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Massive irreparable rotator cuff tears

Treatment options, indications, and role of fully arthroscopic latissimus dorsi transfer

The management of massive irreparable cuff tears remains a challenge, especially in young and active patients [1]. When Gerber et al. [2] published their landmark paper in 1988 reporting the outcome of latissimus dorsi (LD) transfer for massive irreparable cuff tear, they reproduced Hoffer's procedure described in 1975 to restore active external rotation (ER) in Erb's palsy [3]. However, patients with Erb's palsy and those with massive irreparable rotator cuff tear are two very different groups. Erb's palsy concerns a pediatric population with neurologic palsy, contracture in internal rotation (IR), and glenohumeral (GH) joint deformation with posterior dislocation of the shoulder. On the other hand, massive irreparable posterosuperior cuff tear concerns an adult population without any neurologic palsy (but tendon rupture), stiffness, or dislocation of the joint. Therefore, different results can stem from the same technique when proposed for two different pathologies or groups of patients. The results of the Gerber technique are still debatable regarding indications, techniques, and results [4]. Patient selection plays an important part in the success of LD transfer. Associated subscapularis tear, anterior deltoid deficit, proximal migration of the humeral head, poor preoperative function of the shoulder, and osteoarthritis are considered contraindications to this procedure. The purpose of this paper is to point out that LD transfer

1. can be proposed for other indications rather than for the sole restoration of active ER,
2. can be performed entirely arthroscopically, and
3. can be combined with a reverse shoulder arthroplasty.

General considerations

Background

If you wish to converse with me, define your terms! (Voltaire, 1674–1778)

Massive cuff tear is not synonymous with irreparable cuff tear, which is different from pseudoparalytic shoulder.

Massive cuff tear was defined by Cofield et al. [5] as a lesion with a diameter >5 cm, whereas Gerber et al. defined it as the involvement of a minimum of two tendons [6]. Experience has shown that a massive cuff tear can be reduced and repaired [7].

Irreparable tears can be defined in terms of retraction [8], fatty infiltration [9], and atrophy of the muscle belly [10]. Superior escape of the humeral head with a subacromial distance <6 mm [11], Hamada stage 3 with acetabulisation of the acromion [12], general risk factors (smoking, cholesterol, hypertension, diabetes, obesity, cardiovascular, apnea; [13]), and failed previous cuff repair are considered as negative prognostic factors for rotator cuff healing.

Pseudoparalytic shoulder was redefined by Burks et al. [14] as the association of a normal passive range of motion (no stiffness) with no active forward flexion (FF; <45°). We would add limited active ER and/or IR. A massive cuff tear is not systematically associated with pseudoparalysis, as the deltoid is strong enough to compensate for the cuff tear; thanks to an intact inferior part of the subscapularis ("subscapularis minor") and/or an intact teres minor (Tm), a patient can have active forward elevation [15].

In conclusion, whatever the anatomic status of the rotator cuff, some patients have a functional shoulder with a—quite—normal active range of motion (ROM). On the other hand, others have a non-functional shoulder as they have lost active ROM in one (or more) direction: FF, ER, and/or IR.

Why does a functional shoulder become non-functional?

Burkhart et al. [16] defined the balance of the shoulder in the horizontal plane.

In the vertical plane, the supraspinatus (SS) counterbalances the deltoid to allow elevation of the shoulder. In case of a weak SS, superior escape of the shoulder can be observed and the acromiohumeral distance decreases. Boileau et al. [17] defined this situation as isolated loss of elevation (active) or ILEA. The patient has lost active elevation, but still has ac-

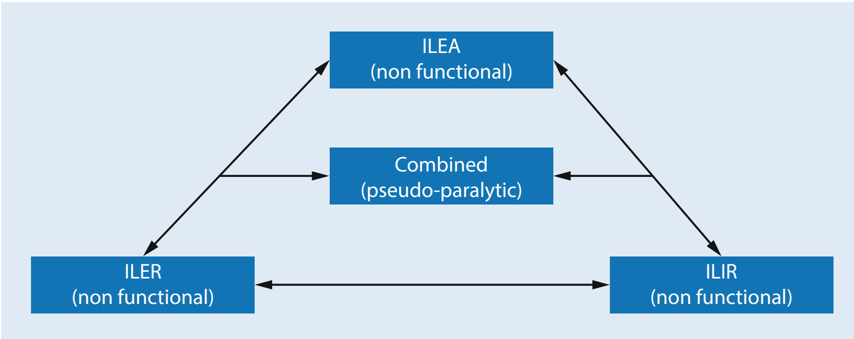

Fig. 1 ▲ The three patterns of irreparable cuff tear: isolated loss of elevation active (*ILEA*), isolated loss of external rotation (*ILER*), and isolated loss of internal rotation (*ILIR*) can each lead to a non-functional shoulder, i.e., to the inability to achieve active elevation, external rotation, or internal rotation. Combination of two of these patterns could lead to a real pseudoparalytic shoulder (combined loss of elevation and external rotation, combined loss of elevation and internal rotation, or both)

tive external rotation. This is the *vertical imbalance* of the shoulder.

