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Isolated loss of active external rotation: a distinct entity and results of L'Episcopo tendon transfer

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Background: The purpose of this study was to characterize a subgroup of cuff-deficient patients with isolated loss of active external rotation (ILER) but preserved active elevation and to evaluate the outcomes of the L'Episcopo procedure to restore horizontal muscle balance.
Methods: During a 10-year period, 26 patients (14 men, 12 women) were identified with ILER in the setting of massive irreparable posterosuperior cuff tears. A modified L'Episcopo tendon transfer was performed to restore active external rotation and to improve shoulder function. The mean age at surgery was 64.5 years (29-83 years). Patients were evaluated with a mean follow-up of 52 months (range, 24-104 months).
Results: Preoperatively, despite maintained active elevation (average of 161°), ILER patients complained about loss of spatial control of the arm and difficulties with activities of daily living. On computed tomography scan or magnetic resonance imaging, there was severe fatty infiltration of infraspinatus and absent or atrophic teres minor. After L'Episcopo transfer, 84% of patients were satisfied. The gain in active external rotation was +26° in arm at the side and +18.5° in 90° abduction. Adjusted Constant score and Simple Shoulder Value increased from 63.6% to 86.9% and from 36.9% to 70.8%, respectively ($P < .001$). The ADLER score increased from 10 to 24.5 points ($P < .002$). Two patients with advanced cuff tear arthropathy (Hamada stage 3 and 4) required conversion to a reverse shoulder arthroplasty (RSA) 7 and 9 years after the index surgery.
Conclusions: ILER is a distinct entity that is a cause of severe handicap because of loss of spatial control of the upper limb. This symptom is related to absent or atrophied infraspinatus and teres minor. In properly selected cases (Hamada stage 1 or 2), the modified L'Episcopo transfer is effective at restoring anterior-posterior rotator cuff force balance. In more advanced cuff tear arthropathy (Hamada stage ≥3), the tendon transfer should be performed with an RSA because of possible secondary degeneration of the glenohumeral joint.

This study was approved by the local ethics committee: No. 2016-19. All participants signed an informed consent form for treatment and gave consent to participate in the study.

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The prevalence of massive irreparable rotator cuff tears (MIRCTs) reported in the literature has ranged from 10% to 40%.[1,21,32,37] Most MIRCTs are chronic and often asymptomatic, occurring in elderly, less active patients. This pathologic process relates to a progressive and degenerative "tendon wear" under the acromial arch.[4,22,28,40] In these patients, in whom the cuff tendon degeneration process is slow and progressive, the cuff-deficient shoulder often remains *functional* with normal or nearly normal active elevation and external rotation (ER).[4,23,40] Some cuff-deficient shoulders may become *non-functional* and symptomatic, either traumatically or atraumatically, resulting in pain, weakness, and loss of motion.[4,40] In such circumstances, patients may lose active forward elevation (AFE) or active ER (AER), temporarily or permanently.[3,4]

In 2003, we saw for the first time at our institution a patient with a massive irreparable posterosuperior rotator cuff tear who had permanently lost AER but with preserved AFE. This 67-year-old woman complained that as she elevated her shoulder, her forearm would fall into progressive internal rotation (IR), the dropping sign. On clinical examination, she had presence of the Hornblower,[35] ER lag,[19] drop,[28] and dropping signs.[35] This resulted in difficulty with simple activities of daily living (ADLs), such as eating, drinking, combing her hair, applying makeup, holding a phone to her ear, or shaking someone's hand. Imaging studies revealed severe fatty infiltration (Goutallier grade 3 and grade 4)[16] of supraspinatus and infraspinatus with a completely atrophic teres minor (Tm).

The treatment of MIRCTs is still controversial and depends on the symptoms presented by the patient; conservative therapy, arthroscopic débridement with or without partial cuff repair, tendon transfers, and reverse shoulder arthroplasty (RSA) have all been proposed.[1,4,12,14,21,32,37] An RSA was not indicated in our patient because AFE was conserved (ie, the vertical muscle balance of the shoulder was maintained).[2,5] We hypothesized that a tendon transfer, which could re-establish the lost horizontal muscle balance of the shoulder, would result in improved AER and restore shoulder function.[3,4] This led us to propose a modified L'Episcopo procedure, which successfully restored AER in our patient without compromising AFE.[3,26]

In 2007, we introduced the concept of isolated loss of ER (ILER) to define the subset of patients with definitive *horizontal muscle imbalance* and have proposed a modified L'Episcopo procedure as a surgical solution for these patients.[3] Here we describe the largest series of MIRCT patients presenting with ILER and the results obtained after modified L'Episcopo transfer. The purposes of the study were to characterize the clinical and imaging presentation of this subgroup of cuff-deficient patients with ILER and to evaluate outcomes of the modified L'Episcopo procedure in this population. We hypothesized that the tendon transfer would provide efficient and durable functional improvement in patients with ILER.

Materials and methods

Study design

We performed a retrospective cohort study, collecting prospectively comprehensive preoperative and postoperative data, of all ILER patients who were operated on. All surgical ILER patients were invited to return for clinical, radiographic, and follow-up examination at 6 months, 1 year, 2 years, and yearly. Patients were called back for maximum follow-up and evaluated with minimum 2-year follow-up. The average follow-up was 52 months (range, 24-104 months).

