackow stitches with heavy-gauge nonabsorbable sutures are then performed at either edge of the harvested tendon[24,25] (Fig. 1, *A*). An unfolded gauze swab is passed from lateral to medial, posterior to the humeral neck, piercing the teres major tendon (Fig. 1, *B*), through which these whipstitches are then passed and subsequently retrieved posteriorly (together with the LDT) from medial to lateral using the gauze swab as a dilating graft shuttle (Fig. 1, *C*). The teres major tendon is pierced at the appropriate level to provide an optimal line of pull for the transferred tendon once the inferiorizing effect of a Grammont-style RSA implant on the humerus is taken into account. RSA is then performed using the standard implants and operative technique for the Delta Xtend reverse shoulder prosthesis (DePuy Synthes, Warsaw, IN, USA).[31] Following testing of the stability and passive range of motion of the implanted prosthesis, the LDT is inserted into the lateral crest of the bicipital groove, at the level of its original insertion, with intraosseous fixation and use of the tendon of the long head of the biceps as soft-tissue reinforcement. The released upper third of the pectoralis major is then repaired on top of this attachment. Range of motion is again tested to ensure that over-tensioning of the latissimus dorsi transfer does not block forward elevation or abduction. A single drain is placed deep, followed by closure in subcutaneous and skin layers.

Postoperatively, the arm is protected in an abduction pillow brace for 6 weeks. This may be removed for hygiene, gentle pendular motion, and passive mobilization. Following this period, mobilization—limited only by pain—is commenced with gradual strengthening exercises, rehabilitation, and focused latissimus dorsi re-education with use of biofeedback.

Clinical findings and follow-up

Patients received routine postoperative outpatient follow-up. At final follow-up (minimum of 2 years postoperatively), shoulder function was assessed by a shoulder fellow using the Oxford Shoulder Score, Constant score, University of California–Los Angeles (UCLA) score, and American Shoulder and Elbow Surgeons score. ADLs with regard to internal and external rotation function were assessed with the ADLEIR and ADLIR scores. Maximal isometric shoulder strength (in kilograms) was measured, minimizing trunk compensation, using a handheld electronic dynamometer (EZ Force; TAG Medical Products, Ga'aton, Israel) in neutral external rotation at 0° of abduction (ER1), neutral external rotation at 90° of abduction (ER2), neutral internal rotation at 0° of abduction (IR1), internal rotation in the belly-press position (IR belly), and 90° of abduction in the scapular plane (Constant force) as described by Constant and Murley.[11]

Statistical analysis

All variables are presented as mean ± standard deviation. Normality was tested using the Shapiro-Wilk normality test. Having met assumptions for normal distribution, preoperative

Figure 1 Cadaveric demonstration of isolated latissimus dorsi tendon transfer in isolation before proceeding to reverse shoulder arthroplasty. (**A**) Krackow stitches through harvested latissimus dorsi tendon. The conjoint tendon (↓), deflected upper third of pectoralis major tendon (⬤), and teres major tendon (★) are indicated. (**B**) Piercing of teres major tendon for transfer passage. (**C**) New insertion site of transferred tendon.

and postoperative values were compared using the paired *t* test for continuous data; otherwise, the Wilcoxon signed rank test was used for continuous non–normally distributed variables. All tests were 2-sided with $P < .05$ considered statistically significant throughout the study. A Pearson product moment correlation coefficient was computed to assess the relationship between the measured force and ADLEIR or ADLIR scores. Data were collated using Microsoft Excel (Microsoft, Redmond, WA, USA). All statistical calculations were performed using SPSS Statistics for Windows (version 24.0; IBM, Armonk, NY, USA).