In the horizontal plane, the external rotators (infraspinatus, IS; Tm) counterbalance the internal rotators (subscapularis, Sscp; pectoralis major, PM; LD; teres major, TM). In case of a weak IS and/or Tm, there is a lack of active external rotation either in ER1 (external rotation with the elbow at the side) or ER2 (external rotation with the shoulder at 90° of abduction). Boileau et al. [17, 18] defined this situation as isolated loss of external rotation (active) or ILER. The patient is able to elevate the arm but unable to achieve (active) ER. This is the *horizontal imbalance* of the shoulder.

In cases of massive posterosuperior rotator cuff tear with both vertical and horizontal imbalance of the shoulder, the following is observed: weak SS, IS, and Tm. Boileau et al. [17] defined this situation as the combined loss of elevation and external rotation (CLEER). These patients have a combined deficit in (active) FF and (active) ER. Collin et al. [19] showed that this situation (type "D" in their classification) could lead to posterosuperior escape and 33% pseudoparalytic shoulder.

In our own experience, two additional situations need to be defined in case of Sscp deficiency. The Sscp itself represents 50% of the power of the rotator cuff [20, 21].

In case of a massive Sscp tear, horizontal imbalance of the shoulder can also be observed. However, this time it is the weak (active) IR that cannot counterbalance the strong external rotators. The patient is unable to reach his belt or his belly with his hand. We define this situation as isolated loss of internal rotation (ILIR).

In case of a combined lesion of the Sscp and SS, there is a combined loss of elevation and internal rotation (CLEIR). Collin et al. [19] showed that this situation (type "B" in their classification) could lead to anterosuperior escape and 80% pseudoparalytic shoulder.

To sum up, the three patterns of irreparable cuff tear (ILEA/ILER/ILIR) can each lead to a non-functional shoulder, i.e., to the inability to achieve active FF, ER, or IR. The combination of two of these patterns could lead to a real pseudoparalytic shoulder (CLEER, CLEIR, or both; **Fig. 1**).

Correction of vertical imbalance

Two different levels of ILEA must be considered. In the first situation, the patient is able to elevate his arm, but this movement is very painful at around 90° of elevation. He must help this elevation with the contralateral arm to cut the pain. At 170° of elevation, the patient is able to maintain the position, but it will it become very painful again at 90° of elevation when the arm is descending. Boileau et al. call this situation the painful loss of active elevation (PLAE; [16]). This situation can be considered as an isolated loss of elevation active "type 1" (ILEA type 1). In the second situation (which is the evolution of the previous situation), the patient is not able to elevate his shoulder because of both the pain and the weakness of his shoulder. Boileau et al. call this situation the isolated loss of elevation active (ILEA; [16]). This second situation can be considered as an isolated loss of elevation active "type 2" (ILEA type 2). In both situations (ILEA types 1 and 2), the patient preserves some (active) ER and IR.

Treatment of ILEA type 1

To replace the irreversibly lost posterosuperior contractile elements, LD muscle–tendon transfer can be performed, providing good results. Associated irreparable subscapularis tear, deltoid palsy, and associated arthritis are contraindications to LD transfer. Several authors have investigated different techniques for performing the LD muscle–tendon transfer in open surgery, reporting variable results (single or double incision, LD augmentation with patch, or harvested along with a small piece of bone; [4]). Many techniques have been published to improve the results with a stronger humeral head fixation [22] or an LD tendon augmentation [23]. Recently, techniques for arthroscopy-assisted LD muscle–tendon transfer [24, 25] have been described, with the advantages of better visualization of the neighboring neurovascular structures at risk (radial nerve, axillary nerve), no damage to deltoid muscle, and the ability to address a reparable associated subscapularis tear or long head of biceps tendon (LHB) pathology. We developed [26] a bone tunnel technique for three main reasons: first, we have shown that it is the strongest biomechanical fixation onto the humeral head; second, this technique allows a very precise transfer fixation zone beyond the center of rotation of the joint (i.e., "over-the-top"), aiming for a passive and active depressor transfer action in combination with the forward flexion; third, the physiological tension of the transfer can be perfectly adjusted. Thanks to metallic markers placed intraoperatively at regular intervals into the transferred tendon, we showed an early-ruptured tendon rate of 38% (3 months postoperatively), mainly at the junction between the bone and the tendon due to a "guillotine" effect, the so-called killer turn [27]. Therefore, we decided to conduct a prospective study to analyze the rate and modes of failure of LD transfer with three different types of fixation. Within a 4-year period (2014–2017), we performed consecutive LD transfers either for irreparable posteriosuperior rotator cuff tears or failed prior repair (ILEA type 1). All the LD transfers were performed by a single surgeon and were arthroscopically assisted and fixed as follows: a tubularized LD tendon fixed into a bone tunnel drilled inside the humeral head (group 1), a tubularized LD tendon fixed with three anchors "over the top" (group 2), and a "flat" tendon fixed with two Krakow sutures and two anchors onto a more posterior location at the junction between the supra- and the infraspinatus (group 3; ◘ Fig. 2a–c). Three metallic markers were systematically placed intraoperatively in the tendon at a fixed distance of 2, 4, and 6 cm from the tip of the tendon. Immediate postoperative standard anteroposterior radiographs were obtained and the position of the markers was compared with their position on radiographs obtained 6 weeks, 3 months, and 24 months postoperatively. We compared the rate of LD transfer rupture with these three types of fixation and were able to analyze the level of the tear in each group thanks to the markers. Constant score, subjective shoulder value (SSV), simple shoulder test (SST), activities of daily living requiring active external rotation (ADLER), visual analog scale (VAS), American Shoulder and Elbow Surgeons score (ASES), and patients' subjective satisfaction (assessed by self-report questionnaires) at last follow-up were compared between the three groups. Included were 152 patients with a mean age of 62.5 years (range 46–83 years) who underwent arthroscopically assisted LD transfer for ILEA type 1, 59 in group A (the "bone tunnel"), 47 in group B (the "over the top"), and 46 patients in group C (the "more posterior fixation without tension").

