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ORIGINAL PAPER

Mid- to long-term outcomes after reverse shoulder arthroplasty with latissimus dorsi and teres major transfer for irreparable posterosuperior rotator cuff tears

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Abstract

Aim The objective of this study was to describe the outcome of reverse shoulder arthroplasty (RSA) combined with modified L'Episcopo procedure at long-term follow-up (5 to 12 years).

Methods A retrospective review of 17 RSAs (mean age 67.2 years) with the modified L'Episcopo procedure conducted between 2006 and 2016 was performed. All patients had a combined loss of active elevation and external rotation with an irreparable posterosuperior rotator cuff tear. Clinical assessment was performed with a minimum follow-up of five years (mean 97.3 months). Outcome measures included range of motion, subjective shoulder value (SSV), visual analogue scale (VAS), and Constant-Murley scores.

Results All patients (16) demonstrated a significant improvement in all clinical and functional parameters. VAS pain scores improved from 6 ± 2.6 to 1 ± 1; SSV improved from 35 ± 14 to 72 ± 10; active forward elevation increased from 66° ± 34 to 125° ± 29; and active external rotation arm at the body increased from −11° ± 22 to 21° ±11 and in 90° of abduction from −10° ± 17 to 37° ± 24. The mean Constant score improved from 25 ± 11 to 59 ± 8. Active internal rotation did not significantly change (p = 0.332).

Conclusion At long-term follow-up, RSA combined with modified L'Episcopo procedure resulted in significant improvements in pain, range of motion, and functional scores for patients with shoulder pseudoparalysis and a lack of active external rotation caused by a massive posterosuperior cuff tear with a teres minor deficiency.

Keywords Cuff tear arthropathy · Tendon transfer · Reverse shoulder arthroplasty · CLEER · L'Episcopo · External rotation · Teres minor

Introduction

Reverse shoulder arthroplasty (RSA) can reliably restore the ability to perform overhead daily activities among patients suffering from a pseudoparalytic shoulder due to an irreparable posterosuperior cuff tear [1–3]. However, several studies have shown that traditional RSA is unable to restore active external rotation in the presence of massive posterosuperior cuff tears with non-functional infraspinatus and teres minor muscles [4–6]. Hence, in this subgroup of patients, the inability to control spatial positioning of the arm will remain postoperatively leading to persistent functional impairment in some activities of daily living [7].

Gerber et al. and Boileau et al. [1, 8] were first to propose combining RSA with tendon transfers to address the external rotation deficit following RSA in patients suffering from a massive posterosuperior cuff tear. Each group of authors

Level of evidence: IV

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described a combined procedure that included both RSA and transfer of the latissimus dorsi (LD) with or without teres major (TM) tendon (modified L'Episcopo procedure), which aimed to restore both active shoulder elevation and external rotation. Both reported promising short-term results [8, 9] which have been confirmed in recent systematic reviews [10, 11]. However, all these studies have short-term follow-up [10, 11], and it remains unknown whether these results are maintained over time.

The purpose of this study was to describe the long-term follow-up (5 to 12 years) results of RSA combined with modified L'Episcopo procedure in terms of range of motion, functional results, and patient satisfaction. We hypothesized that the long-term follow-up (5 to 12 years) results of RSA combined with L'Episcopo procedure will demonstrate superiority compared to the pre-operative state.

Materials and methods

Between 2006 and 2016, 17 consecutive shoulders (16 patients, 8 women, one bilateral procedure, and 8 men) undergoing RSA combined with a modified L'Episcopo procedure were retrospectively reviewed from a single institution.

All patients presented with a painful pseudoparalytic shoulder secondary to a massive posterosuperior cuff tear with combined loss of active elevation and external rotation (CLEER) [12]. Pseudoparalysis was defined as the inability to actively forward flex the arm above 90° combined with anterosuperior escape of the humeral head when attempting to actively elevate the arm [12]. CLEER was defined as a combination of pseudoparalysis and loss of active external rotation with the arm at the side of the body (ER1), accompanied by the lag sign [13] and dropping sign [14, 15]. To test the lag sign, the examiner fixed the patient's shoulder in 20° abduction, 45° external rotation, and 90° of elbow flexion. The patient was then asked to maintain the forearm position. The lag sign was deemed positive in case the patient's forearm dropped to 0° or negative external rotation upon release [13]. To test the dropping sign, a similar test was performed, only with 0° of shoulder abduction [14, 15]. Other inclusion criteria were a fully functional deltoid; plain radiographs demonstrating stage 3, 4A, 4B, or 5 in the Hamada and Fukuda classification [16]; a massive irreparable posterosuperior cuff tear with muscle atrophy and fatty infiltration (≥ Goutallier 3 [17]) on CT scan or MRI [18]; failed conservative treatment; and minimum follow-up of five years.