Patient selection

Inclusion criteria included patients who presented with ILER in the context of MIRCT, surgical treatment with a modified L'Episcopo tendon transfer, and minimum 2-year clinical and radiologic follow-up.

We excluded patients with acute post-traumatic posterosuperior cuff tear that could be repaired; patients with massive posterosuperior cuff with conserved AFE and AER who underwent a rotator cuff débridement or partial rotator cuff repair; patients with cuff-deficient shoulder and definitive pseudoparalysis who underwent an RSA; patients with cuff-deficient shoulder and combined loss of active elevation and ER who underwent an RSA in combination with a modified latissimus dorsi (LD) or LD/teres major (TM) transfer[3,4]; patients with loss of *passive* ER related to shoulder stiffness (after fracture sequelae with greater tuberosity migration or adhesive capsulitis); and patients with isolated Tm atrophy (related to neurologic insult, such as traumatic paralysis, compression, or systemic neurologic disorder).[7,8,13,39]

Surgical technique

The procedure was carried out with the patient in the beach chair position under general anesthetic with interscalene block. The arm was draped free. Using a standard deltopectoral approach, the location and irreparability of the cuff tear were confirmed. The coracoacromial ligament was preserved, and no acromioplasty was performed as this could have led to vertical imbalance of the shoulder with anterosuperior escape of the humeral head and secondary pseudoparalysis. The axillary nerve and radial nerves were identified and protected. When present, the biceps tendon was managed with soft tissue tenodesis at the proximal aspect of the bicipital groove.

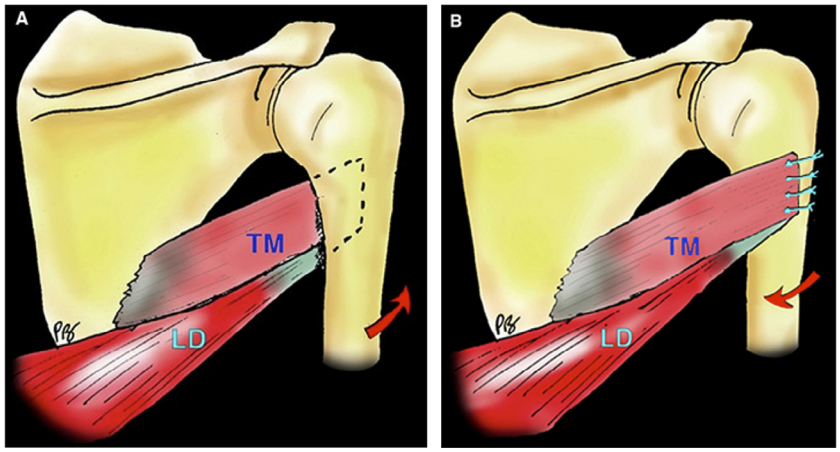

Figure 1 Modified L'Episcopo procedure. Latissimus dorsi (*LD*) and teres major (*TM*) are detached from the anteromedial side of the humerus and transferred on the posterolateral side.

The superior 25%-50% of the pectoralis major tendon was released at its musculotendinous junction, leaving roughly 15-20 mm of tendon attached to the humerus for later pectoralis repair. Both LD and TM tendons (often a conjoint tendon) were detached from the humerus and sutured together. In 5 patients, the tendons were detached with some bone chips. The combined tendons were tagged using 3 or 4 heavy, nonabsorbable sutures with Mason-Allen configuration.

The 2 tendons were released bluntly to gain length while avoiding damage to the neurovascular structures, the most proximate of which is located about 7 cm from the humeral insertion. Inferior adhesions were released under direct vision. When sufficient length was obtained (3-5 cm), a tunnel was bluntly created posterior to the humerus at the level of the tendon insertion. A curved clamp was then passed around the humerus from lateral to medial to retrieve the suture limbs. The LD and TM were rerouted along the posterior aspect of the humerus, with care taken to maintain their native orientation, so that length was maintained and the tendinous portion of the transfer could be applied onto the bone.

With respect to the position of transfer, we advocate tendon transfer to the posterolateral aspect of the humerus (close to the Tm insertion). The goal in this setting is to restore ER and horizontal balance only, and therefore this obviates the need to transfer the tendon to the superior cuff footprint. Indeed, this lower position provides a more direct vector and prevents overtensioning of the tendons.[20]

The tendons were transferred onto the posterolateral aspect of the humeral diaphysis in 22 patients or onto the tuberosity (at the previous insertion site of the Tm) in 4 patients. The transferred tendons were fixed through several drill holes (Fig. 1). The transfer was augmented with additional fixation in the form of a suture anchor or staple in 8 of 26 cases, when deemed necessary. The pectoralis major was then reattached to its anatomic insertion, and the wound was closed in a routine fashion.

Postoperative management

Postoperatively, the shoulder was immobilized in a 30° abduction and 30° ER brace for 4 weeks. After that, the patient began pendulum exercises and passive shoulder elevation and rotation exercises with a physiotherapist. After 12 weeks, the patient began a program of progressive stretching and strengthening in ER. Physiotherapy was continued for 6-12 months postoperatively, depending on the patient's progress.

