Technical Note

Latissimus Dorsi Transfer Combined with Subacromial Balloon Spacer for Bidirectional Rotator Cuff Deficiency

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Abstract: Patients with massive, irreparable rotator cuff tears represent a challenge for treatment, particularly those with loss of external rotation and active elevation. In the cases of glenohumeral arthropathy, reverse shoulder arthroplasty combined with transfer of the latissimus dorsi and teres major tendons has improved active external rotation and overall patient outcomes. However, the reverse shoulder prosthesis could be better used as a second-line treatment in patients without arthropathy. Several joint-preserving surgical approaches have been described for irreparable cuff tears with no substantial differences in results. Although latissimus dorsi transfer has shown long-term clinical reliability and improved functional shoulder function in relatively young patients, isolated tendon transfer appears insufficient to restore range of motion in patients with a bidirectional deficit. The subacromial balloon spacer is an additional new treatment option. This surgical procedure describes an arthroscopic-assisted transfer of the latissimus dorsi tendon followed by the implantation of the subacromial balloon. This combination potentially addresses the bidirectional deficiency by restoring the shoulder external rotational coupling, improving the deltoid load, centering the humeral head, and protecting the transferred tendon from the subacromial compression stresses.

Introduction

Patients with massive, irreparable rotator cuff tears (MIRCTs) can present in many ways, from lack of symptoms to considerable functional loss. The combined loss of active elevation and external rotation (CLEER) refers to patients with vertical and horizontal shoulder imbalance[1,2] and consequently bidirectional pseudoparesis or pseudoparalysis.[2] Patients with active external rotation pseudoparalysis may benefit from reverse shoulder arthroplasty (RSA) with latissimus dorsi and teres major tendon transfer.[2,3] However, in young, relatively active patients with nonarthritic joints and no anterosuperior humeral escape, alternative surgical procedures may be considered based on physical examination, radiography, and chronicity.[4]

This report describes a surgical approach to joint preservation that combines arthroscopic assisted latissimus dorsi tendon transfer (LDTT) with implantation of a subacromial balloon spacer (SBS). The SBS is intended to provide a smooth and frictionless glide that protects the transfer while improving shoulder biomechanics and pain relief (Table 1). MIRCTs in young patients with CLEER, who have a severe compromise of teres minor and active external rotation pseudoparalysis, no anterosuperior humeral escape and no arthropathy, are candidates for surgical reconstruction with this technique (Table 2).

Surgical Technique

This article focuses on the implantation of the SBS (InSpace System; OrthoSpace, Caesarea, Israel) on top of an arthroscopic assisted LDTT (Video 1, Table 3).

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Anesthesia and Patient Setup

Under general anesthesia followed by an interscalene nerve block, the procedure requires the patient to be placed in a standard beach-chair position (Fig 1A). This position facilitates the transition from an arthroscopic approach to an open axillary approach (Fig 1, B and C). In addition, a contralateral arm holder could be used during tendon harvest to keep the arm in the proper overhead position.

Protocol Approval

The study was performed at the Hospital Militar de Santiago, Santiago, Chile. Informed consent was obtained and the right to privacy of human subjects was always respected. The study was conducted in conformity with the Helsinki Declaration and its own modifications, and ethical approval was obtained from our institutional Medical Ethics Committee (Hospital Militar de Santiago, Chile).

Step 1: Creation of the Subacromial Passage Space

This approach uses the standard posterior (P), anteroinferior (AI), anterolateral (AL), and lateral (L) portals, aided by two accessory portals (Fig 1B). The shoulder is placed in 30° of flexion and neutral rotation under 2-kg traction. The 30° arthroscope is inserted in the P portal to perform the intraarticular diagnosis and the biceps tenotomy through the AI portal. Subsequently, the scope is inserted into the L portal to debride the subacromial space using a shaver and a radio frequency device. The greater tuberosity is skeletonized, and the recipient transfer area is identified.

The subacromial passage space is first created by debridement of the subdeltoid bursa and the interval between the teres minor and posterior deltoid through the AL portal (Fig 2A). The dissection continues medially to identify the posterior branch of the axillary nerve. The plane of the latissimus dorsi tendon (LDT) passage is recognized medial to the nerve (Fig 2B). The accessory posterolateral (PL) working portal is established to dissect the vertical fibers of the long head of the triceps in an inferomedial orientation until the horizontal fibers of the teres major are visualized (Fig 2C).