Patients were not eligible for this procedure if they presented with (1) deltoid palsy; (2) severe glenoid bone deficiency which precluded implantation of a glenoid baseplate; and (3) clinical examination demonstrating active external rotation with the arm at the side greater than 0°.

Surgical technique

All surgery was performed by the senior author (PV) in the semi-beach chair position under general anaesthesia and interscalene block. Exposure of the gleno-humeral joint was performed through an extended delto-pectoral approach. The anterior circumflex humeral arteries were ligated before dissecting the bicipital groove and performing a soft tissue biceps tenodesis to the pectoralis major (PM). The subscapularis tendon was detached using a peeling technique, and the LD tendon was identified just below the inferior border of the subscapularis muscle insertion, deep to the insertion of the PM tendon. The PM tendon was spared and most frequently retracted inferiorly, but occasionally superiorly, depending on the patient's anatomy (Fig. 1a, b). Both LD and TM tendons were detached subperiosteally from the bone and were bluntly separated from one another. Carefully preserving their supero-inferior orientation, the harvested tendons were shuttled, using a curved tip blunt instrument, under the PM tendon and around the humeral shaft (Fig. 1c, d, e). Close contact with the humerus was maintained during the shuttling process to avoid iatrogenic injury to the radial nerve.

All RSAs were performed using the Arrow System (FH Orthopedics, Mulhouse, France) which has a highly lateralized design [19]. Following prosthesis implantation and reduction, the LD and TM tendons were fixed separately via two trans-osseous non-absorbable braided sutures (Ethibond 5, Ethicon, Somerville, NJ) to the posterolateral aspect of proximal humerus, directly opposite the native insertion site (Fig. 1f). The tendons were secured with the arm in maximal external rotation. The subscapularis tendon was repaired with a double-row trans-osseous fixation. Post-operatively, the patient was placed in a brace in neutral rotation and 20° of abduction for a period of four weeks. Mobilization of the hand and the elbow with passive pendulum exercises was encouraged immediately following the operation. Passive elevation and external rotation to neutral began after four weeks. Active forward elevation and external rotation began after six weeks. Between 12 weeks and six months post-operatively, pool therapy and internal rotation exercises were initiated together with muscle reinforcement of external rotators.

Clinical and radiographic evaluation

Post-operative visits were scheduled at six weeks, three months, six months, and yearly thereafter. Complications subjected to revision surgeries followed an identical visit protocol. Pre-operative and post-operative clinical evaluation included the examination of active shoulder range of motion in forward flexion, external rotation with the arm at the side of body (ER1) and in 90° abduction (ER2), abduction, and internal rotation. Forward elevation, ER, and abduction were assessed in degrees. Internal rotation