Clinical assessment

Clinical assessment of rotator cuff function included the *dropping sign*, described by Neer, to assess function of the infraspinatus,[28,35] and both the *drop sign*[31] and the *Hornblower sign*[35] to evaluate the Tm. The postoperative AER in neutral (AER1) and 90° abduction (AER2), active IR (AIR), and AFE were compared with the preoperative values. Negative values for ER indicate an inability to achieve neutral rotation with the arm at the side. The functional results were evaluated using the Constant-Murley score[10] and the Simple Shoulder Value.[15]

The ADLs requiring active external rotation (ADLER) score was used to evaluate the patient's ability to perform ADLs in which AER is required. This scoring system, described by the senior author, is a 30-point scale designed to objectively quantify the handicap of these patients before and after tendon transfer.[3] Preoperative and postoperative interviews were conducted regarding a patient's ability to perform 10 ADLs requiring AER (Table I). Each task had to be performed without abducting the shoulder (ie, performing a Hornblower sign) and without flexing the neck or bending the trunk to reach the hand.[3]

The patients were also questioned about their satisfaction with the outcome of the operation (very satisfied, satisfied, disappointed, or unsatisfied). Postoperative complications were identified, as was the need for revision surgery.

Radiologic assessment

All patients had preoperative and postoperative true anteroposterior and lateral radiographs. The anteroposterior radiographs were used to determine the acromiohumeral distance[29,38] and cuff arthropathy stage using the system of Hamada and Fukuda.[18] Preoperative computed tomography arthrography or magnetic resonance imaging was used to evaluate the extent of the cuff tear, to stage fatty infiltration of the infraspinatus and subscapularis per Goutallier,[16] and to classify the Tm per Melis and Walch.[27]

Table I ADLER score

Activities of daily living requiring active external rotation (ADLER)*	Points
1. Comb hair	/3
2. Shave (men) or apply makeup (women)	/3
3. Dress (ie, put on a shirt or a coat without help	/3
4. Fill a glass with a full bottle (sitting at the table)	/3
5. Drink (bring a full glass to the mouth)	/3
6. 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 typewrite or play the piano)	/3
Total	/30

0 = unable to do; 1 = very difficult to do; 2 = somewhat difficult to do; 3 = not difficult at all.
Reprinted from Boileau P et al.[3]
* All activities should be performed *without* the help of flexing the neck or bending the trunk and *without* the help of first abducting the elbow (ie, without doing a Hornblower sign).

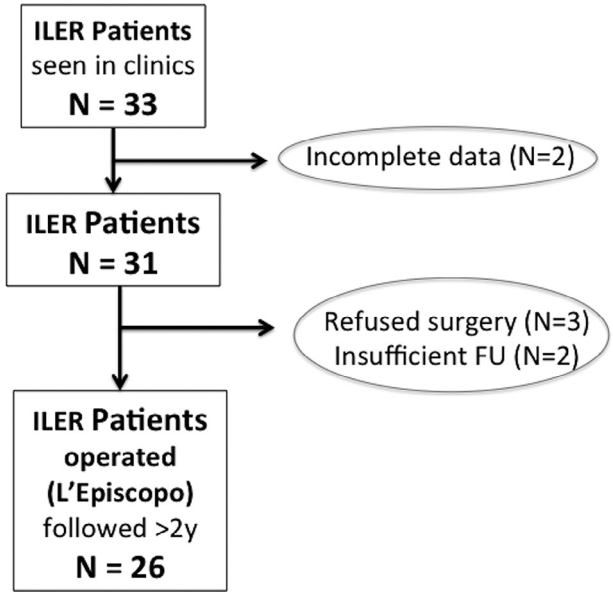

Figure 2 Flow chart. *ILER*, isolated loss of active external rotation; *FU*, follow-up.

Statistical analysis

Wilcoxon paired *t*-test was used for data analysis with the GraphPad InStat for Macintosh software (GraphPad, San Diego, CA, USA). This test was chosen as the data did not follow a normal distribution, and we matched preoperative to postoperative values. A $P < .05$ was considered significant.

Results

Demographics

During a 10-year period (2003-2013), 33 patients were seen in our institution with ILER. Five patients refused to have surgery, and 2 patients had incomplete data. This study included the remaining 26 patients (14 men, 12 women) who underwent modified L'Episcopo transfer (Fig. 2). The average age at the time of surgery was 64.5 years (range, 29-83 years). Twenty-two patients (85%) had surgery performed on the dominant arm. Three patients (11%) had undergone at least 1 previous operation on the affected shoulder, including 1 arthroscopic cuff débridement with biceps tenotomy, 1 attempt at rotator cuff repair, and 1 posterior bone block.

Clinical presentation

Preoperatively, ILER patients complained about severe handicap with ADLs such as drinking, eating, combing hair, shaving or applying makeup, holding a phone, and shaking someone's hand. The preoperative ADLER score averaged 10 points of a maximum 30 points. Patients reported an inability to control spatial positioning of the arm and described symptoms before surgery ranging from 6 to 192 months (average, 28 ± 32 months). All patients had undergone rehabilitation for at least 6 months before surgery.

