

Combined Fully Arthroscopic Transfer of Latissimus Dorsi and Teres Major for Treatment of Irreparable Posterosuperior Rotator Cuff Tears



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Abstract: Many treatment options have been proposed for treatment of irreparable posterosuperior rotator cuff tears. Among these options, latissimus dorsi tendon transfer can be considered a good alternative, especially in young patients before development of glenohumeral arthritic changes, aiming at rebalancing the shoulder with a functioning subscapularis muscle and restoring both active external rotation and elevation with the aid of a properly functioning deltoid muscle. The technique was recently adapted from open to arthroscopically assisted with numerous advantages. We propose a combined fully arthroscopic technique for transfer of latissimus dorsi and teres major in which the tendons are fixed in a flat manner at the junction of supraspinatus and infraspinatus to decrease failure rate.

Massive irreparable cuff tears may represent as high as 20% to 40% of total cases of operated rotator cuff tears (RCTs) and can be a challenging clinical problem.¹ Massive cuff tear is not synonymous with irreparable cuff tear, which is different from pseudo-paralytic shoulder.² Massive tears are defined as lesions with diameters >5 cm or the involvement of 2 or more tendons. Irreparable tears can be also defined as stage 3 tendon retraction according to Patte, stage 3 or 4 fatty infiltration as described by Goutallier et al., stage 3 muscle atrophy according to Thomazeau et al., or superior escape of the humeral head with a subacromial distance <6 mm, Hamada stage 3 with acromioclavicular joint degeneration, failed previous cuff repair,

or inability to anatomically repair the cuff after full arthroscopic release.²⁻⁵

Pseudo-paralytic shoulder was redefined by Burks et al.^{2,6} as the association of a normal passive range of motion (no stiffness) with no active forward flexion (FF; <45°) or limited active external rotation and/or internal rotation.²

Many treatment options have been proposed to manage irreparable RCT including debridement with subacromial bursectomy⁷ and/or tenotomy or tenodesis of the long head of the biceps,^{8,9} partial repair of the residual cuff,¹⁰ deltoid flap,¹¹ lower trapezius transfer,¹² latissimus dorsi (LD) transfer,¹³ reverse shoulder arthroplasty,¹⁴ and the interposition of a subacromial spacer¹⁵ or superior capsule reconstruction.¹⁶

L'Episcopo¹⁷ first described the transfer of teres major tendon alone for the treatment of brachial plexus injuries in children. Later, Gerber et al.^{13,18} reproduced Hoffer's procedure¹⁹ described in 1975 to restore active external rotation in Erb's palsy and described the transfer of the LD alone in the treatment of massive rotator cuff tears. Long-term follow-up of LD transfer has shown that it is an effective treatment for the restoration of shoulder function, with patient satisfaction of around 86%.^{6,18}

Recently, the techniques for arthroscopy-assisted LD tendon transfer have been described with the advantages of better visualization of the neighboring neurovascular structures at risk (radial nerve, axillary nerve), avoidance of blind massive preparation between the deltoid and teres major (TM), no damage to deltoid muscle, and the ability to address a repairable associated subscapularis

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Table 1. Pearls of the Procedures

- The following principles of tendon transfers should be respected whenever possible:²⁵
 1. Accurate positioning of the transferred tendon at implantation site
 2. Physiological tensioning of the transferred muscle tendon unit
 3. Strong osseous fixation of the implanted tendon
 4. Minimally invasive surgery to reduce muscle scarring (so as not to hinder excursion of the transfer)
- Dissection must be kept medial to long head of LHT to avoid injury to axillary nerve
- Proper release is a must to prevent impingement of the transferred tendons and possible failure
- The long head of triceps LHT is a vertically oriented structure, which is an important landmark in posterior dissection
- Slight flexion and internal rotation of the pneumatic arm holder while performing anterior release is required to increase the room available
- Use switching sticks to lift deep deltoid while performing anterior dissection
- Avoid any injury to the axillary nerve (vertical), and the radial nerve (horizontal), the three sisters, the musculocutaneous nerve
- The bicipital groove (LHB) is a landmark in anterior dissection
- During detachment of LD/TM insertions, it is highly recommended to take the tendon as long as possible
- Using colored sutures to mark the upper border (blue/white) from the lower border (green/white) is advisable to avoid twisting of the transferred tendons
- Fixation of the transferred tendons at junction of SS/IS is done in a flat manner to prevent the killer turn effect
- Bone quality may be not good, so take care of anchor failure

LD, latissimus dorsi; LHB, long head of the biceps; LHT, long head of triceps; TM, teres major.

tear or long head of biceps tendon (LHB) pathology with quicker postoperative rehabilitation, decreased pain, and improved cosmesis.^{2,6,20}

Many different techniques have been described ranging from open to mini-open to fully arthroscopic techniques, perhaps with tendon or bony augmentation²¹; however, there was still high rate of transferred LD rupture (38% to 43%).¹⁻³

Such a high rate of rupture may be explained by the weakness of the LD tendon or too high a tension after reinsertion of a tubularized tendon into the bone (guillotine effect) in over-the-top position.²² Moreover, it is difficult to separate and harvest LD from TM because of very close anatomical connections.²³ Finally, LD alone could not be strong enough to rebalance the shoulder posteriorly especially in case of 2 or 3 ruptured tendons (supraspinatus [SS], infraspinatus [IS], TM) because, according to the rules of tendon transfers, 1 transfer can supply for 1 tendon only. We therefore considered a combined fully arthroscopic transfer of LD and TM to facilitate the full arthroscopic dissection and to make the transfer stronger with less risk of rupture.

Indications of Combined LD/TM Transfer

1. Functionally impairing, massive, irreparable posterolateral rotator cuff tears in young patients before

the development of glenohumeral osteoarthritis. Supple shoulder movement is essential specifically for passive FF and abduction (>80).