Step 2. Latissimus Dorsi Tendon Harvesting

First, identify the LDT. The arm is held at a 180° (forward flexion and neutral rotation). From the mid-axillary line to the posterior axillary line, a 5-cm curved incision is created (Fig 1C). After subcutaneous dissection, the teres major is usually the first visible muscle belly. Despite this, it is nearly indistinguishable from the latissimus dorsi (Fig 3A). Continue proximally with blunt dissection, following the orientation of muscle fibers, and rotate the arm to maximum internal rotation, improving the exposure of the aponeurotic band leading to the LDT near its insertion on the humerus (Fig 3B).

The LDT's margins are then identified and released. The inferior margin of the LDT is oriented laterally and superficially in the surgical field (Fig. 3C), while the superior margin is medial and deeper due to the arm's position. The inferior border of the LDT is separated from the teres major, and the dissection proceeds carefully beneath the tendon (Fig 3D). A blunt dissector is used to gently release the superior border of the LDT up to the axillary nerve. The dissection beneath the tendon is finished, while the axillary nerve and circumflex artery are protected.

The belly of the latissimus dorsi muscle is released from the teres major, scapular insertions, and anterior subcutaneous adhesions to improve excursion (Fig 3E). Thoracodorsal neurovascular structures do not have to be dissected. To reach humeral insertion, secure maximum internal rotation, use a blunt retractor on the

Table 1. Advantages and Disadvantages

Advantages	Disadvantages
• Joint preservation procedure • Single tendon transfer aims to restore a single muscle function • Theoretical restoration of the subacromial space and joint contact pressure • Combination of the biomechanical advantages of SBS and LDTT on deltoid loading. • The SBS protects the transferred tendon from compressive acromiohumeral stress. • The selected insertion site provides a lower risk of rupture of the LDTT while achieving a high external rotation capacity. • Potentially lower complication rate than arthroplasty procedures. • No allograft or double tendon transfer is required. • Only two suture anchors are required for fixation. • Relatively small approach to tendon harvest.	• Designed for highly qualified and experienced arthroscopists. Knowledge of anatomy is crucial. • Surgery is time-consuming. • Theoretical benefits in shoulder kinematics resulting from the combination of LDTT with SBS have not been demonstrated. • Considerable risk of neurovascular damage. • The surgical time and the mini-open approach on the axillary area can increase the risk of wound infection. • The latissimus dorsi must be re-trained to function as an active flexor and external rotator of the shoulder.

LDTT, latissimus dorsi tendon transfer; SBS, subacromial balloon spacer.

Table 2. Indications and Contraindications

Indications	Contraindications
• Massive and irreparable posterosuperior rotator cuff tears • Fatty infiltration of the teres minor Goutallier grade III-IV. • RC arthropathy stages 1-2 of Hamada. • Combined loss of active elevation and external rotation. • Failure after conservative treatment. • Young and relatively active patients.	• Anterosuperior humeral scape • RC arthropathy Hamada ≥ 3 • Subscapularis tear Lafosse ≥ type III • Elderly patient. • Deltoid dysfunction. • Permanent and complete axillary nerve palsy. • Stiff shoulder despite complete physical therapy. • Poor compliance with rehabilitation.

RC, rotator cuff.

humeral shaft to protect the radial nerve, and perform a sharp tenotomy (Fig 4A). Finally, the elbow is positioned on the side of the body, followed by the placement of two rows of nonabsorbable Krackow stitches, one at each border of the LDT (Fig 4, B and C).

Step 3: Transport and Fixation of the LDT

A plane is established by blunt dissection between the long head of the triceps and the posterior deltoid (Fig 5, A and B). The shoulder is then moved to the arthroscopic position, with the scope positioned in the L portal. The radiofrequency is introduced through the P portal and guided to the plane between the long head of the triceps and the deltoid, exiting through the axillary incision (Fig 5C). The radiofrequency is used as a suture retriever when it is brought up from the P portal. Meanwhile, the surgeon's fingertip prevents the LDT from twisting during transportation (Fig 5D).