On preoperative clinical examination, ILER patients had absent or negative AER at either 0° (AER1) or 90° of abduction (AER2), whereas both AFE and AIR were preserved. If the contralateral side was considered to have normal ER, there was an average deficit of 57.4° of ER. All patients presented with posterior shoulder muscle wasting and could not achieve or maintain the arm at neutral with the arm by the side. They all had presence of the ER lag, drop, dropping, and Hornblower signs (Fig. 3).

Anatomopathology

On advanced imaging (computed tomography scan, magnetic resonance imaging) and at surgery, all ILER patients presented with irreparable posterosuperior MIRCT involving supraspinatus, infraspinatus, and Tm (Figs. 4 and 5). The subscapularis was grossly intact in all cases, with 8 patients demonstrating a cleavage-type tear of the upper tendon related to hypertrophy and subluxation of the biceps tendon. According to Goutallier's classification, there was at least grade 3 fatty infiltration in 23 of 26 infraspinatus muscles (87%). According to the classification of Walch, all Tm muscles were either atrophic (21) or absent (4).[27,36] The long head of the biceps, when present, was torn, unstable, or delaminated.

Complications and revisions after tendon transfer

After modified L'Episcopo tendon transfer, there were no neurovascular injuries, fractures, or infections. One patient, who had 2 episodes of traumatic anterior subluxation in the first 6 months after surgery, was treated with reduction and

Figure 3 Typical clinical presentation of a patient with isolated loss of active external rotation (ILER) in the setting of massive irreparable posterosuperior rotator cuff tear. (**A**) Normal active forward elevation and (**B**) normal internal rotation. (**C**) Loss of active external rotation with the arm at the side with dropping sign and (**D**) Hornblower sign; because the patient has no active external rotation, he can reach his head only by cheating with abduction of the arm.

immobilization in a sling. He had a final good result, with a stable shoulder, and was satisfied with the procedure. Another patient had postoperative traumatic shoulder instability 1 year after surgery, with subsequent rupture of the tendon transfer. She was managed with RSA; although this patient had good active elevation, she never regained AER.

Two patients had progression of cuff tear arthropathy with increasing shoulder pain and progressive range of motion limitation. Both patients had preoperative advanced arthropathy (Hamada stage 3 and 4). They were reoperated, respectively, 7 and 9 years after the initial L'Episcopo transfer to add an RSA, with excellent functional and subjective results at final follow-up. The 3 patients revised with RSA were excluded from functional evaluation.

Shoulder function

At a mean follow-up of 52 months, 84% of the patients were satisfied or very satisfied with the procedure (Fig. 6). After modified L'Episcopo transfer, there was statistically significant improvement across all 4 outcomes measures (Table II). The gain in ADLER score was 14.5 points, indicating an ability to perform ADLs. Twenty-six patients had presence of a Hornblower sign preoperatively; 13 patients (50%) had a persistent or recurrent Hornblower sign at most recent follow-up. These patients were still satisfied or very satisfied because they could control the hand in space and could do most of their ADLs.

Shoulder mobility

There was a mean difference of 57.4° of ER1 and 60° of ER2 for each patient compared with the normal side. The gain in AER was 25.8° with the arm by the side (AER1) and 18.5° in abduction (AER2), whereas AFE and AIR remained unchanged at final follow-up. There was a slight improvement in AFE and minimal change for IR at final follow-up (Table III).

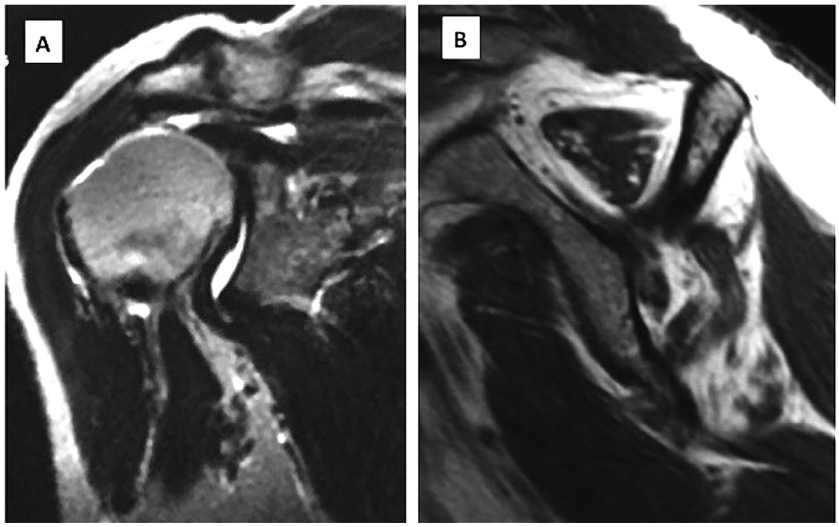

Figure 4 Typical magnetic resonance imaging of an isolated loss of active external rotation (ILER) patient. (**A**) Coronal view demonstrates massive irreparable rotator cuff tear with upward migration of humeral head. (**B**) Lateral oblique sagittal magnetic resonance image demonstrating atrophy and fatty infiltration of the supraspinatus, infraspinatus, and teres minor.