2. Negative prognostic factors for rotator cuff repairs are considered indications for combined LD/TM transfer.⁴
3. Partial isolated loss of active elevation (type 1).²
4. Isolated loss of external rotation, which means loss of ER1 with positive external rotation lag sign or positive Hornblower sign; inability to maintain externally rotated position of the arm against resistance while the arm is abducted to 90° in the scapular plane and the elbow flexed to 90°, but the lower trapezius transfer seems better suited.²
5. Total isolated loss of active elevation (isolated loss of active elevation type 2) and combined loss of elevation and external rotation in association with reverse shoulder arthroplasty.²

Contraindications of Combined LD/TM Transfer

1. Associated irreparable tear of the subscapularis.
2. Cuff tear arthropathy with glenohumeral arthritis (stage 4 or 5 according to Hamada et al.)
3. Associated complete and permanent axillary nerve palsy.
4. Pseudo paralytic shoulder (active FF <70 despite 3 months of physiotherapy).
5. Stiff shoulder (limitation of passive movements in forward elevation, external rotation, and internal rotation despite 3 months of physiotherapy).^{1,2}

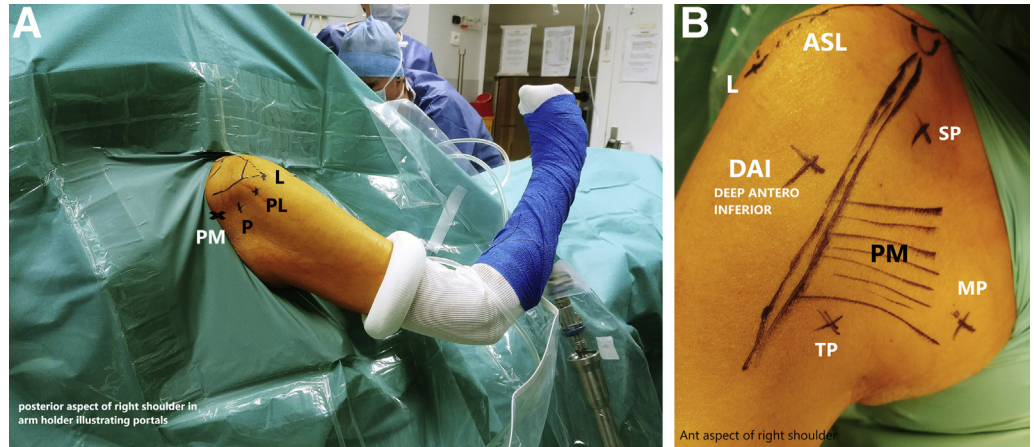
Technique

The operative technique is demonstrated in [Video 1](#) and pearls of the procedure are illustrated in [Table 1](#).²⁵ Negative prognostic factors for rotator cuff repair are presented in [Table 2](#).

Table 2. Negative Prognostic Factors for Rotator Cuff Repair⁴

- Previous failed rotator cuff repair
- Chronic tear (6 months)
- Older age (65 years)
- Tobacco use
- Poorly controlled diabetes mellitus
- Pseudo paralysis
- Marked weakness with lag signs
- Hornblower sign
- Acromiohumeral interval, 7 mm
- Critical shoulder angle 35°
- Acetabularization of the greater tuberosity
- Tendon length, 15 mm
- Grade 3 fatty atrophy
- Subscapularis insufficiency
- Moderate or severe glenohumeral arthritis

Fig 1. (A) Patient in beach chair position with the upper limb in pneumatic arm holder with posterior portal (P), posterolateral portal (PL), posteromedial (PM), and lateral portal marked (B) anterior aspect of right shoulder showing lateral (L), deep anteroinferior (DAI), suprapectoral (SP), transpectoral (TP), and medial pectoral (MP) portals.



Patient Positioning and Portals

Under general anesthesia, in the beach chair position, the arm is held in a pneumatic arm holder (Spider, Smith & Nephew, London, UK) and the following portals are used: the posteromedial (PM), posterior, posterolateral, lateral, anterosuperolateral (AS), deep anteroinferior portal 4 cm below anterior corner of the acromion, mediopectoral, transpectoral, and suprapectoral (SP) portals. No axillary portal is needed (Fig 1).

General Arthroscopic Examination and Management of Concomitant Shoulder Pathology (LHB or Subscapularis Lesion if Needed)

A general arthroscopic examination is performed to assess the glenohumeral joint, address repairable subscapularis tears, and manage biceps pathology if any (Fig 2).

Debridement of the Subacromial Space

We do not perform any acromioplasty to prevent possible humeral head superior escape.

Posterior Release/Dissection and Creation of Posterior Pathway

The dissection is started posteriorly using a radiofrequency probe (VAPR Mitek Sports Medicine, DePuy Synthes Companies, Zuchwil, Switzerland) after identifying the spine of the scapula by the fat around it, which is the landmark between SS and IS. Then dissection is continued in an inferomedial direction between the distal deltoid aponeurosis posteriorly and the remnants of IS and teres minor anteriorly. Visualization of the vertical fibers of the long head of triceps (LHT) is meticulously performed to prevent any injury to the axillary nerve crossing through the quadrilateral space (lateral to the LHT). Furthermore, release is