At a mean of 12 months (range 2–38 months) of follow-up, there were 22 LD ruptures (38%) in group A (66% ruptures at the bone–tendon interface), 13 LD ruptures (27%) in group B (50% ruptures at the muscle belly–tendon interface), and 6 LD ruptures (12%) in group C (100% ruptures at the suture–anchors interface; <0.001; ◘ Table 1).

The six scores and patient satisfaction were all significantly lower for patients who had a ruptured transfer versus those who had an intact transfer: Constant score 42.8 versus 68.7 ($p = 0.001$), SSV 48.9 versus 71.6 ($p = 0.001$), SST 4.8 versus 8.4 ($p = 0.012$), ADLER 19.7 versus 26.7 ($p = 0.005$), VAS 3.7 versus 2.3 ($p = 0.082$), ASES 55.4 versus 74.8 ($p = 0.056$), and 13% versus 78% satisfied or very satisfied patients ($p < 0.001$), respectively [27].

Our study shows that a more posterior fixation onto the supra- and infraspinatus junction in a tension-free manner seems to give better results. With this type of

Abstract · Zusammenfassung

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Abstract

Management of massive irreparable posterosuperior rotator cuff tears is a surgical challenge, particularly in young active patients without any signs of osteoarthritis. Different surgical techniques have been described. To the three main deficits of active range of motion previously reported for a massive irreparable cuff tear, i.e., isolated loss of active elevation (ILEA), isolated loss of active external rotation (ILER), and combined loss of elevation and external rotation (CLEER), we add two new entities: isolated loss of active internal rotation (ILIR) and combined loss of active elevation and active internal rotation (CLEIR). We suggest that a combined deficit (CLEER or CLEIR) could lead to a new definition of a pseudoparalytic shoulder and propose a novel algorithm to redefine the role of latissimus dorsi transfer in each of these situations. We also describe a fully arthroscopic latissimus dorsi transfer technique that prevents any deltoid muscle insult, offers better visualization of the neighboring neurovascular structures at risk, and allows simultaneous management of biceps pathology and partial rotator cuff repair.

Keywords

Tendons · Arthroscopy · Pseudoparalytic · Muscles · Shoulder

Massive irreparable Rotatorenmanschettenrupturen. Behandlungsoptionen, Indikationen und Bedeutung des vollständig arthroskopischen Latissimus-dorsi-Transfers

Zusammenfassung

Die Behandlung massiver irreparabler posterosuperiorer Rotatorenmanschettenrupturen stellt eine operative Herausforderung dar, insbesondere bei jungen aktiven Patienten ohne Anzeichen einer Arthrose. Verschiedene Operationstechniken wurden beschrieben. Zu den bisher beschriebenen 3 Hauptdefiziten des aktiven Bewegungsumfangs („range of motion") bei einer massiven irreparablen Rotatorenmanschettenruptur, d. h. isolierter Verlust der aktiven Armhebung (ILEA), isolierter Verlust der aktiven Außenrotation (ILER) und kombinierter Verlust der Armhebung und Außenrotation (CLEER), fügen die Autoren 2 neue Entitäten hinzu: isolierter Verlust der aktiven Innenrotation (ILIR) und kombinierter Verlust der aktiven Armhebung und aktiven Innenrotation (CLEIR). Ein kombiniertes Defizit (CLEER oder CLEIR) könnte zu einer neuen Definition der pseudoparalytischen Schulter führen. Die Autoren schlagen einen neuen Algorithmus vor, um die Rolle des Latissimus-dorsi-Transfers in diesen Situationen neu zu definieren. Auch wird die Technik eines vollständig arthroskopischen Latissimus-dorsi-Transfers beschrieben, der Verletzungen des M. deltoideus verhindert, eine bessere Visualisierung gefährdeter benachbarter neurovaskulärer Strukturen bietet und die gleichzeitige Behandlung von Bizepspathologien sowie die Rekonstruktion von Teilrupturen der Rotatorenmanschette erlaubt.