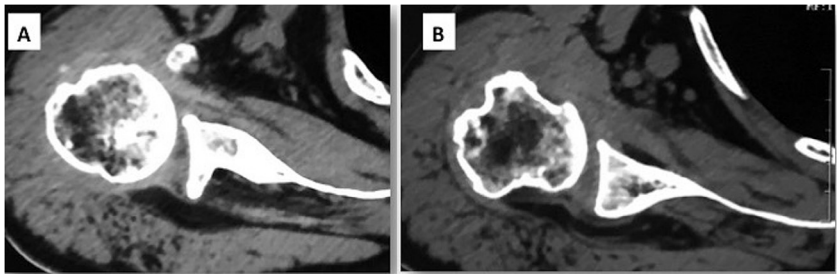

Figure 5 Typical computed tomography scan of an isolated loss of active external rotation (ILER) patient. (**A**) Fatty infiltration stage 4 of the infraspinatus muscle, whereas the subscapularis is intact. (**B**) Complete atrophy of the teres minor.

Radiologic outcomes

There was an increase in the mean Hamada value from 2 to 2.6 at final follow-up (Fig. 7). Ten patients (38%) had worsening of Hamada[18] grade during the study period; 8 patients lost 1 grade and 2 patients lost 2 grades (Table IV).

Discussion

Our study shows, first, that ILER is a distinct clinical, anatomic, and biomechanical entity and, second, that the L'Episcopo procedure does restore AER and shoulder function for these patients.

From a clinical standpoint, ILER patients complain about the impossibility of externally rotating the arm at the side and a *dropping arm*, indicating IR of the forearm when the arm is elevated or abducted, which inhibits use of the hand above the horizontal. Despite the preservation of AFE, these patients are severely handicapped in many ADLs requiring abduction and ER, such as eating, drinking, shaving, applying makeup, combing hair, dressing, writing, or shaking someone's hand. To be able to perform these tasks or to reach the head, they need to hold the forearm with the other hand. In addition to dropping sign (which indicates an irreparable tear of infraspinatus), clinical examination reveals presence of the ER lag and Hornblower signs, which have been shown to be specific to Tm dysfunction.[9,19,36]

From an anatomic standpoint, ILER patients have no more ER cuff muscles on imaging studies and at surgery; supraspinatus and infraspinatus are severely fatty infiltrated, whereas Tm is absent or atrophic. The highly compromised shoulder function in ILER patients is not surprising because the Tm muscle has been shown to be an important ER muscle of the shoulder, contributing up to 20% to 45% of the strength of ER.[36] As shown by clinical and experimental studies, the Tm muscle has little participation in ER at 0° of abduction but does contribute at 90° of abduction in the plane of the scapula.[17,24,27,36] This can explain why, despite preserved active elevation, ILER patients have difficulties in or are unable to accomplish many ADLs that require ER.

From a biomechanical standpoint, ILER patients present with *horizontal muscle imbalance* but conserved vertical muscle balance (ie, conserved active elevation). In this scenario,

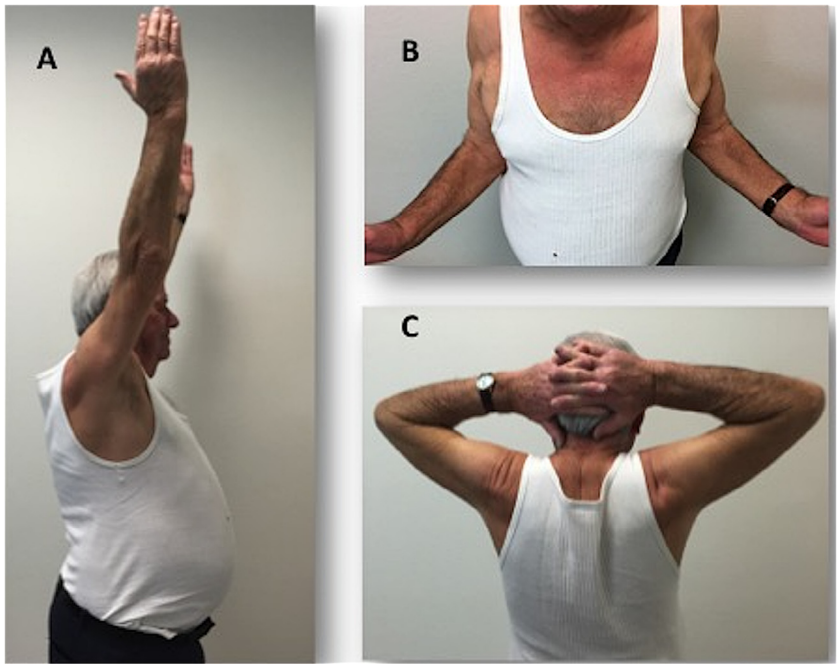

Figure 6 Functional outcomes 10 years after modified L'Episcopo tendon transfer for isolated loss of active external rotation (ILER). (**A**) Active forward elevation is conserved. (**B**) Active external rotation at side (AER1) and (**C**) active external rotation in abduction (AER2) are restored.

Table II Functional outcomes after modified L'Episcopo transfer (mean follow-up, 52 months; range, 24-104) months

Functional outcomes adjusted (23 patients)				
	Preoperative	Final	Change	*P* (WT)
Simple Shoulder Value (%)	36.9 ± 17	70.8 ± 20.1	33.9	<.00001
ADLER (out of 30 points)	10 ± 6.2	24.5 ± 7.3	14.5	.002
Constant (out of 100 points)	49.8 ± 6.5	68.2 ± 12.9	18.4	.0008
Adjusted Constant (%)	63.6 ± 16.2	86.9 ± 14.8	23.3	.0018

ADLER, activities of daily living requiring active external rotation; *WT*, Wilcoxon paired *t*-test.