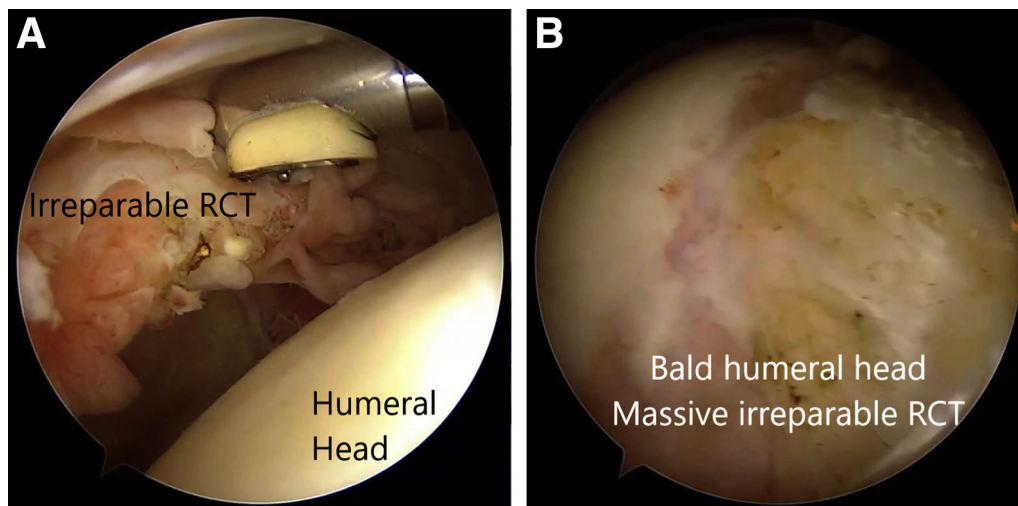


Fig 2. (A) Arthroscopic intraarticular view of right shoulder showing irreparable RCT, (B) bald humeral head with remnants of rotator cuff foot print. (RCT, rotator cuff tear.)

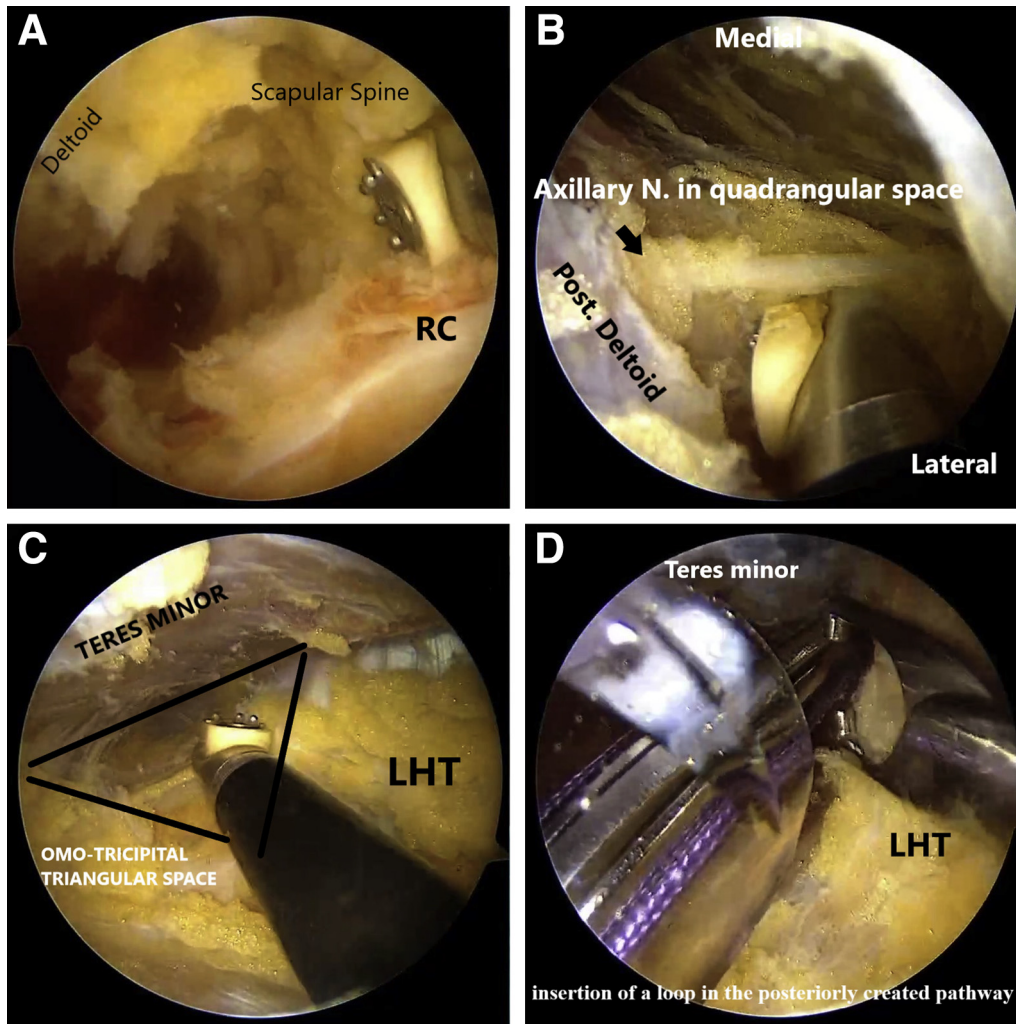


Fig 3. Arthroscopic posterior views of the right shoulder showing (A) axillary nerve in the quadrilateral space penetrating the deep surface of posterior deltoid fibers. (B) View of the right shoulder showing teres minor and LHT and dissection toward the omo-tricipital triangular space. (C) Boundaries with LHT (vertical and lateral), teres minor (horizontal and superior), and the upper edge of the teres major. (D) Insertion of a loop in the posteriorly created pathway between deltoid and cuff (infraspinatus, teres minor), then medial to LHT into the triangular space. (LHT, long head of triceps; RC, rotator cuff.)

performed medial to LHT toward the omo-tricipital triangular space (delimited with the LHT laterally, the TM superiorly, and the LD/TM distally) while avoiding injury to the inferior pedicle of the scapula penetrating this space. Finally, a fiber force suture is inserted in the created pathway in a posterosuperior to anteroinferior direction, which is retrieved from the axilla (Fig 3).