Schlüsselwörter

Sehnen · Arthroskopie · Pseudoparalytisch · Muskeln · Schulter

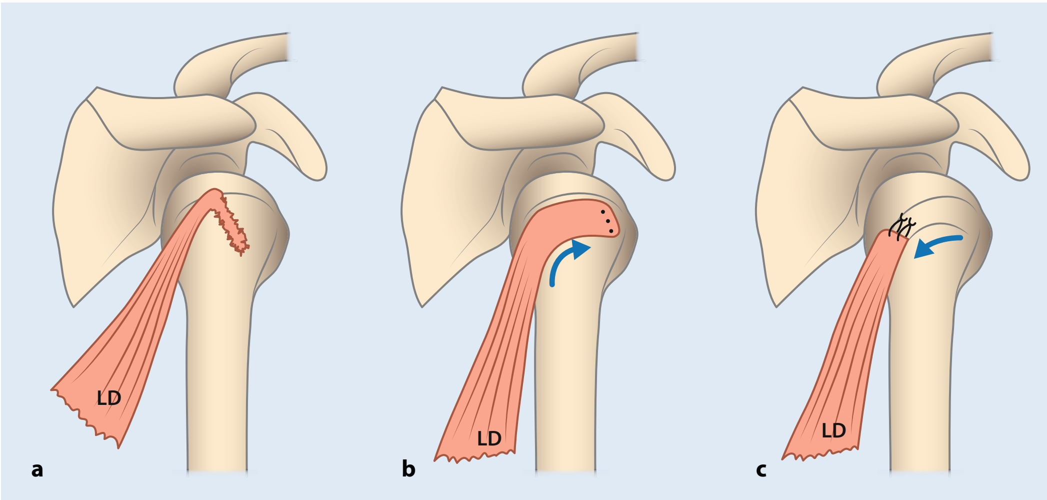

Fig. 2 ◀ **a** Group A with tubularization and tunnel. **b** Group B "over the top" (*blue arrow*) . **c** Group C footprint infraspinatus. *Blue arrow* indicates a more posterior LD transfer fixation to decrease the tension. *LD* latissimus dorsi

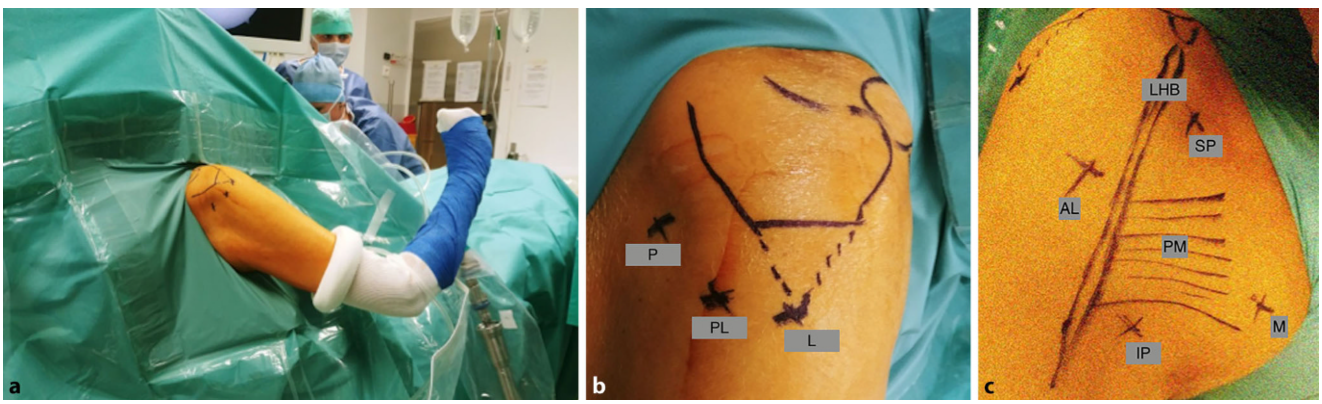

Fig. 3 ▲ **a**, **b**, **c** (right shoulder): in the beach chair position with the arm in a pneumatic arm holder (Spider, Smith & Nephew, London and Hull, UK), the following portals are used for arthroscopic latissimus dorsi tendon harvesting: the posterior (*P*), posterolateral (*PL*), lateral (*L*), anterolateral (*AL*), anterosuperior or suprapectoral (*SP*), infrapectoral (*IS*), and medial (*M*) portals. *LHB* lon head of the biceps, *PM* pectoralis major

fixation, the LD transfer can efficiently treat ILEA type 1. Consequently, we have decided to stop tubularization and bone tunnel fixation, and decided that a "flat" tendon fixation onto the footprint of the infraspinatus should be much preferred to the former technique.

Fully arthroscopic LD transfer technique

Under general anesthesia supplemented by local nerve block for better postoperative analgesia, in the beach chair position with the arm in a pneumatic arm holder (Spider, Smith & Nephew, London and Hull, UK), the following portals are used for arthroscopic LD tendon harvesting: the posterior (P), anterosuperior (AS), posterolateral (PL), anterolateral (AL) and suprapectoral (SP) portals (**Fig. 3**).

General arthroscopic examination is performed to assess the GH joint, address reparable subscapularis tears, and to manage biceps pathology. No subacromial decompression is performed to prevent postoperative superior escape of the shoulder. The arthroscope is switched to the PL portal to release the posterosuperior cuff and to additionally prepare a partial cuff repair, if possible. The dissection progresses posteriorly using a radiofrequency probe (VAPR Mitek Sports Medicine, DePuy Synthes Companies, Zuchwil, Switzerland) after identification of the spine of the scapula by the fat around it. The dissection continues in an inferomedial direction between the deltoid posteriorly and the remnant IS and Tm anteriorly. Visualization of the vertical fibers of the long head of triceps (LHT) is performed, taking care not to injure the axillary nerve crossing through the quadrilateral space (**Fig. 4**). After full adequate dissection, a shuttle-relay is introduced and insufflated from the posterior portal medially from the LHT.