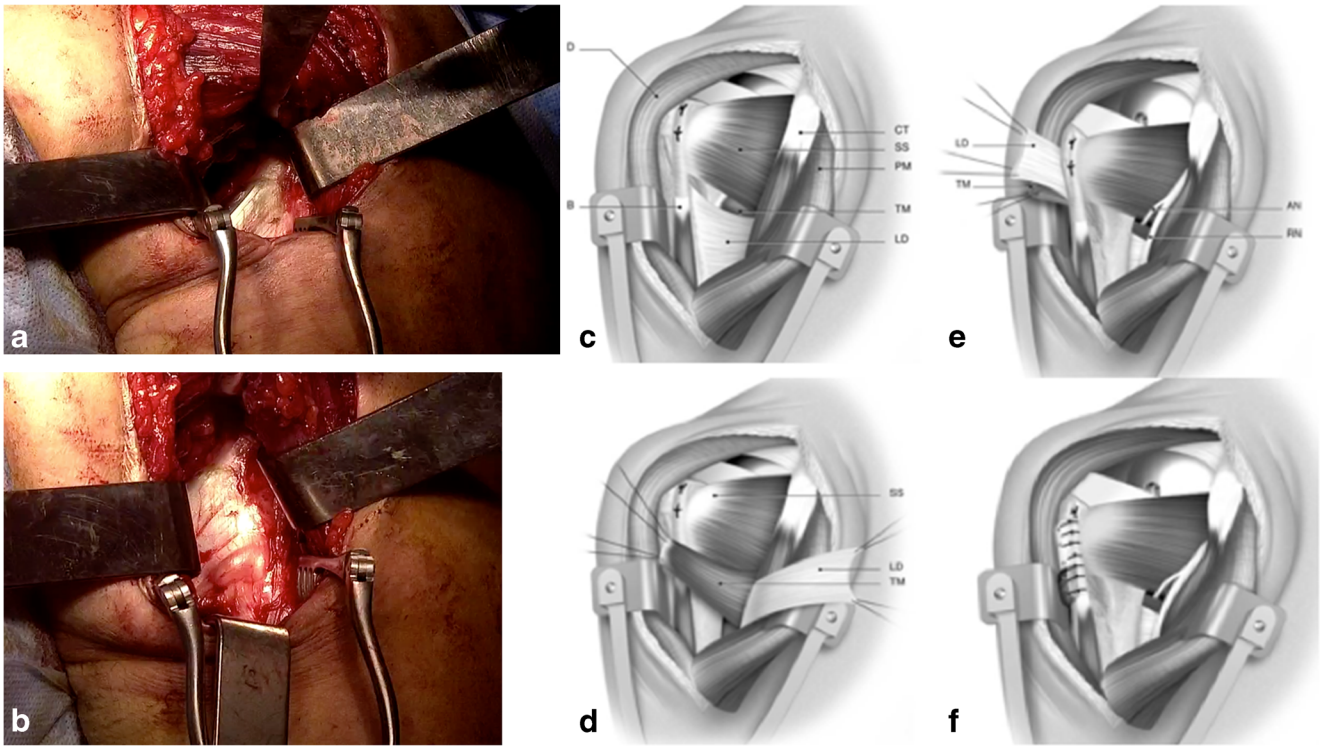

Fig. 1 **a**, **b** RSA performed through a delto-pectoral approach. PM is superiorly retracted by a Hohmann retractor, represented by the blue star. LD tendinous band exposed, represented by the yellow star. **c**–**f** A schematic drawing describing the transfer procedure. **c** Anatomical landmarks; **d** detachment of both LD and TM; **e** shuttling of the 2 tendons to the posterolateral aspect of the humerus; **f** tendon fixation by transosseous sutures. PM pectoralis major, LD latissimus dorsi, CT conjoined tendon, SS subscapularis, TM teres major, D deltoid, B biceps, AN axillary nerve, RN radial nerve

assessment was based on Constant-Murley score (CMS) scale. Documentation of the presence or absence of the lag sign and dropping sign was recorded. Pain was assessed using the visual analogue scale (VAS). Additionally, several scores were used to evaluate patients' functional outcomes including CMS, subjective shoulder value (SSV), and Simple Shoulder Test (SST). At the last follow-up, patients were asked to rate satisfaction as either (1) very satisfied, (2) satisfied, (3) acceptable, or (4) unsatisfied.

Pre-operatively, all patients were evaluated with plain radiographs including anterior-posterior (AP) views in internal, neutral, and external rotation to evaluate cuff tear arthropathy according to Hamada et al. [16]. CT scans were also routinely obtained to evaluate glenoid bone stock and fatty infiltration/atrophy of the rotator cuff muscles according to Goutallier et al. [17] and Zanetti et al. [20] (Table 1) Complications, re-operations, and revisions were also noted.

Statistical analysis

All statistical analyses were performed using SPSS Statistics software. Descriptive statistics are described as minimum, maximum, mean, and standard deviation for continuous measures and number (percentage) for discrete variables. A Student *t* test was used to compare pre-op and post-op state for quantitative values. A Mann-Whitney *U* test was to compare the group of patients suffering from complications and patients not suffering from complications for quantitative values. A chi-square or Fisher exact test was used to compare nominal values depending on sample size.

Results

Seventeen shoulders met inclusion criteria and were evaluated at a mean follow-up of 97.3 months (range 63–141). The average age at the time of surgery was 67.2 years (range, 52–82). The distribution of patients' gender, operated sides, and laterality is detailed in Table 1. Rotator cuff arthropathy was the most common indication for surgery (16/17). Hamada stages 3 and 4A were equally distributed and accounted for 16 out of the 17 shoulders. Hamada stage 4B was diagnosed once. Seven patients underwent 8 operations prior to the abovementioned RSA (Table 1).