Results

Of the 13 patients who underwent the described procedure, 10 patients (6 women and 4 men) presented for the final follow-up. The mean postoperative follow-up period was 57 months (range, 31-85 months), and the mean patient age at surgery was 73 years (range, 55-89 years). We observed improvements in the Constant score, from 29.8 ± 6.64 preoperatively to 71.9 ± 10.45 postoperatively ($P < .05$), and the measured force in abduction (Constant force, 2.1 ± 1.19 kg preoperatively and 5 ± 1.91 kg postoperatively; $P < .05$). As depicted in Table II, active range of motion improved in all planes ($P < .05$) with the exception of internal rotation, which failed to demonstrate statistical significance ($P = .588$).

Mean postoperative force was 3.65 ± 1.24 kg in ER1 and 4 ± 1.20 kg in ER2. Mean force was 5.45 ± 2.42 kg in IR1 and 4.5 ± 2.84 kg in IR belly. No cases of the external rotation lag or Hornblower sign were observed postoperatively.

Postoperative patient satisfaction scores demonstrated that all patients were satisfied (n = 2) or very satisfied (n = 8) with the results of their surgical procedures. On the UCLA function question, 7 patients reported "slight restriction but able to work above the shoulder" whereas the

other 3 patients reported full normal shoulder function on the operated side.

For the question "Is it difficult to wash your back/do up bra?," 4 patients responded "unable"; 3, "very difficult"; and 2, "somewhat difficult." For the question "Is it difficult to manage toileting?," 3 patients responded "somewhat difficult" and 7 responded "not difficult."

A full breakdown of reported ADLs is presented in Table II, but in summary, ADLs taking place anterior to the frontal plane, whether in internal or external rotation, scored highly whereas all activities requiring internal rotation behind the frontal plane, for example, "remove an object from the opposite back pocket" or "reach the lower back," scored fewer points. Finally, the measured force in ER1 demonstrated good correlation with both ADLIR ($r = 0.648$, $P = .043$) and ADLEIR ($r = 0.766$, $P = .10$) scores. Further positive correlation was seen between IR belly and both ADLIR ($r = 0.739$, $P = .015$) and ADLEIR ($r = 0.667$, $P = .035$) scores.

Discussion

This study aimed to investigate midterm outcomes of CLEER patients following RSA coupled with an isolated LDT transfer performed without subscapularis repair. It assessed subjective and objective shoulder outcomes focusing specifically on ADLs in internal and external rotation. It was hypothesized that by transferring the LDT in isolation rather than together with the teres major as in a modified L'Episcopo transfer, equivalent improvement in external rotation would be provided while maintaining a more optimal force couple for shoulder function during ADLs.

A systematic review of RSA coupled with the modified L'Episcopo procedure by Wey et al[38] (2017) revealed that, with a mean follow-up period of 44 ± 10.4 months,