Anterior Release and Dissection

The scope is switched to the AS portal, following the LHB tendon in its groove to reach lateral to the conjoint tendon and the vertical upper border of the PM. The 3 sisters (terminal branches of the circumflex vessels) are identified, marking the inferior border of the subscapularis tendon (anterior to the chest wall) and the upper border of LD tendon insertion

(posterior to the chest wall). Through the SP portal, a 2-cm upper PM release is performed to allow visualization of the LD posterior to the conjoint tendon. Great care is taken to prevent any injury to the axillary nerve (vertically oriented), the circumflex vessels (quadrilateral space, lateral from the LHT), the 3 sisters at the upper border of the latissimus dorsi (LD), and the radial nerve (horizontal), which is located medially at the deep surface of the conjoint tendon and crossing the superficial surface of the LD 3-4 cm medial to their humeral insertion which gives 3 branches to the LT at its distal edge (Fig 4).^{2,23}

Release of the LD and the TM insertions is continued in a medial and posterior direction to find the LHT and the triangular space medial to it (LD is oblique and its fibers run distally, whereas TM is horizontally oriented

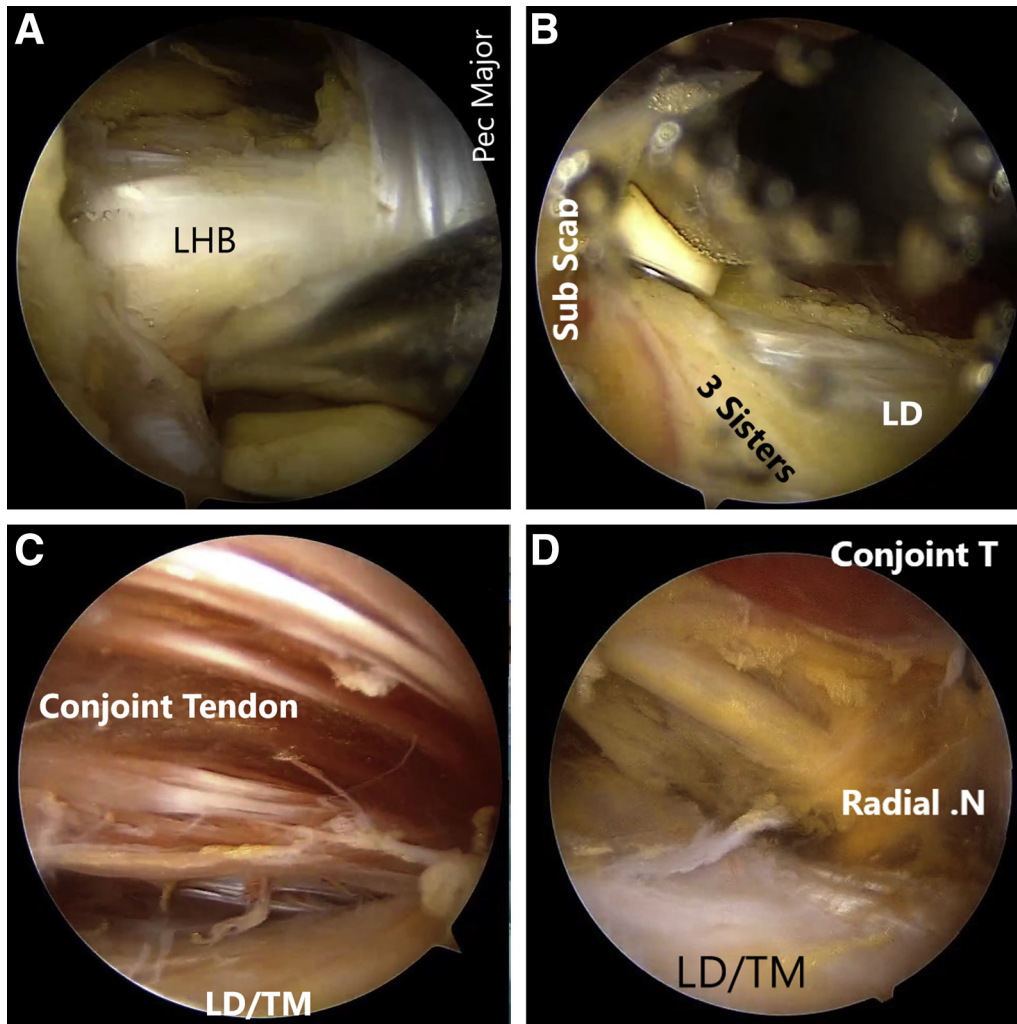


Fig 4. Arthroscopic anterior views of the right shoulder during anterior dissection for harvesting LD/TM showing (A,B) LHB (vertical landmark), pectoralis major, 3 sisters separating upper border of LD from lower border of subscapularis (C) after cutting the upper 1-2 cm of the pectoralis major for proper viewing of LD, radial nerve (and its branches to the LHT). (LD, latissimus dorsi; LHB, long head of the biceps; LHT, long head of triceps; TM, teres major.)

and its fibers run medially). The release has to deal with the intramuscular septum at the distal edge of the LD, just medial and posterior to the radial nerve, which is a constant anatomic connection with the LHT. If this release is not performed, the transfer will not be possible because it will be too short.^{2,3}

Harvesting LD/TM Tendons

Expressw (Mitek, Raynham, MA) is used to make 3 Krackow stitches with green/white high-strength suture (Fiber Force Suture Loop, VIMS, Saint Jory, France) through the lower border of LD/TM. Then both tendons are partially detached in a progressive manner from their humeral insertion from distal to proximal with the shoulder in internal rotation to facilitate the release of LD (which turns around the shaft of the humerus just medial to the bicipital groove). Another 3 Krackow stitches of the upper border of both LD/TM is made with

fiber force (blue/white) and both tendons are fully released together from the humerus (without any dissection between) (Fig 5).