The scope is switched to the AS portal, following the LHB tendon in its groove to reach the (vertical) upper border of the PM and the conjoint tendon. The "three sisters" (circumflex vessels) are identified, marking the inferior border of the Sscp tendon (**Fig. 5**). Through the SP portal, a 2 cm upper PM release is performed to allow visualization of the LD. Care is taken to avoid any injury to the (vertical) axillary nerve, the "three sisters," and the (horizontal) radial nerve, which is found medially at the deep surface of the conjoint tendon and crossing the superficial surface of the LD and TM

Table 1 Comparison between groups A (tubularization + tunnel), B (over the top), and C (footprint IS)

	Group A	Group B	Group C
Mode of fixation	Tubularization + tunnel	Over the top	Footprint IS
Patients (*n*)	59	47	46
Ruptured LD (%, *n*)	38, 22	27, 13	12, 6
Rupture zone	Bone/tendon (2/3)	Muscle/tendon (1/2)	Anchors

LD latissimus dorsi; *IS* infraspinatus

tendon 4 cm medial to their humeral insertion (◘ Fig. 6).

The dissection is continued as far as possible, releasing all connections of the LD to the LHT (intermuscular septum) and TM to facilitate passage of the transfer (◘ Fig. 7a). Blunt scissors may also be used for this step (◘ Fig. 7b). It is also advisable to use switching sticks to aid in retraction of the PM and conjoint muscle to help create a working space, while the arm is in forward flexion and IR. The two edges of the LD tendon are arthroscopically whip-stitched along their medial and lateral border with different colored sutures (Sutureloop, VIMS, Saint-Jory, France) with a Krakow technique (◘ Fig. 8). The LD insertion is then released from the humerus at the crest of the lesser tubercle.

The sutures are then shuttled and retrieved from the posterior portal through the triangular space (◘ Fig. 8a). Sutures are kept under tension by clamping above the posterior portal.

The final step is arthroscopic LD fixation at the junction between the footprint of the SS and the IS. The two pairs of sutures, green and blue, are retrieved with the scope in the AS portal. The LD excursion is checked to prevent over-tensioning, which could create subsequent tendon rupture. Thanks to a cannula, the LD is fixed with appropriate tension after preparation of the footprint using two knottless anchors (Versalock, Mitek, Raynham, MA, USA; ◘ Fig. 9). Care is taken to avoid any twisting of the transfer or impingement under the deltoid due to insufficient posterior release.

Postoperative rehabilitation & follow-up. The arm is immobilized using an abduction pillow in neutral rotation for 6 weeks. Self-assisted passive exercises in the supine position are started after 3 weeks. After 6 weeks, the patient begins slow active rehabilitation. The first goal is to restore passive flexion and gentle water exercises are recommended. After 3 months, slow strengthening exercises are started. Electromyography (EMG) is systematically performed at 12 months postoperatively to control whether the transferred tendon is active (or dynamic) or not (sole tenodesis effect).

Complications and risks. This is a demanding procedure and experimentation in the anatomy laboratory with cadavers is mandatory. High risks can be considered, such as radial and/or axillary nerve lesion. We report one case of transitory radial nerve palsy. Nevertheless, these complications are not more frequent than after the open or arthroscopically assisted technique. Making a large passageway to obtain appropriate unobstructed excursion for the transfer, release of the LD from the TM, and harvesting the LD tendon with two Krakow sutures are the three most demanding steps of the procedure.

Treatment of ILEA type 2

No tendon transfer is strong enough to compensate a total loss of active elevation. Plagenoef et al. [28] and de Leva et al. [29] showed that the upper limb length is 40% of the body height and the upper limb weight is 5.7% of the body weight. In order for the shoulder to perform elevation, the humeral head needs to be centered in front of the glenoid vault. This is made possible by the contraction of the rotator cuff muscles around the shoulder. Therefore, these need to be strong enough to allow dynamic centering of the humeral head. In this situation, only modification of the center of rotation of the joint by a reverse shoulder arthroplasty can recreate elevation. This leads to medialization of the center of rotation and increases the torque of the deltoid to allow active elevation.

Alternatives to LD transfer in ILEA

Tenotomy of the LHB has been proposed [30] but is not an option if already performed with persistence of symptoms. Partial repair can be another option [31]. This can be combined with LD transfer as a dynamic, biologic, and augmentation patch [32]. Superior capsular reconstruction has been published in such an indication; however, in their study, Mihata et al. [33] reported the results of patients with a mean preoperative active elevation of 84°. This differs from our definition of a pseudoparalytic shoulder. Implantation of a subacromial spacer [34] has also been proposed, but neither long-term follow-up nor dynamic effects have been reported to date.

Correction of horizontal imbalance of the shoulder

Both deficit in external and in internal rotation (ILER and ILIR) have to be treated separately.