Table III Range of motion before and after modified L'Episcopo transfer

Active range of motion	Preoperative	Final	Change	***P*** (WT)
AER1 (degrees)	−19.2 ± 9.7	6.6 ± 24.6	+25.8	<.001
AER2 (degrees)	21.5 ± 21.5	40.0 ± 34.2	+18.5	.038
AFE (degrees)	161 ± 29.6	165 ± 26.0	+4.2	.663
AIR (points)	7.6 ± 2.0	7.5 ± 2.4	−0.1	.807

AER1, active external rotation in neutral; *AER2*, active external rotation in 90° abduction; *AFE*, active forward elevation; *AIR*, active internal rotation; *WT*, Wilcoxon paired *t*-test.

the actions of the 4 internal rotators (subscapularis, pectoralis major, LD, and TM) dominate the absent or nonfunctional external rotator muscles (infraspinatus and Tm) (Fig. 8).[3,4] Similar to when a horse with only 1 checkrein turns in circles and cannot go straight, a shoulder with 4 internal rotator muscles and *no* external rotator muscle is "turning in circles." Realizing that ILER patients have kept their 4 IR muscles but have lost their 2 ER muscles is helpful in understanding why these patients have difficulties in using the hand for most common ADLs. Because the weight of the forearm cannot be counteracted on attempting abduction or flexion, ILER patients have difficulties in use of the hand above the horizontal level. As shown by Walch et al,[27,35,36] the Tm is a key muscle to preserve the horizontal balance of the shoulder; in patients with massive rotator cuff tears in whom it is intact or hypertrophic, this muscle can give useful function for ADLs.

The concept of glenohumeral force couples, which emphasizes the existence of vertical and horizontal muscle

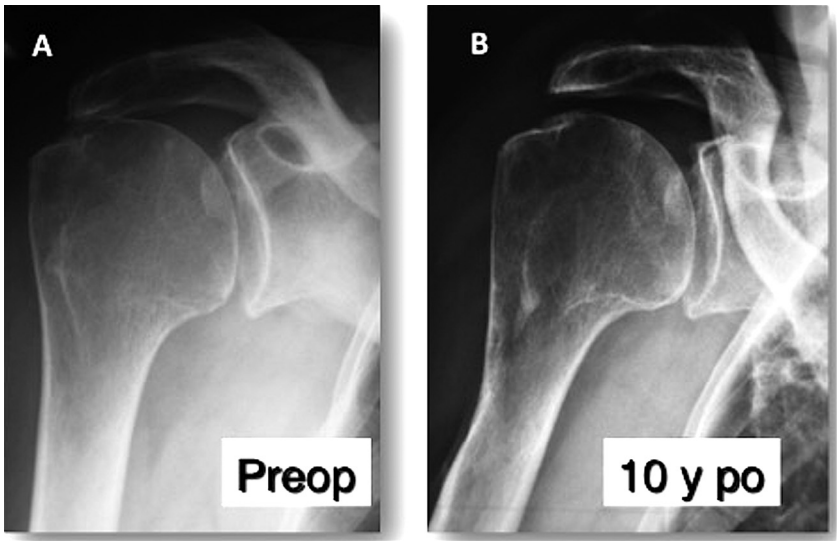

Figure 7 Radiographic evolution 10 years after modified L'Episcopo tendon transfer (same patient as in Fig. 6). (**A**) Preoperative cuff tear arthritis Hamada stage 2. (**B**) Anteroposterior radiograph taken 10 years after surgery does not demonstrate major change. Notice the footprint of the LD/TM transfer on the lateral aspect of the humerus.

Table IV Preoperative and postoperative staging of cuff tear arthropathy according to Hamada and Fukuda

Staging of cuff tear arthropathy	Preoperative	Final
Hamada 1	2	0
Hamada 2	18	13
Hamada 3	5	11
Hamada 4	1	2

See Hamada K et al[18] for more information about the classifications in this table.

balance, is helpful to understand the possible impairments in patients with MIRCTs and to propose a surgical treatment (Table V).[4,6] To be functional, a shoulder needs to present both a good vertical muscle balance (between the deltoid and the rotator cuff muscles) and a good horizontal balance (between IR and ER muscles). Many patients with MIRCTs, hopefully, conserve a good vertical and horizontal muscle balance and therefore a *functional shoulder.* They complain of painful loss of active elevation (group 1-PLEA). By contrast, some other patients with MIRCTs may lose one or both shoulder muscle balances and present with a *nonfunctional shoulder*. In some cuff-deficient shoulders, patients present with isolated loss of active elevation but have preserved AER (group 2-ILEA); they present with shoulder pseudoparalysis (ie, vertical muscle imbalance). As mentioned before, ILER patients present with definitive loss of horizontal muscle balance (group 3-ILER). Finally, some other patients may lose both AFE and AER (ie, vertical and horizontal muscle imbalance).[3-5] These patients present with a combined loss of active elevation and ER (group 4-CLEER).