Shuttling of Transferred Tendons of LD/TM Posteriorly

Finally, after complete detachment of both LD/TM tendons, the dissection is continued in a medial direction until LHT and omo-tricipital triangular space until the previously inserted loop from posterior dissection is found. The dissection has to be performed until seeing the LD muscle belly (the LD tendon length is about 7-8 cm).^{2,3} It is possible to control both pedicles of the TM (6-7 cm from the humeral side) and that of the LD (more distal and more medial; 10-13 cm from the humeral side) at the upper edge of the muscle bellies from the apex of the scapula without any axillary incision.^{2,3}

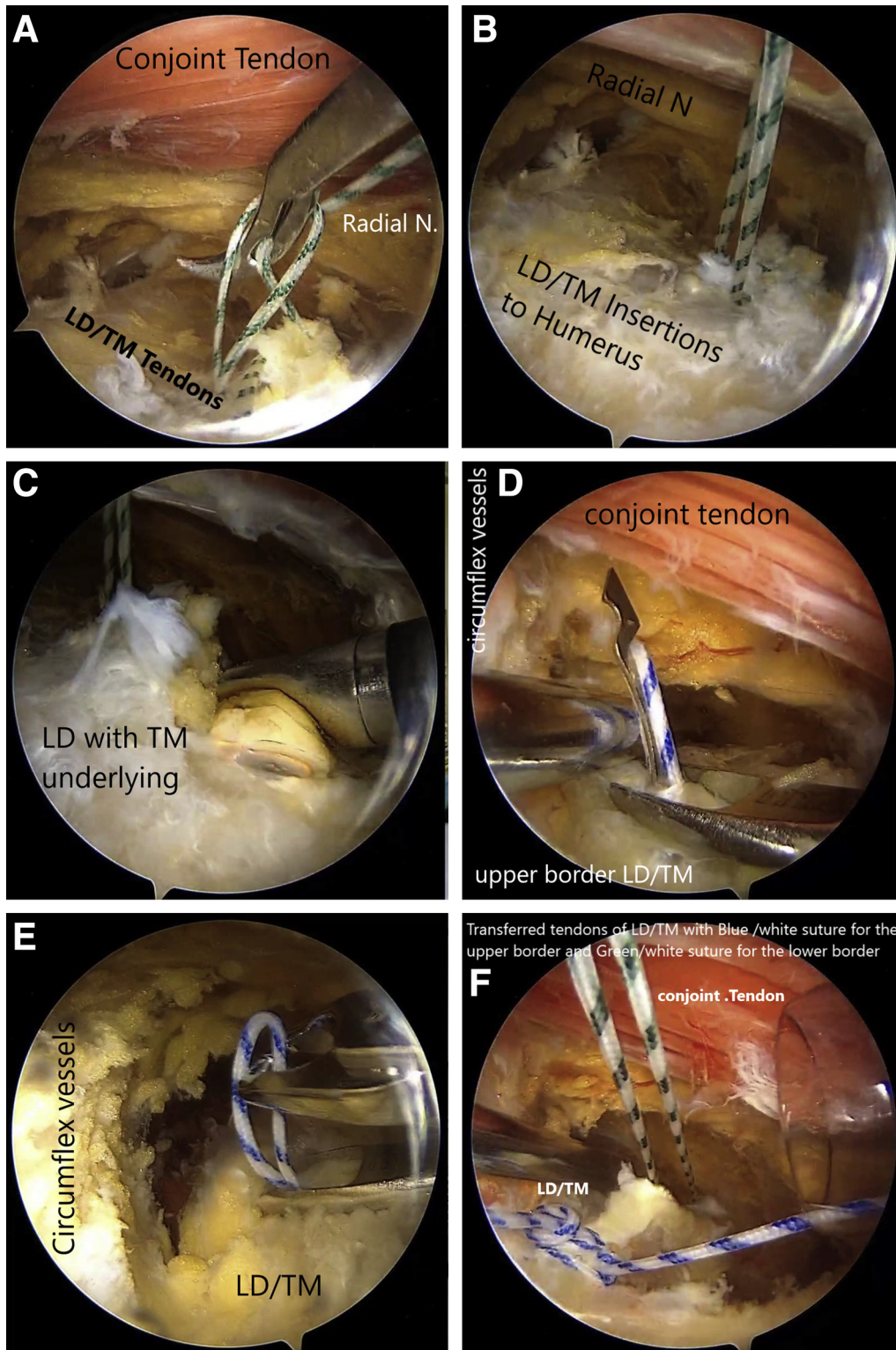


Fig 5. Arthroscopic anterior views of the right shoulder during harvesting the insertion of LD and TM from its humeral attachments and making double Krackow sutures. (A,B) Green/white nonabsorbable suture on the lower border. (C) Partial release of LD/TM insertions to facilitate suturing of the upper border (D,E) during suturing of the upper border of LD/TM with blue/white sutures using an Expressw suture passing device (taking care not to injure the circumflex vessels and/or the radial nerve, horizontally crossing the anterior aspect of the LD tendon at 3-4 cm from the humeral shaft). (F) Final view after harvesting LD/TM tendons with the blue/white suture on the upper border and green/white suture on the lower border. (LD, latissimus dorsi; TM, teres major.)