Restoration of (active) external rotation (ILER)

The first option was described by L'Episcopo (1934), with a double transfer (LD and TM) around the humerus to restore external rotation through a double anterior and posterior approach [35]. Boileau et al. [36] modified the L'Episcopo technique by a single anterior approach and reinserted both the LD and TM onto the posterior surface of the humerus at the level of their anatomic insertion. We proposed a second option to get a stronger tendon fixation by fixing the tendon through a bone tunnel but more posteriorly than for ILEA type 1, behind the center of rotation of the humeral head (HH) (at the IS footprint), looking for a (real) active external rotation transfer. We reported restoration of 12–15° active ER1 only [37]. Biomechanical and anatomical studies [38, 39] showed that lower trapezius transfer could be more efficient

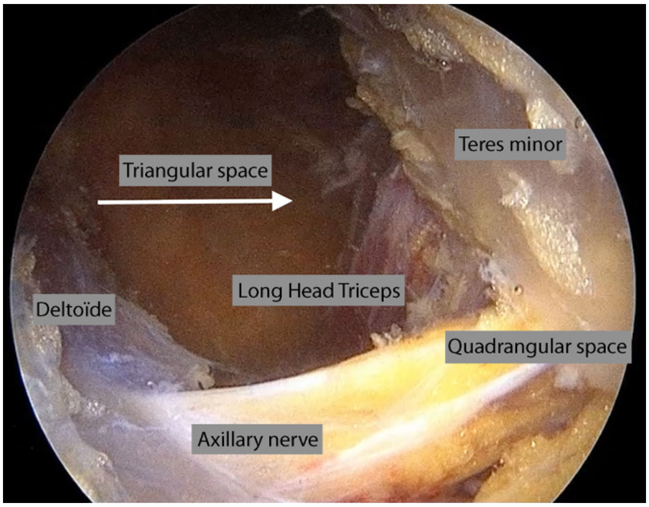

Fig. 4 ▲ Posterior dissection (right shoulder). Visualization of the vertical fibers of the long head of triceps is achieved, taking care not to injure the axillary nerve crossing through the quadrilateral space. *White arrow* route for the transfer

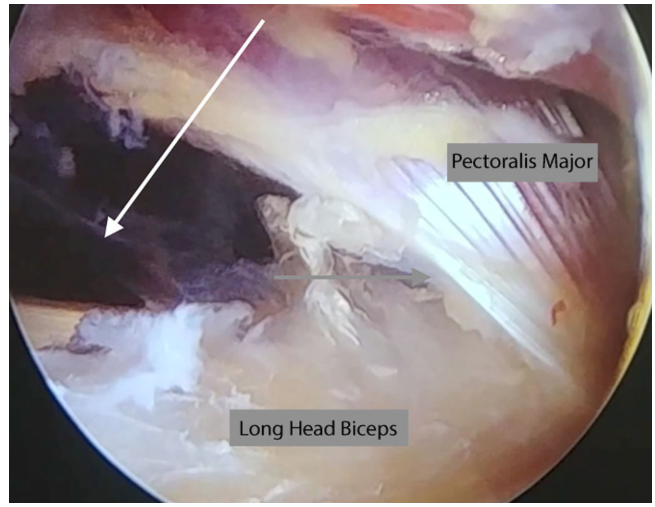

Fig. 5 ▲ Right shoulder: the scope is switched to the anterosuperior portal following the long head of biceps tendon in its groove to reach the (vertical) upper border of the pectoralis major and the conjoint tendon. The "three sisters" (circumflex vessels) are identified, marking the inferior border of the subscapularis tendon. *White arrow* route for the transfer

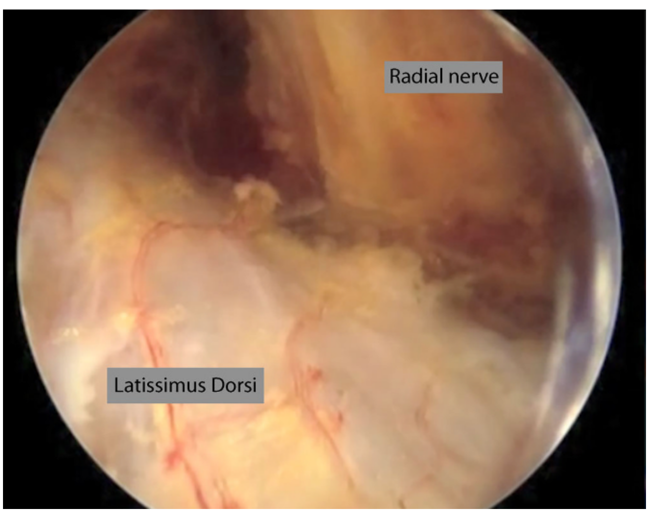

Fig. 6 ◀ Right shoulder: care is taken to avoid any injury to the (vertical) axillary nerve, the "three sisters," and the (horizontal) radial nerve, which is found medially at the deep surface of the conjoint tendon and crossing the superficial surface of the latissimus dorsi and teres major tendon 4 cm medial to their humeral insertion

for restoring ER1 than LD transfer. On the other hand, LD transfer can better restore active ER2. Indeed, the trapezius has a similar line of pull to that of the IS (ER1), whereas the LD has a more similar line of pull than the Tm (ER2). Therefore, a third option is currently proposed to restore active ER1: lower trapezius transfer [40]. However, there are some drawbacks, as this transfer is too short to reach the humeral head and an allograft is mandatory with the risk of failed healing or rupture.