All shoulders undergoing RSA with a modified L'Episcopo demonstrated significant improvements in all ROM parameters except IR (Table 2, Fig. 2). Improvements in forward flexion (58.2° ± 41.9) and ER1 (31.8° ± 23.5) both

Table 1 Demographic data. *FU* follow-up, *SSC* subscapularis, *SSP* supraspinatous, *ISP* infraspinatus, *T. Minor* teres minor

	Study Group 17 RTSA			
Age at Surgery	67,2±7,3 (52-82)			
FU (months)	97,3±23,9 (63-141)			
	F	M		
Gender	8	8		
	L	R		
Affected Side	5	12		
Dominant Side	0	17		
HAMADA				
3	8			
4A	8			
4B	1			
Goutallier	SSC	SSP	ISP	T.Minor
0	4	0	0	0
I	5	0	0	0
II	6	0	0	0
III	2	16	16	16
IV	0	1	1	1
Previous Surgery				
Primary	10			
Cuff Repair	4			
Cuff Repair + Flap	1			
Acromioplasty	1			
Fracture	2			
Etiology				
Post Traumatic Arthrosis	1			
Cuff arthropathy	16			

Table 2 Pre- and post-operative results of the study group (17 RTSA). *FE°* forward elevation in degrees, *ER1* external rotation arm at the side to the body, *ER2* external rotation arm at 90° abduction, *IR* internal rotation, *SST* Simple Shoulder Test, *VAS* visual analogue scale, *SSV* subjective shoulder value

Variable		Study Group 17 RTSA
	Pre-op	
	Post-op	
	Gain	
	P Value	
FE (°)		66±34 (20-150)
		125±29 (80-160)
		58,2±41,9 (0-140)
		<0.05
Abduction (°)		59±26 (20-120)
		110±24 (80-150)
		51,2±31,6 (10-110)
		<0.05
ER1 (°)		-11±22 (-40-30)
		21±11 (0-40)
		31,8±23,5 (-10-70)
		<0.05
ER2 (°)		-10±17 (-40-20)
		37±24 (10-90)
		47,1±29,7 (10-110)
		<0.05
IR (grade)		5±3 (0-10)
		5,5±2 (2-8)
		0,6±2,4 (-4-4)
		0.332
Constant (X/100)		25±11 (4-48)
		59±8 (42-70)
		33,9±13,8 (10-60)
		<0.05
Constant W. (%)		40±14 (19-69)
		80±13 (51-100)
		40,1±20,5 (-6,5-69,6)
		<0.05
SST		2±1 (0-5)
		8±1 (6-11)
		5,9±1,9 (3-9)
		<0.05
VAS		6±2,6 (0-9)
		1±1 (0-3)
		-5,4±2,3 (-8-0)
		<0.05
SSV		35±14 (20-70)
		72±10 (60-90)
		37,1±14,5 (20-60)
		<0.05