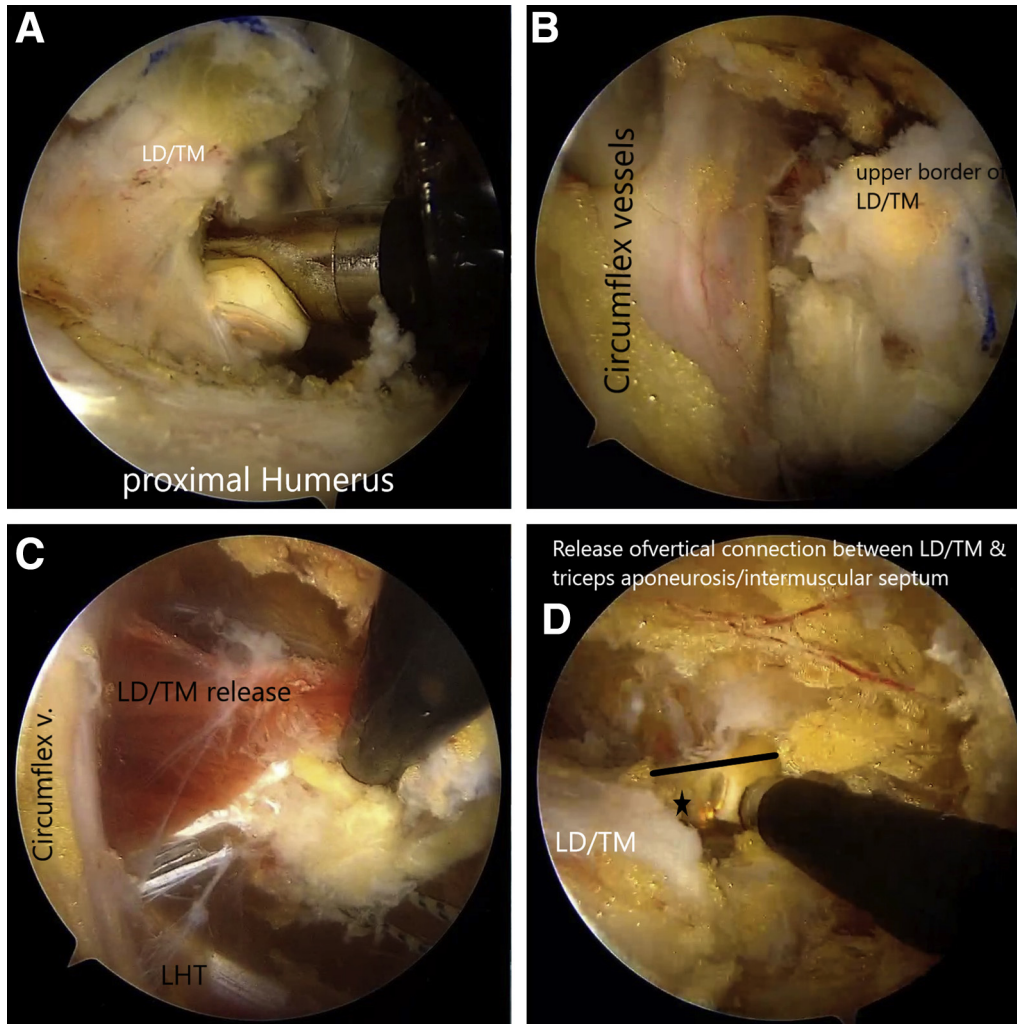


Fig 6. Arthroscopic anterior views of the right shoulder showing (A) release of the upper border of LD/TM from the humeral shaft. (B) Proximity of the circumflex vessels and axillary nerve to the upper border of LD/TM. (C) Release of connections of TM medial to long head of triceps LHT. (D) Release of a vertical connection between LD and triceps aponeurosis /intermuscular septum. (E, F) Release medial to LHT using radiofrequency device and long scissors in the omo-tricipital triangular space. (G) Muscle belly of latissimus dorsi LD about 8 cm medial to the humerus and obliquely oriented, whereas teres major TM is more horizontally oriented. (LD, latissimus dorsi; LHT, long head of triceps; TM, teres major.)

Then, the combined tendons of LD/TM are pulled back through the omotricipital triangular space in the previously prepared pathway with the blue/white suture marking the upper border and the green/white suture marking the lower border (Figs 6 and 7).

Fixation of LD/TM to the Humeral Head

Both pairs of sutures (the green/white and the blue/white) are retrieved from the posteromedial portal to the AS portal. The LD excursion is checked to prevent overtensioning, which could create tendon rupture. The combined LD/TM transfer is fixed with appropriate tension at the junction between supraspinatus and infraspinatus foot prints in neutral rotation of the arm using 2 knotless anchors (Versa

lock, Mitek) with the blue/white suture medially and the green/white suture laterally to prevent any twist and to fix it flat onto the footprint of the IS (Fig 8).²²

Postoperative Rehabilitation and Follow-up

The arm is immobilized using a 30°-abduction pillow in neutral rotation for 4 weeks. Self-assisted passive exercises in the supine position are started immediately. After 4 weeks, the patient begins slow active rehabilitation. The first goal is to restore passive flexion; gentle water exercises are recommended. After 3 months, slow strengthening exercises are started. Electromyography is systematically performed at 12 months postoperatively to control whether the transferred tendon is active (or dynamic) or not (sole tenodesis effect).