Restoration of (active) internal rotation (ILIR)

Wirth and Rockwood proposed a first option in 1996: transfer of the PM to restore active internal rotation [41]. Resh et al. [42] published long-term follow-up with satisfactory results in terms of pain relief. Since 1996, different techniques have been published to improve results using either the sternal head of the PM or the clavicular head of the PM. No clinical differences were found between the two different heads of the PM [43]. As the PM originates from the anterior chest wall, whereas the Sscp comes from the posterior chest wall, this PM transfer was proposed to be passed underneath the conjoint tendon, proximal to the musculocutaneous and axillary nerves, to reproduce a more anatomic line of pull of the Sscp on the shoulder. But this modification creates a 90° turn, which can limit excursion of the transfer. No clinical differences were found with such a modification. Finally, the PM transfer probably acts more with a tenodesis effect (or even with an interposition effect alone) than with a real active effect. A second option was proposed by Elhassan et al. [44] with the LD for three reasons: first, it comes from the posterior chest wall, as does the Sscp; second, it has almost the same direction as the distal part of the Sscp (which is the strongest and muscular part); third, it is an internal rotator, as is the Sscp, and it is synergistic. We published the first clinical experience with an assisted arthroscopic technique. We performed it with a "full" arthroscopic technique [45]. The installation and anterior dissection are the same as described previously for ILEA type 1. Similarly, the LD tendon is harvested arthroscopically with two blue and green sutures with a Krakow technique. No axillary incision is necessary as the LD is pulled up anteriorly to the Sscp insertion. The two pairs of sutures are just pulled up to the AS portal and the LD is fixed with two Versalok (Mitek,

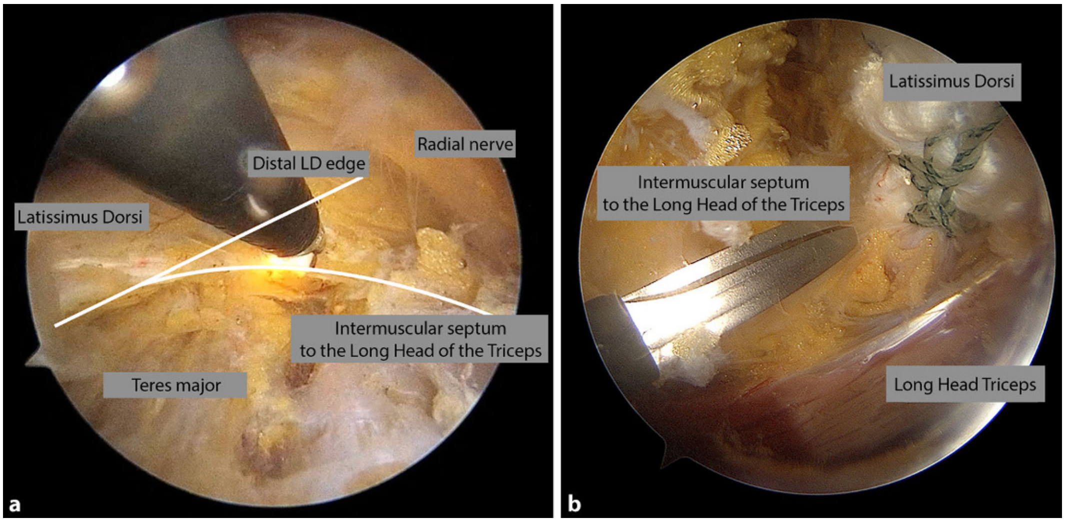

Fig. 7 ◂ **a** Right shoulder: the dissection is continued as far as possible, releasing all connections of the latissimus dorsi (*straight white line* distal edge of the latissimus dorsi) to the long head of triceps (intermuscular septum [*curved white line*] connecting the latissimus dorsi and the long head of the triceps) and teres major to facilitate passage of the transfer. **b** Left shoulder: blunt scissors may also be used for this step