Returning to the arthroscopic position, a suture grasper is inserted into the AI portal to retrieve and tighten the suture limbs to confirm the intra-articular excursion of the LDT. The transfer target site and the future anchor position are identified (Fig 6, A and B). An accessory portal (AS) is created using an outside-in technique for cannula insertion near the acromial border. The two suture strands from the lateral row are recovered via the AS portal and loaded into a 4.75-mm SwiveLock anchor (Arthrex, Naples, FL). The anchor is inserted through the cannula and placed at the target site, while the remaining sutures are tensioned (Fig 6C). Finally, the medial row sutures are recovered and fixed with an additional knotless anchor (Fig 6, D and E).

Table 3. Pearls and Pitfalls

	Pearls	Pitfalls
Patient positioning	Establish the surgical fields, allowing enough exposure for the anterolateral side of the thorax to palpate the belly of the LD muscle in the posterior axillary fold. Use the arm-holder to facilitate the tendon harvest.	A small surgical field can make it challenging to identify the anterior edge of the muscle and the posterior axillary line. In the absence of an arm-holder, an assistant must hold the arm properly.
LDT harvesting	Before sharp release, circumferential visualization of the humeral insertion of the LD is required to avoid injury to the radial or axillary nerves. Dissection should progress distally from the inferior edge of the LDT.	Insufficient blunt dissection could prevent adequate visualization of the axillary nerve, which lies superior to the LD insertion. The muscle bellies appear to blend in the distal part of the surgical field. Dissect first underneath the LDT and track the fibers to separate the bellies.
Subacromial passage space	Once the interval between Tm and deltoid is created, a switch stick can be used through the P portal to increase the space through blunt mobilization. An accessory portal (between the L and the P portal) can be established to insert a switch stick as a deltoid retractor, increasing the gap between Tm and the deltoid.	This strategy could avoid impingement and axillary nerve neuropathy. Decrease the potential nerve injury due to the radiofrequency. The lack of visualization at this stage could lead to iatrogenic nerve injury. A narrow interval would compromise excursion and fixation site selection even after full LD release.
Transport and fixation of the LDT	Ensure smooth sliding and excursion of the LD by widening the interval between the deltoid and the long head of the triceps by blunt dissection. Place the anchors for LDT fixation in the ISP2 area of the infraspinatus footprint.	A different placement could decrease the risk of rupture while impairing its ability to generate a maximum external rotation moment.
SBS implantation	Fill the balloon with an adequate volume.	Try not to exceed 25 ml to restore the GH conditions best.

GH, glenohumeral; LD, lISP2, Infraspinatus middle portion; L, lateral; LD, latissimus dorsi; LDT, latissimus dorsi tendon; P, posterior; Tm, teres minor; TM, teres major; SBS, subacromial balloon spacer.

Fig 1. Positioning of the patient and surgical approaches for arthroscopy-assisted latissimus dorsi transfer and implantation of a subacromial balloon spacer. Right shoulder in beach-chair position. (A) The arm is supported on one side of the body during all steps of the arthroscopy. (B) Portals used for the arthroscopic approach: AS, accessory superior; AI, anteroinferior; AL, anterolateral; L, lateral; P, posterior; PL, accessory posterolateral. (C) Axillary approach skin incision line for harvesting the latissimus dorsi tendon with the shoulder in forward elevation.

Step 4: Subacromial Balloon Spacer Implantation

An arthroscopic probe is inserted through the AL portal. To calculate the proper spacer size, add 1 cm to the distance between the superior glenoid rim and the greater tuberosity (Fig A; and place the balloon-loaded insertion tube 1 cm medial to the glenoid margin. Afterward, the insertion tube is drawn back, showing the balloon rolled up (Fig 7B). A graduated syringe connected to the introduction equipment was used to fill the balloon with a 25 ml of irrigation fluid. The balloon is then sealed, and the insertion device is removed (Fig 7C).

Closure and Postoperative Care

After incision closure, a compressive bandage is applied to the axillary fold. The patients used a 60° abduction and neutral rotation sling for 6 weeks. Wagner et al.[5] described our rehabilitation protocol.