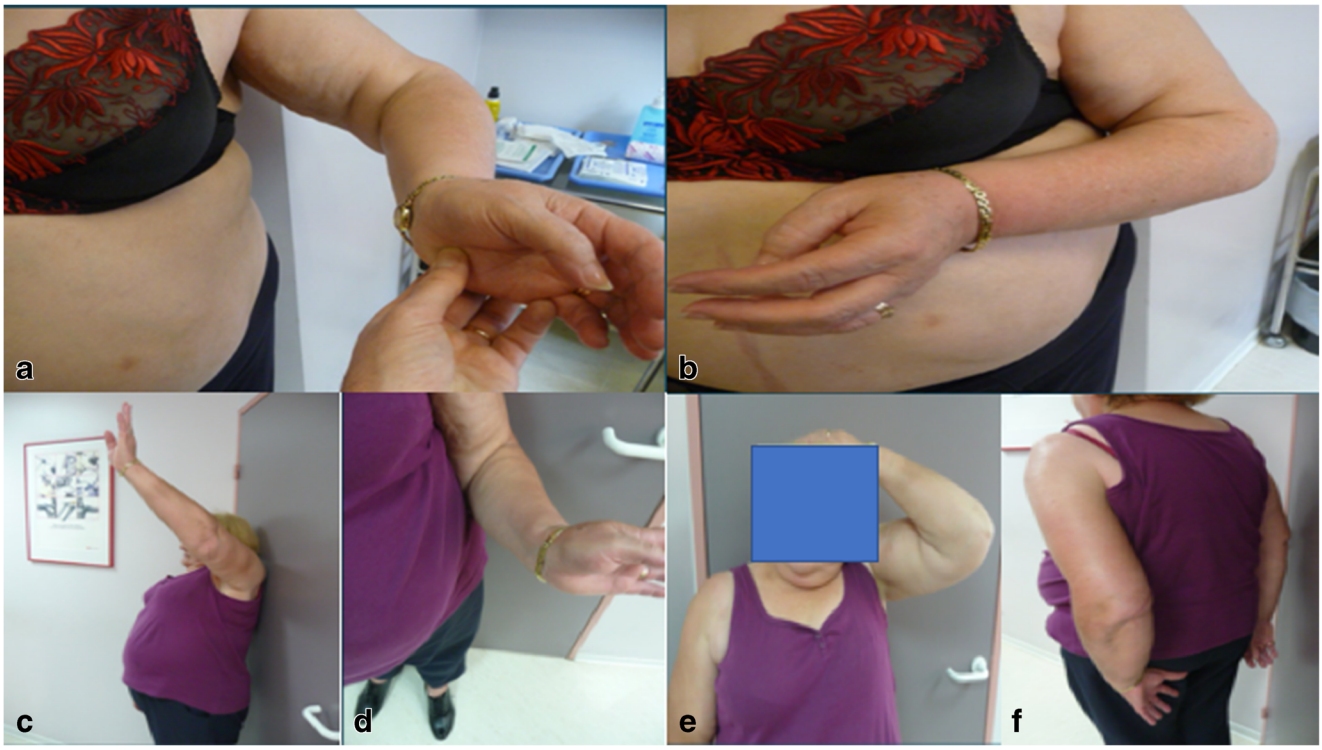

Fig. 2 Pre- and post-operative clinical examination. **a**, **b** Pre-operative exam demonstrating a positive dropping sign; **c**–**f** post-operative range of motion; **c** forward elevation; **d** external rotation 1; **e** external rotation 2; **f** internal rotation

exceeded the minimally clinically important difference [21]. Significant improvements were also demonstrated for all functional outcome scores displaying a 37.1 ± 14.5–point increase in SSV score, a 5.4 ± 2.3–point decrease in VAS, a 5.9 ± 1.9–point increase in SST, and a 33.9 ± 13.8–point increase in CMS (Table 2).

With regard to patient satisfaction, 11 of the cases were very satisfied, five were satisfied, and one patient reported an acceptable result. No patient reported an unsatisfied result.

Complications

A total of six complications (35%) were identified in the study. Five cases were revised, and one was offered a revision surgery but refused any further surgical intervention. These cases consisted of five major complications including two infections, one case of inferior subluxation of the prosthesis, one traumatic dislocation with polyethylene disengagement, one superior migration of the baseplate, and one minor complication consisting of soft tissue irritation caused by a metaphyseal cerclage wire.

Mean time to revision occurred earlier within the follow-up period, 32.5 months. Information regarding complications, treatment, and outcome at final follow-up are summarized in Table 3.

Subgroup analysis

In order to assess the influence of complications on post-operative outcomes, a subgroup analysis was performed. A comparison of the post-operative outcomes between patients with complications (6 cases) and without complications (11 cases) was performed to assess the impact of these patients on post-operative outcomes. Subsequently, no significant differences were observed between groups in terms of ROM and functional scores including constant score, SSV, SST, and VAS (Table 4).

Discussion

CLEER is a functionally limiting condition that incompletely restores function when treated with RSA in isolation. Treatment with a combined RSA and L'Episcopo procedure for patients with shoulder pseudoparalysis and a lack of active external rotation caused by a massive posterosuperior cuff tear with a teres minor deficiency resulted in long-term significant improvements in pain, range of motion, and functional scores. Furthermore, the modified L'Episcopo transfer had lasting effects on active ER, with maintained ER at long-term follow-up.