L'Episcopo tendon transfer was initially described as a treatment option for children with loss of ER secondary to brachial plexus palsy.[25,26] This series confirms our hypothesis: the modified L'Episcopo procedure, performed through a single deltopectoral approach, provides efficient and durable functional improvement in patients with ILER. As shown by our study, the modified tendon transfer is a safe alternative to the traditional double-incision technique.[26,34] At a mean follow-up of 52 months, 84% of the patients were satisfied or very satisfied with the procedure. In all cases, the LD/TM tendon transfer was effective in restoring some *horizontal balance* and providing enough strength in ER to counterbalance the weight of the forearm. Although the gain in ER was modest (+26° in ER1 and +18° in ER2), patient satisfaction remained high over time, with a low rate of reoperation. Even patients with persistent Hornblower sign after the tendon transfer were pleased with the results because they were at least able to control the positioning of the hand in space and to perform their ADLs. It is our interpretation that in these patients, the main benefit of L'Episcopo tendon transfer is a "tenodesis effect," which prevents the dropping arm and restores the patient's ability to perform most ADLs. The question then arises as to whether a single tendon transfer, using LD only, would be sufficient and as effective as the double tendon transfer. Because there is no series of ILER patients treated with LD transfer in the literature to allow us to answer this question, further studies will be needed.[11,21,37]

The development of cuff tear arthropathy is characterized by upward migration of the humeral head and progressive joint degeneration.[1,12,28,32,38] The radiographic examinations of our ILER patients revealed some progression of the cuff arthropathy after tendon transfer over time. Two patients with preoperative advanced cuff tear arthropathy (Hamada grade 3) required reoperation to perform an RSA (7 and 9 years after the tendon transfer, respectively) because of progressive glenohumeral joint degradation (Fig. 9). Based on these observations, we now evaluate even more carefully the preoperative radiographs for more accurate staging of the cuff tear arthropathy according to Hamada and Fukuda.[18] We ask

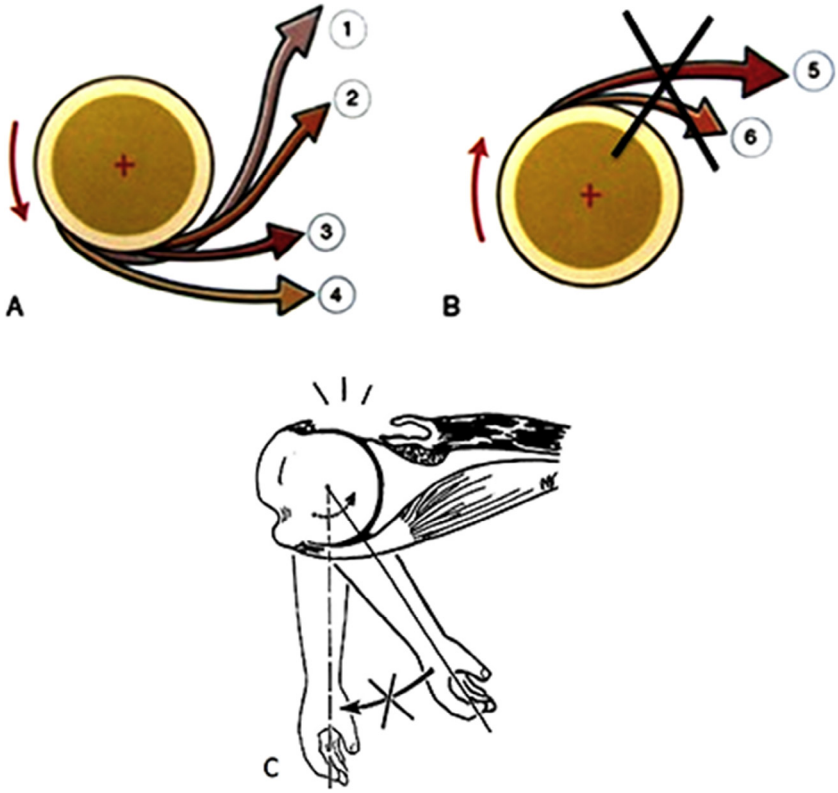

Figure 8 Horizontal muscle imbalance of the shoulder in isolated loss of active external rotation (ILER) patients. (**A**) The 4 powerful internal rotator muscles are still present: *1*, latissimus dorsi; *2*, teres major; *3*, subscapularis; and *4*, pectoralis major. (**B**) The two external rotator muscles (*5*, infraspinatus; *6*, teres minor) are lost (absent or atrophic). (**C**) Active external rotation is definitively lost with the arm at the side and in abduction because there is no other muscle to provide active external rotation.