Discussion

MIRCTs, especially those with CLEER, often represent a significant treatment challenge. Posterosuperior rotator cuff deficiency can develop when the infraspinatus and teres minor muscles are dysfunctional because of significant atrophy and fatty infiltration. CLEER is an infrequent but incapacitating condition observed in a subset of patients with MIRCTs.[1,3]

Isolated tendon transfer appears not sufficiently robust to restore active external rotation in patients with CLEER,[6] especially in grade 2 cases.[2] In conjunction with RSA, the L'Episcopo procedure[7] has demonstrated a substantial improvement in active external rotation.[8] However, RSA is associated with consistently high rates of complications in patients under 60 years of age.[9,10] In addition, research focused on the results of RSA in young patients is scarce, as are existing data on

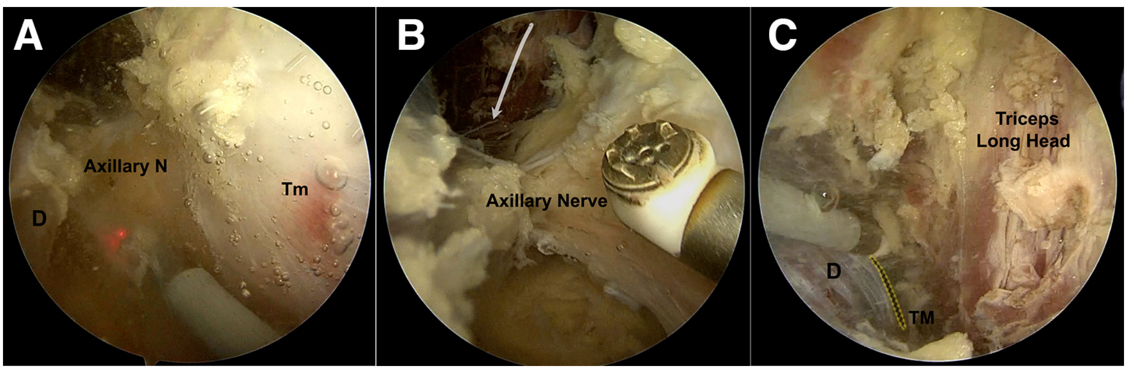

Fig 2. Arthroscopic view of the right shoulder in beach-chair position using a 30° arthroscope from the lateral viewing portal for the arthroscopy-assisted latissimus dorsi transfer and implantation of a subacromial balloon spacer. Creation of the subacromial passage space. (A) Opening the interval between the teres minor (Tm) and deltoid (D) muscle. (B) Neurolysis of the posterior branch of the axillary nerve. The white arrow indicates the area where the latissimus dorsi (LD) tendon should be transferred. (C) Identification of the passage space. Medial to the axillary nerve, the vertical fibers of the long head of the triceps are identified and dissected down to the horizontal fibers of the teres major (TM). The plane between the deltoid and the TM (yellow dotted lines) is recognized for the passage of the LD tendon.