Table II Patient characteristics and results

	Age at final follow up, yr/sex/follow-up, mo	Preoperative/postoperative						Postoperative								
		Constant score (out of 100)	Constant force, kg	Active forward elevation, °	Active abduction in scapular plane, °	Active external rotation, °*	Active internal rotation, points†	Force in ER1, kg	Force in ER2, kg	Force in IR1, kg	Force in IR belly, kg	UCLA score (out of 35)	ASES score (out of 100)	OSS (out of 60)	ADLEIR score (out of 36), points	ADLIR score (out of 100), points
Patient 1	81/F/85	32/75	2/4	90/160	50/160	0/50	4/4	3	3.5	3	3	33	98	48	33	84
Patient 2	83/F/60	45/83	2/5.5	50/180	50/180	0/10	4/4	4	3.5	5	3.5	35	98	48	35	88
Patient 3	89/F/68	30/63	1/4	90/130	90/130	0/40	6/2	2	2.5	5	3	31	94	46	29	72
Patient 4	57/M/56	35/56	5/4	90/170	90/170	0/10	8/0	4	6	4.5	0.5	33	91	44	30	70
Patient 5	55/F/55	23/68	1/3	50/180	50/180	0/20	0/6	4	5	6.5	6	33	96	46	34	94
Patient 6	77/M/31	25/89	3/9	90/170	90/170	0/10	4/4	5	5	10	10	33	97	47	35	96
Patient 7	74/F/44	25/61	1/3.5	50/140	50/140	0/20	2/2	1.5	3	2.5	2	32	88	44	31	79
Patient 8	73/F/68	26/68	2/3	90/160	90/160	0/10	4/4	3	2.5	5	5	33	94	48	32	87
Patient 9	67/M/37	32/77	2/7	50/170	50/170	0/10	6/4	5	5	9	8	33	97	47	35	89
Patient 10	77/M/70	25/79	2/6	30/170	30/170	0/30	4/6	5	4	4	4	35	98	48	35	96
Mean ± SD/ statistical comparison	73/6 F and 4 M/57	29.8 ± 6.64/ 71.9 ± 10.45/ improvement, $P < .05$	2.1 ±/ 1.19/5 ± 1.91/ improvement, $P < .05$	68 ± 23/ 163 ± 16.36/ improvement, $P < .05$	64 ± 23.19/ 150 ± 23.57/ improvement, $P < .05$	None/ 21 ± 14.49/ improvement, $P < .05$	No improvement, $P = .588$	3.65 ± 1.24	4 ± 1.20	5.45 ± 2.42	4.5 ± 2.84	33.1 ± 1.2	95.1 ± 3.38	46.6 ± 1.58	32.9 ± 2.28	85.5 ± 9.31

ER1, neutral external rotation at 0° of abduction; *ER2*, neutral external rotation at 90° of abduction; *IR1*, neutral internal rotation at 0° of abduction; *IR belly*, internal rotation in belly-press position; *UCLA*, University of California–Los Angeles; *ASES*, American Shoulder and Elbow Surgeons; *OSS*, Oxford Shoulder Score; *ADLEIR*, activities of daily living requiring active external and internal rotation; *ADLIR*, activities of daily living requiring active internal rotation; *SD*, standard deviation; *F*, female; *M*, male.

* Preoperative external rotation of 0° represents pseudoparalysis, with no active external rotation possible.

† Internal rotation is evaluated in points according to Constant and Murley[10]: dorsum of hand to lateral thigh, 0 points; buttock, 2 points; sacrum, 4 points; L3, 6 points; T12, 8 points; and T7, 10 points.

Constant scores improved from 28 ± 11 preoperatively to 65 ± 12 postoperatively, demonstrating similar outcomes to those of our study (from 29.8 ± 6.64 preoperatively to 71.9 ± 10.45 at final follow-up); similar improvements were also achieved for active elevation (from 72° to 138° vs. from 68° to 163° in our study) and external rotation (from –7.4° to 22.9° vs. from none to 21° in our study). By using the technique described in our study, comparable outcomes to those reported in the literature for RSA combined with the modified L'Episcopo transfer[36] and indeed comparable to published midterm outcomes for the Delta Xtend[20] in general were achieved.

Boileau et al[3,5] and Puskas et al[32,33] have previously described excellent restoration of external rotation using the modified L'Episcopo transfer, though at the cost of a slight reduction in internal rotation, which was not considered a relevant outcome parameter. We, however, have concerns regarding the modified L'Episcopo transfer with RSA, particularly with a dysfunctional subscapularis, hypothesizing that this may result in an imbalance of force couples around the shoulder. As a result, it is proposed that the use of an isolated LDT transfer, to maintain satisfactory internal rotation force and function while restoring power in external rotation, presents a more optimal solution.