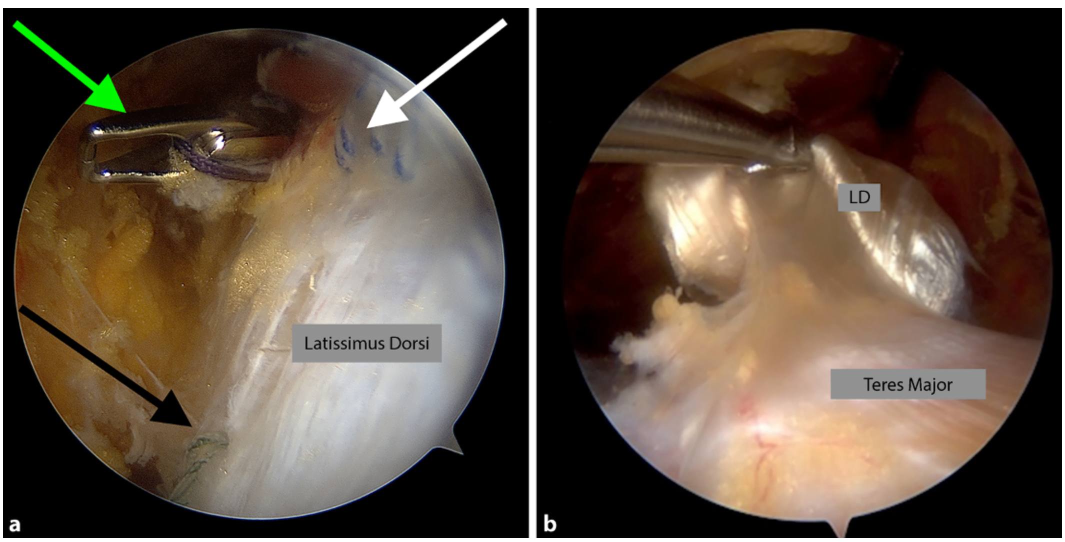

Fig. 8 ◂ **a** Left shoulder: the two edges of the latissimus dorsi tendon are arthroscopically whip-stitched along medial and lateral borders with green and blue sutures (Sutureloop, VIMS, Saint-Jory, France) with a Krakow technique (*white* and *black arrows*). **b** Right shoulder: thereafter, the latissimus dorsi (*LD*) insertion is released from the humerus at the crest of the lesser tubercle. The sutures are then shuttled and retrieved from the posterior portal (*green arrow*) through the triangular space

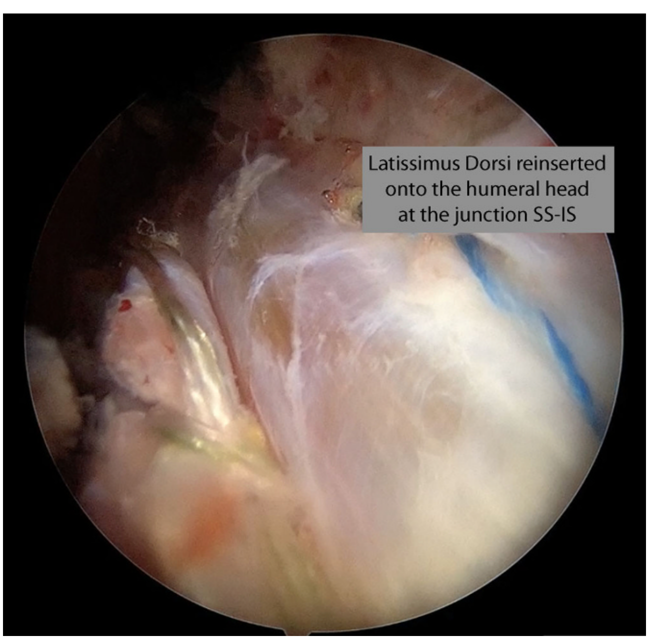

Fig. 9 ◂ Right shoulder: thanks to a cannula, the LD is fixed with appropriate tension after preparation of the footprint using two knottless anchors (Versalock, Mitek Sports Medicine, DePuy Synthes Companies, Zuchwil, Switzerland)

Raynham, MA, USA) onto the footprint of the Sscp after freshening with a motorized burr.

Correction of horizontal and vertical imbalance of the shoulder (CLEER, CLEIR)

Both CLEER and CLEIR have to be treated separately.

With reverse shoulder arthroplasty alone (RSA), the vertical balance can be restored but the horizontal balance cannot. Absence of rotation is the price to pay if nothing else is done in addition to RSA. In the same way, an isolated LD transfer can fail to treat both the vertical and horizontal imbalance of the shoulder. Tendon transfers have some rules that must be respected: firstly, one tendon means one transfer only and therefore one function only and secondly, a transfer causes a decline in muscle power [20].

Treatment of CLEER

In case of CLEER (which is a pseudoparalytic shoulder), a minimum of two ruptured tendons (or more) are observed. This is the reason why Neyton et al. [46] proposed a first option: RSA combined with a modified L'Episcopo technique. Through a single deltopectoral approach, the procedure is made easier because the humerus can be dislocated to improve exposure and to facilitate tendon harvest and transfer. After implantation of an RSA, active external and internal rotations could be improved by increasing the recruitment of medial fibers of the deltoid and by tensioning the remaining external and internal rotators. This could be achieved by increasing the lateral offset of the RSA, either by using RSA with a lateralized design or by using a biological (bony) lateralization with a BIO-RSA (bony increased offset; [47]). Therefore, lateralized RSA could be an option to manage patients with CLEER by restoring both elevation and ER. Nevertheless, this option requires the presence of a strong and functional Tm.

Treatment of CLEIR

In case of CLEIR (which is a pseudoparalytic shoulder) a minimum of two ruptured tendons (or more) are observed. Werthel and Elhassan [48] have proposed RSA plus transfer of PM, as this seems to be the best option to restore both deficits of elevation and internal rotation. With such an option, a lateralized RSA can prevent mechanical impingement between the humerus and the glenosphere, as a strong Sscp cannot recreate a good IR with a Grammont-type RSA.

Practical conclusion

The LD transfer has lots of indications in the irreparable cuff tear. It has a very good indication for partial isolated loss of active elevation (ILEA type 1) and for isolated loss of internal rotation (ILIR). It could be indicated in isolated loss of external rotation (ILER), but the lower trapezius transfer seems better suited. It has a good indication in case of total isolated loss of active elevation (ILEA type 2) and combined loss of elevation and external rotation (CLEER) in association with RSA.

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Compliance with ethical guidelines

Conflict of interest. J. Kany is consultant for VIMS & DePuy, Mitek and receives royalties from FH Orthopedics (Arrow shoulder prosthesis). J.D. Werthel receives royalties from FH Orthopedics (Arrow shoulder prosthesis). H. Anis declares that he has no competing interests.

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