Table V Classification of massive irreparable rotator cuff tears based on shoulder muscle imbalance and possible surgical treatment options

Clinical presentation	Muscle balance	Surgical treatment options
Group 1-PLEA (painful loss of active elevation)	Conserved muscle balance (painful/weak shoulder)	Biceps tenotomy/tenodesis ± partial cuff repair L'Episcopo transfer (or LD transfer)
Group 2-ILEA (isolated loss of active elevation or pseudoparalyzed shoulder)	Definitive loss of vertical muscle balance	Reverse shoulder arthroplasty
Group 3-ILER (isolated loss of external rotation)	Definitive loss of horizontal muscle balance	L'Episcopo transfer (or LD transfer)
Group 4-CLEER (combined loss of active elevation and external rotation)	Definitive loss of vertical and horizontal muscle balances	Reverse shoulder arthroplasty + L'Episcopo transfer (or LD transfer)

LD, latissimus dorsi.
See Boileau et al[4] for more information about the muscle imbalance groups in this table.

for anteroposterior views in 3 rotations because decreased acromiohumeral distance may depend on the rotation and vary.[30,38] In ILER patients with late-stage arthropathy (Hamada stage 3 or above), we now prefer combining an RSA with the tendon transfer.[3,5]

The exact etiology of the atrophy of Tm in the context of MIRCTs remains unclear. Some branches of the axillary nerve mainly innervate the Tm. One theory is that upward migration of the humeral head in massive cuff tears causes a traction injury of the axillary nerve branches to the Tm.[37] Another explanation, given by Friend et al,[13] highlights the variations of the anatomy of the nerve to the Tm; individuals with a significantly longer final nerve to Tm (ie, early branching or bifurcation) may be more vulnerable to compression or entrapment, thereby accounting for Tm atrophy in the absence of concurrent deltoid disease. An anatomic study by Chafik et al has suggested that a fascial sling, present in all specimens, could be a potential site of tethering or compression

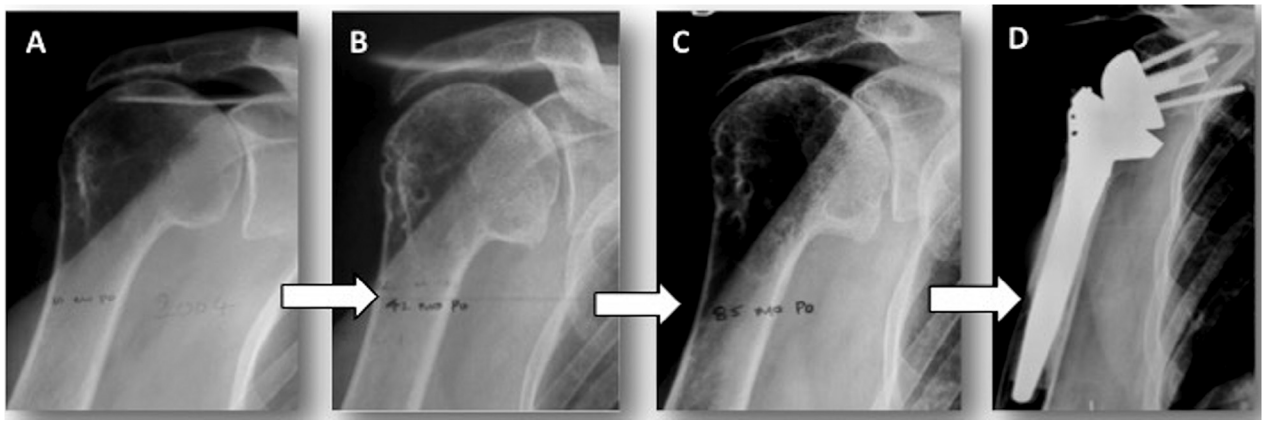

Figure 9 An example of progressive deterioration of the clinical and radiologic results 7 years after L'Episcopo transfer. (**A**) Preoperative radiograph demonstrates some acetabulization of the acromial arch and some glenohumeral joint narrowing (Hamada grade 4). (**B** and **C**) Postoperative radiographs show progressive deterioration of the glenohumeral joint. (**D**) Seven years after the tendon transfer, the patient was reoperated on for implantation of a reverse shoulder prosthesis and had a good functional result.

of the nerve to the Tm.[8] Finally, associated cervical spine disease, frequently encountered in our patients, could explain some Tm atrophies without tendon detachment.[33]

The main limitation of this study is the small size of the patient cohort. However, ILER is a rare clinical entity—in the busy shoulder practice of the senior author (600-700 shoulder operations per year), only 3 to 5 ILER patients per year are seen. The study has some strengths. We were able to achieve midterm and long-term clinical and radiographic follow-up for all patients, and more important, patients were objectively evaluated preoperatively and postoperatively with the ADLER score, a specific score quantifying their ADLs requiring AER.

Conclusion

ILER is a distinct clinical, anatomic, and biomechanical entity, representing a subgroup of patients with massive posterosuperior cuff tears involving supraspinatus, infraspinatus, and significant Tm dysfunction. Despite preserved active elevation, ILER patients have difficulties in or are unable to accomplish many ADLs that require ER and are severely handicapped because of loss of spatial control of the upper limb. Horizontal muscle imbalance (4 IR muscles vs. 0 ER muscles) in this subgroup of patients leads to significant loss of AER with the arm at the side and in abduction. In properly selected cases (Hamada stage 1 or 2), a modified L'Episcopo transfer allows re-establishment of the lost horizontal muscle balance of the shoulder (2 IR muscles vs. 2 ER muscles), resulting in improved AER and restoration of shoulder function. In more advanced cuff tear arthropathy (Hamada stage 3 or above), the tendon transfer should be performed in combination with an RSA because of possible secondary degradation of the glenohumeral joint.

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