Although no similar studies exist in the literature for direct comparison, by reconfiguring the force vectors responsible for internal and external rotation in CLEER patients as described in the present technique (with the pectoralis major performing internal rotation; the teres major performing internal rotation, adduction, and extension; the transferred latissimus dorsi performing external rotation; and the deltoid muscle performing abduction and forward flexion), our cohort achieved sufficient force in ER1, ER2, and abduction, as well as in IR1 and IR belly, to satisfactorily perform ADLs. Likewise, the ADLEIR and ADLIR scores suggest excellent functional outcomes specifically in activities performed within the visual field. Lower scores for activities performed posterior to the body's frontal plane (behind the visual field), however, were seen, which affected global scores to some extent—a finding that may relate to limitations posed by the biomechanics of the RSA implant itself. Even though no improvement in internal rotation range was found in our study group, measured force in the IR belly position was observed to have a positive impact on the ability to perform ADLs. Nevertheless, the causes of limitation in internal rotation range of motion following RSA in this cohort remain unclear.

Despite this finding, a high UCLA score, American Shoulder and Elbow Surgeons score, Constant score, and Oxford Shoulder Score, as well as subjective self-evaluation scores, demonstrated high overall subjective satisfaction and objective levels of function in this cohort. This outcome demonstrates the ability of an isolated LDT transfer, coupled with RSA, to successfully restore function in patients with CLEER deficits, particularly in the performance of routine ADLs around the midline, within the visual field.

The vital importance of restoring the shoulder's midline function is commonly discussed in patients with brachial plexus palsy, as it is directly related to the quality of life and the ability to perform ADLs.[8,12,15,28-30,34] This concept may equally be applied to patients with CLEER, in whom restoration of midline function is a key goal. The midline of the shoulder is defined as a line obtained by intersecting the body's frontal plane with the sagittal plane through the humeral shaft at 0° of abduction. Activities that take place around this midline at different degrees of abduction, in either external or internal rotation, but anterior to the frontal plane are the most common ADLs, which relate directly to patient satisfaction and quality of life. Functionally, this can be translated to ADLs performed within the visual field. Increased force in ER1 and in internal rotation at the belly position (IR belly) were correlated with higher ADL scores in our patient group, thus demonstrating the importance of reconstructing the midline function of the shoulder by balancing the force couples in RSA for CLEER patients, as with the present technique.

Although it may be feasible to use an isolated teres major tendon transfer for restoration of external rotation in place of LDT transfer in RSA, no literature evidence on this combination was found. The teres major tendon is described as being short and bulky, making its transfer more technically challenging compared with LDT transfer,[22,23] and as such, a combination of the original L'Episcopo procedure[24] with RSA was not considered as an alternative to the present technique. Nevertheless, comparative biomechanical and feasibility studies on different tendon transfers in RSA may change the perspectives of restoring the midline shoulder function.

Our study has limitations that must be taken into account when drawing conclusions. The number of patients in this cohort does somewhat limit the scope of the conclusions presented, as does the absence of a control or direct comparator group with which to draw comparisons or to build shoulder strength profiles. Comparison with contralateral shoulder strength and function was avoided because of the high incidence of concomitant shoulder pathology on the opposite side. Nevertheless, we feel that the consistent positive subjective and objective shoulder outcome scores, together with the reported patient satisfaction, allows some robust conclusions to be drawn from this study. At the same time, this may inform the direction of future studies, which could usefully investigate the concepts presented in this study, in terms of restoring shoulder midline function, performing strength pattern analysis, and restoring balanced force couples, as well as investigating factors affecting internal rotation restriction and function in RSA. Likewise, further group-matched clinical studies on tendon transfers associated with RSA would be useful in corroborating the findings and hypotheses presented in this study.

Conclusion

Our study demonstrates that by balancing force couples around the shoulder with use of an isolated LDT transfer combined with RSA, comparable outcomes to those described with use of a modified L'Episcopo transfer may be achieved while maintaining sufficient power in internal and external rotation to perform ADLs with a high level of patient-reported satisfaction. On the basis of these findings, it is proposed that an isolated LDT transfer, combined with RSA, may be considered a useful therapeutic strategy for restoring the shoulder's midline function in patients with combined loss of elevation and external rotation.

Disclaimer

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Supplementary data

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