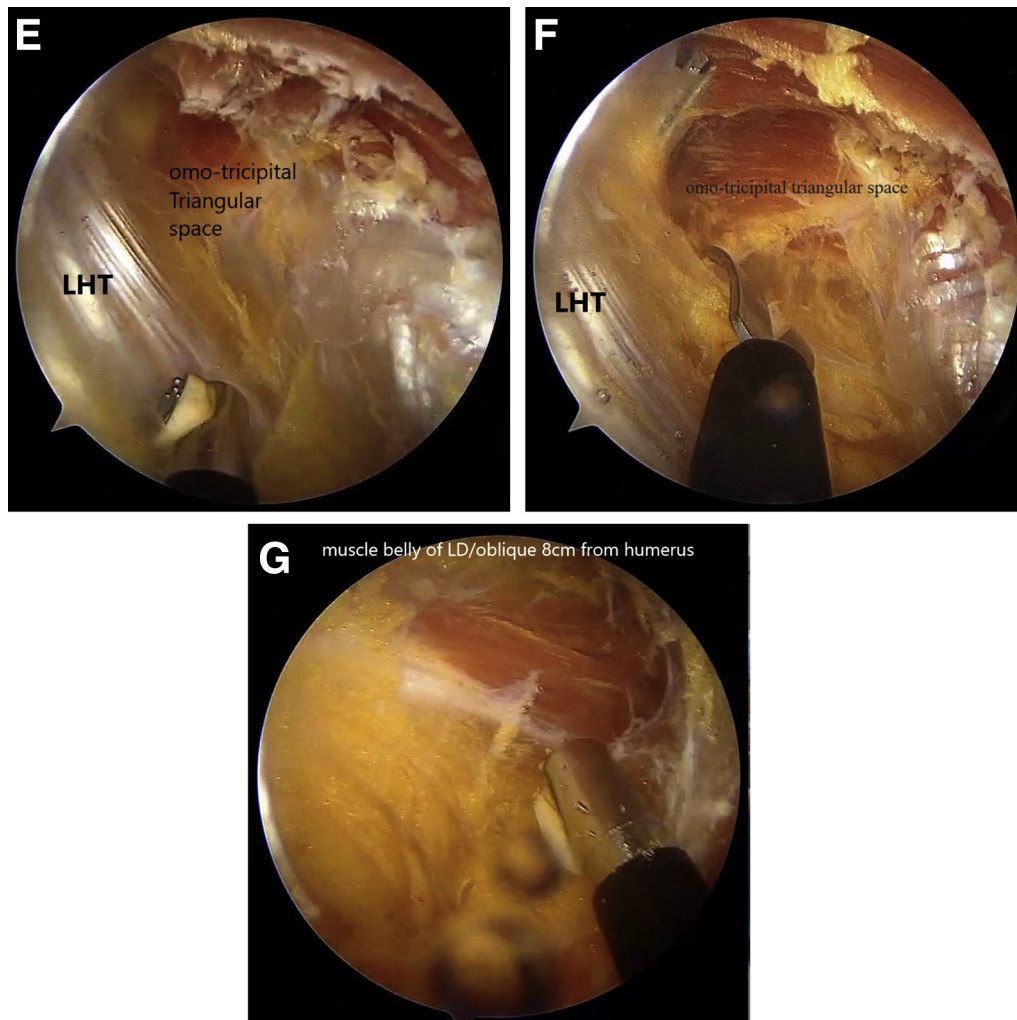


Fig 6. Continued

Discussion

Latissimus dorsi tendon transfer is a well-established method for the treatment of massive irreparable posterosuperior cuff tears in young patients without significant glenohumeral arthritis. However, initially reported results were variable, with inconstantly positive outcomes. Gerber et al.¹⁸ have published their long-term results of LD tendon transfer for treatment of posterosuperior RCTs and concluded that LD tendon transfer offers an efficient treatment with substantial improvement in shoulder function and pain relief.¹⁸ Poor outcomes may be due to inadequate patient selection (e.g., those who had associated lesions of the subscapularis, deltoid damage, poor quality of the LD tendon) or from possible ruptures of the LD tendon, which could be underestimated by ultrasonographic and or magnetic resonance imaging.¹

A prospective study performed by the French Arthroscopic Society on 218 patients with massive RCTs

reported a 43% rupture rate in patients treated with arthroscopic latissimus dorsi transfer.³ We have reported a 38% postoperative rupture rate at 2 years' follow-up of 60 patients treated with arthroscopic-assisted LD tendon transfer for irreparable posterosuperior cuff tears in whom the tubularized LD tendons were fixed in a bone tunnel inside the humeral head. The outcome of LD tendon transfer is significantly lower in those with rupture compared with those without rupture¹

We have also compared the effect of the LD tendon fixation technique to the humeral head on the rates of postoperative tendon rupture. Three different techniques were compared: 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 2 Krakow sutures and 2 anchors onto a more posterior location at the junction between the

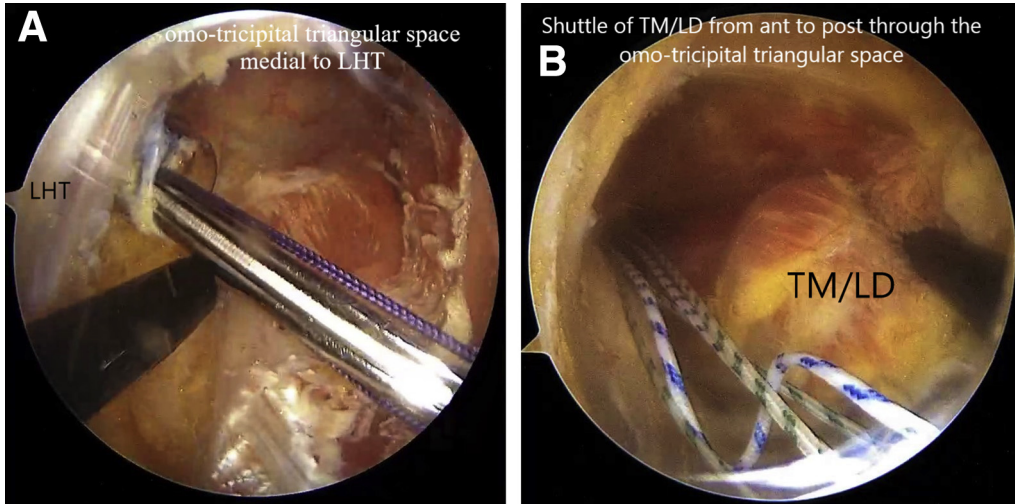


Fig 7. (A) Retrieval of the loop inserted from the posteriorly created space for passage of tendons medial to LHT in the omo-tricipital triangular space. (B) The TM teres major muscle belly (during shuttling of the transferred tendons through the omo-tricipital triangular space from anterior to posterior). (LD, latissimus dorsi; LHT, long head of triceps; TM, teres major.)