The concept of a combined procedure (RSA with L'Episcopo), for the treatment of muscle imbalance in both

Table 3 Complications, treatment, and outcome at final follow-up

Patient	Complication	Treatment	FU at revision (months)	Final result					
				Final FU (months)	Constant score (Pts)	SSV%	Degree of satisfaction	FE°	ER1°
1	Infection (PBA)	One-stage revision	53	144	58	90	VS	150	40
2	Infection (PBA)	One-stage revision	24	70	70	70	VS	160	30
3	Inferior instability	Revision: stem (proud position), insert	51	132	47	60	A	90	30
4	Traumatic mechanical failure PE socket	Revision: PE tray	5	92	61	80	VS	160	10
5	Hardware irritation	Metaphyseal cerclage removal	39	98	88	70	VS	160	30
6	Superior metalback migration	Conservative (patient declined operative treatment)	23	69	57	60	S	90	20

FU follow-up, *SSV* subjective shoulder value, *VS* very satisfied, *S* satisfied, *A* acceptable, *FE°* forward elevation in degrees, *ER1* external rotation arm at the side to the body, *PBA Propionibacterium acnes*

the vertical and horizontal planes, has been reported in the literature [1, 2, 12]. In their study, Ortmaier et al. [22] harvested solely the LD using a "bone-chip" method, which relies on a strong bone to bone healing. They report equivalent or better results in external rotation gains and suggest a better conservation of internal rotation apparatus compared to studies transferring both LD and TM tendons. Contrarily, various publications [7, 12, 23] consider the LD tendon to be too thin and fragile, as opposed to a conjoined LD\TM tendon transfer, which forms a stronger tendon unit. In a recent systematic review, Ortmaier et al. [11] presented a tendency of surgeons' preference towards transfer of both LD and TM tendons. In our study, LD\TM tendon transfer has proven to be a reliable solution for restoring active external rotation, resulting in an ER1 gain of 31° ± 21.4 for the entire study cohort, with maintained improvements at midterm follow-up.

Although various fixation sites of the LD/TM transfer have been described in the literature, none of these sites is considered the gold standard for tendon fixation [10]. Fixation sites may be proximally at the greater tuberosity [1] or more distally opposite to the original insertion of LD\TM [11, 12]. Boughebri et al. [23] reported a 36° gain in external rotation when attaching the transferred LD\TM tendons to the lateral aspect of the humerus. In their article, Gerber et al. [1] described a fixation site at the posterolateral aspect of the greater tuberosity at the level of the teres minor insertion. They

Table 4 Comparison of post-operative ROM and functional scores between patients without complications (11) and patients with complications (6)

Variable	No complications (11)	Complications (6)	*p* value
FE (°)	133.6±28 (80–160)	103.3±36.7 (80–140)	0.571
Abduction (°)	113.6±22.5 (80–150)	103.3±26.6 (80–140)	0.381
ER1 (°)	21.8±10.8 (0–40)	23.3±15 (10–40)	0.918
ER2 (°)	34.6±21.6 (10–90)	46.7±26.6 (20–80)	0.383
IR grade	5.6±2 (2–8)	5.3±2.7 (2–8)	0.917
Constant (*X*/100)	66.8±10 (49–88)	58.7±10.1 (47–71)	0.174
Constant W. (%)	92.3±15.3 (65.3–120.6)	81.9±12.6 (62.7–101.4)	0.145
SST	8.2±1.3 (6–11)	7.7±1.5 (6–10)	0.463
VAS	0.8±0.8 (0–2)	1.2±1.2 (0–3)	0.593
SSV	74.6±8.2 (60–90)	68.3±11.7 (60–90)	0.139
Satisfaction			
Very satisfied	7	4	0.309
Satisfied	4	1	
Acceptable	0	1	

FE° forward elevation in degrees, *ER1* external rotation arm at the side to the body, *ER2* external rotation arm at 90° abduction, *IR* internal rotation, *SST* Simple Shoulder Test, *VAS* visual analogue scale, *SSV* subjective shoulder value

reported a 27° gain in external rotation with the arm at the side to the body. Ortmaier et al. [22] utilized the same insertion site and presented a 37° gain in external rotation. Their preference relies on a biomechanical model study, suggesting that fixating the rerouted tendons to teres minor's insertion site results in a greater gain of external rotation compared to insertion sites lateral and inferior to the bicipital groove [9]. In the presented study, the 31° ± 21.4 gain in ER1 documented by the entire cohort is comparable with the results of these previous studies and supports the assumptions that both fixation sites may function as a reliable anchor site for the transferred tendons [1, 12, 22, 23].

Lateralized reverse shoulder prostheses, similar to the implant used in this study, have also been shown to improve patients' post-operative functional results including external rotation [3, 19, 24, 25]. In their study, Berglund et al. [3] investigated the restoration of external rotation in patients with a pre-operative diagnosis of CLEER. Patients were treated with a lateralized reverse shoulder prosthesis without LD transfer. The authors reported an excellent mean gain of 48° in external rotation and an overall patient satisfaction of 93.9%. The authors concluded that a RSA with a lateralized centre of rotation adequately restores external rotation. The average follow-up was 43.4 months and strength of external rotation was not measured. Various publications disagree with the presented concept. In their study, Boileau et al. [7] argue that a lateralized reverse prosthesis alone is not sufficient to restore active external rotation and that the posterior deltoid alone is not strong enough to restore the desired external rotation. Puskas et al. [2] also argue that lateralized implants alone cannot address the loss of muscle force for external rotation in patients with irreparable posterosuperior cuff tears. In the presented study, the use of both a lateralized center of rotation prosthesis and LD\TM tendon transfer demonstrated a significant improvement in active external rotator which was consistent over time. Whether the LD\TM transfer is active or acts through a tenodesis effect remains unclear, but a RSA by itself cannot compensate for absent posterior structures and a tendon transfer might be necessary in these patients.

The 35% total complication rate observed in this study included one major complication of a traumatic dislocation with polyethylene disengagement and a minor complication of soft tissue irritation caused by a metaphyseal cerclage wire. Excluding these externally derived complications leaves the study with a 23.5% complication rate which is comparable with the reported range in recent systematic reviews of RSA (17–29%) [2, 11, 26]. In this study, no significant differences were finally detected between patients suffering from complications (6 cases) and patients without complications (11 cases) in terms of ROM and functional scores (Table 4). Additionally, despite the high complication rate, five of six patients sustaining complications were ultimately satisfied with their outcome at final follow-up. Despite complications, after undergoing re-operation, these patients still noted clinically meaningful improvement compared to their pre-operative state.

This study is one of the few that describe long-term follow-up outcomes of RSA combined with a modified L'Episcopo procedure. All surgery was performed by the senior author at a single institution. The study is limited by its retrospective nature over a long time period, small number of patients, and lack of control group. In addition, no imaging control was performed to assess healing of the tendon transfer. The inclusion of shoulders undergoing reoperation also likely influenced the clinical outcomes, but we feel their inclusion better represents the true outcome of patients electing to undergo such a procedure which does have known risks. Larger studies are needed to confirm the long-term benefit of RSA with a modified L'Episcopo procedure.

Conclusion

At long-term follow-up, RSA combined with modified L'Episcopo procedure resulted in significant improvements in pain, range of motion, and functional scores for patients with shoulder pseudoparalysis and a lack of active external rotation caused by a massive posterosuperior cuff tear with a teres minor deficiency.

Authors' contribution Philippe Valenti: literature search, study design, data analysis, data interpretation, writing

Leila Oryadi Zanjani: data collection, data analysis, data interpretation

Bradley S. Schoch: data analysis, data interpretation, writing

Efi Kazum MD: literature search, data analysis, data interpretation, writing

Jean David Werthel: literature search, study design, data analysis, data interpretation, writing

Declarations

Ethics approval and consent to participate This study was classified as observational (non-interventional) by our local ethics committee. Statutory and ethical obligations of observational (non-interventional) studies in France: According to the past Huriet law on biomedical research, and to the current regulation that went into effect in August 2006 (law no. 2004-806), such studies do not require prior submission or approval to/from an IRB, and they do not require written consent. There is a current discrepancy on observational studies between the French legal requirements and the editors' requirements. This observational research on data fulfills current French regulatory and ethical obligations. Consent to participate is not applicable.

Consent for publication Neither the article nor portions of it have been previously published elsewhere; the manuscript is not under consideration for publication in another journal and will not be submitted elsewhere; all authors consent to the publication of the manuscript in *International Orthopaedics*.

Competing interests Philippe Valenti and Jean-David Werthel receive royalties for shoulder prosthesis design from FH Orthopedics. Bradley

Schoch is a paid consultant and receives royalties from Exactech, Inc. All other authors, their immediate family, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

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