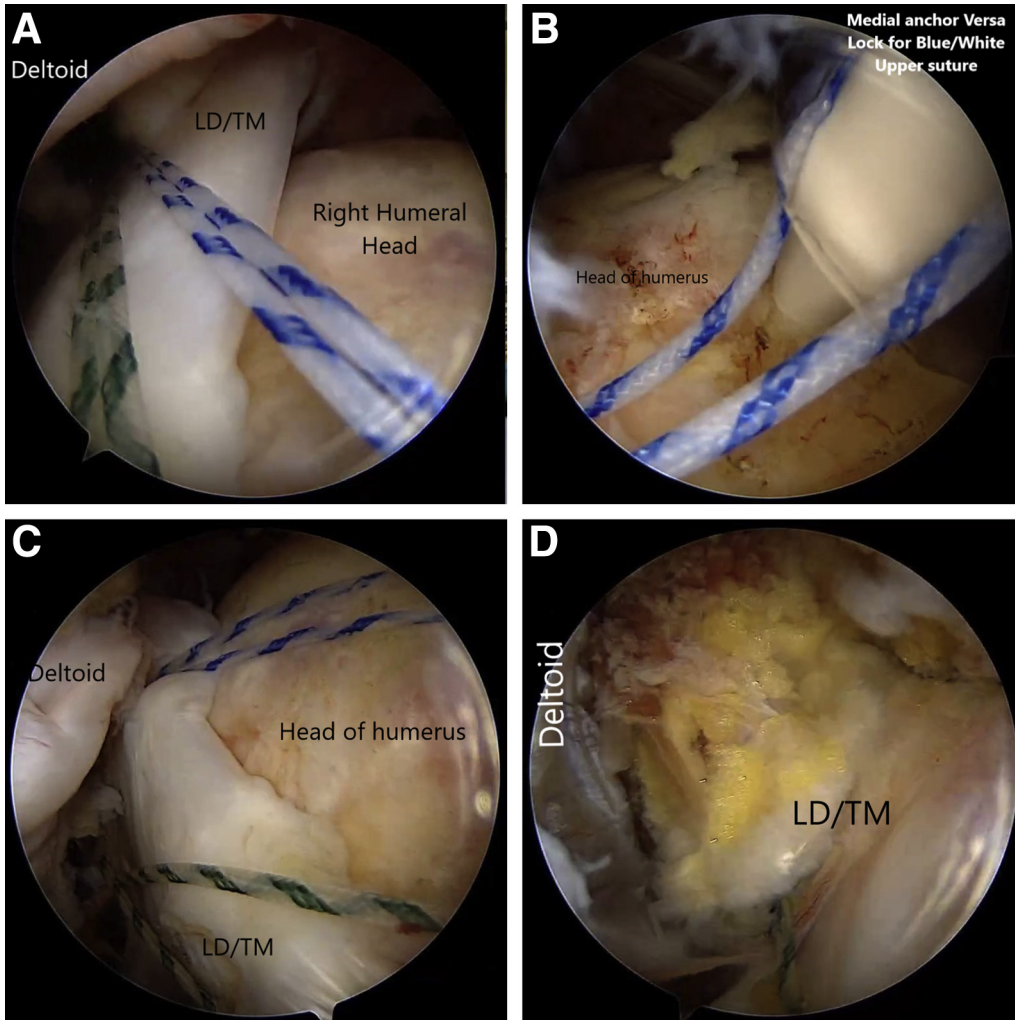


Fig 8. Arthroscopic posterior views of the right shoulder. (A-C) Insertion of the first anchor for fixation of the upper blue/white suture onto the humeral head (D) after fixation of both anchors to the humeral head and the LD/TM. (E,F) Final view of transferred tendons. (LD, latissimus dorsi; TM, teres major.)

supraspinatus SS and the infraspinatus IS (group 3). The rate of LD rupture was 38%, 27%, and 15% in the groups, respectively.^{2,22} Thus we now fix the tendons flat at the junction between SS and IS to prevent over-tensioning and the killer turn “guillotine” effect with subsequent tendon rupture.

Pogorzelski et al.²⁶ investigated the results of Achilles tendon allograft-augmented latissimus dorsi tendon transfer for the treatment of massive irreparable posterosuperior RCTs and there was no significant post-operative improvement in patient-reported outcomes. Gerhart et al.²⁴ did a 5-year follow up of a modified L’Episcopo single incision technique that transferred both LD and TM. They demonstrated maintenance of constant score at 5 years.

We have modified our previously described arthroscopic-assisted LD transfer² to this combined fully arthroscopic combined transfer of LD and TM because it is easier to separate the 2 muscles with variable and inconstant anatomic connections. In addition, the combined LD/TM transfer is stronger than LD only because with TM being a bulky muscle, there is less risk of tendon necrosis or rupture as the LD alone is very thin. Moreover, there is less tension onto the transferred tendons because we fix it onto the footprint of the IS as the purpose of this procedure is to rebalance the shoulder with the subscapularis and not to pull down the humeral head, as we believed a few years ago. We do not have to release LD onto the apex of the scapula as a very long transfer is not required and the combined LD/TM naturally falls at the level of the IS.

Despite this technique being considered 1 of the most demanding procedures in shoulder arthroscopy, cadaveric training being recommended and there being potential risk of nerve injuries such as radial and/or axillary or vascular injury to the circumflex vessels, whip stitching the transferred LD/TM tendons is the most difficult part of the procedure. We have been performing this technique for 1 year without any complications.

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