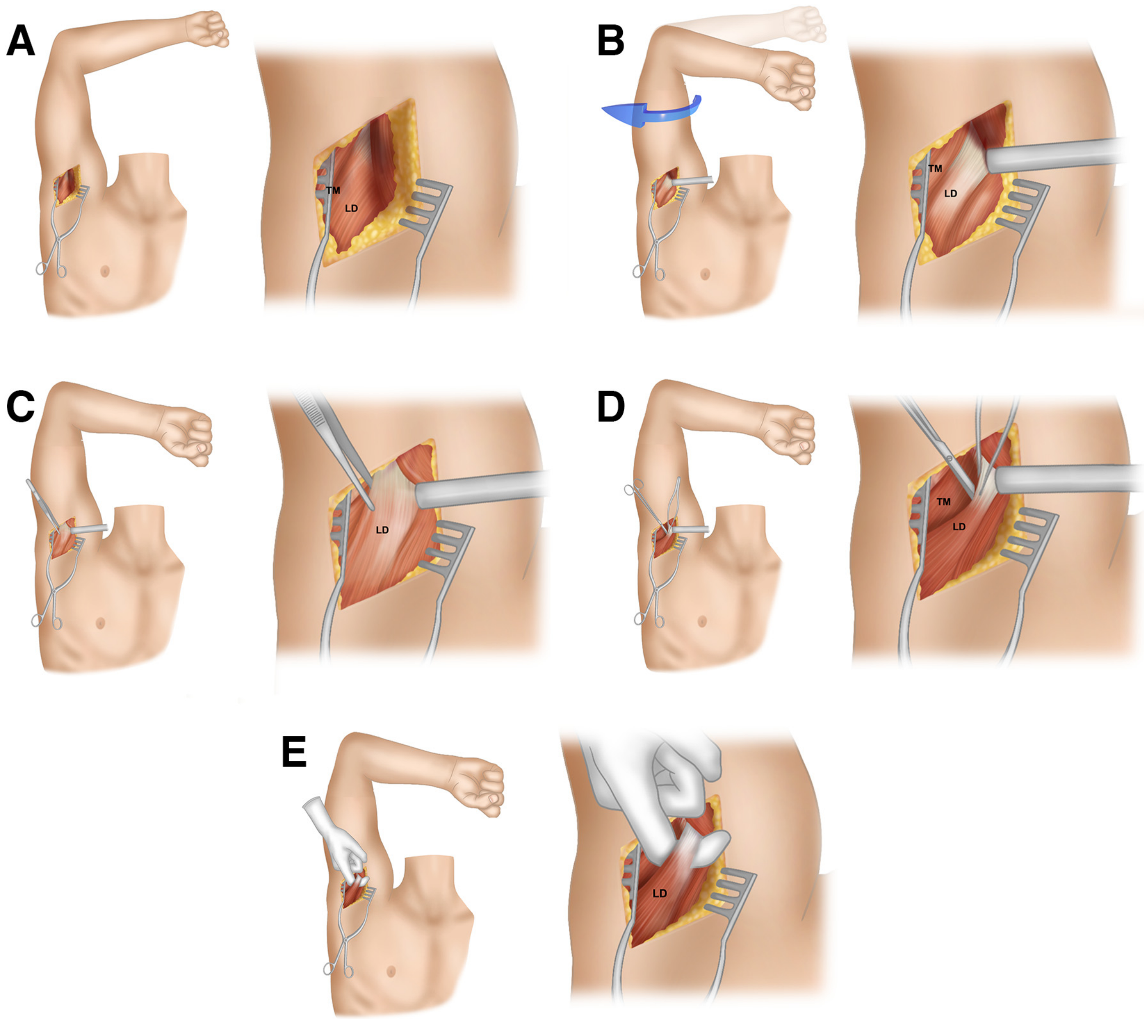

Fig 3. Illustration of the harvesting of the latissimus dorsi tendon through the axillary approach in a patient's right shoulder placed in a beach-chair position. The shoulder is in full forward elevation. (A) Belly of the latissimus dorsi (LD) and teres major (TM) after subcutaneous dissection. The shoulder remained in internal rotation. (*B*) The shoulder is internally rotated for the following steps. Exposure of the LD aponeurotic band and tendon after blunt dissection in internal rotation of the arm. (C) The inferior margin of the LD tendon is more clearly identified toward its proximal insertion, facilitating the dissection of the LD from the TM. (D) The posterior surface of the LD tendon is dissected until the superior border is released from the TM. Care must be taken at this stage to protect the axillary nerve. (E) Excursion of the LD muscle is verified after subcutaneous adhesions and periscapular insertions are released.

surgical options for MIRCT in patients without severe osteoarthritis.[9]

The optimal treatment for patients with forward elevation pseudoparesis and loss of external rotation is unknown,[2,6,8,9] and the options that include RSA appear to be reserved for patients with arthropathy.[9] Among the various joint preservation surgical approaches described for MIRCTs,[4,6] many studies have demonstrated the clinical reliability of LDTT,[4] particularly as a primary procedure.[11,12] In a long-term follow-up cohort of 108 patients, the rate of clinical failure of LDTT was 10%, and the conversion to RSA was 4%. Pain relief and improved shoulder function were consistent after 9 years, particularly in younger patients.[13] However, in cases with CLEER grade 2, an isolated tendon transfer might not be effective in restoring the bidirectional deficit,[4] according to the general principle guiding tendon transfers, which states that a single tendon should be transferred for a single function.[14]

SBS is a new surgical option for a subset of patients with MIRCTs.[15] In a cadaveric model of MIRCT, SBS restored the glenohumeral contact pressure close to the intact state and lowered the humeral head at post-operative time zero.[16] Additional biomechanical studies demonstrated that SBS had an effect on deltoid load comparable to that observed in RSA.[16] Furthermore, in an experimental study, mean and peak pressures in the

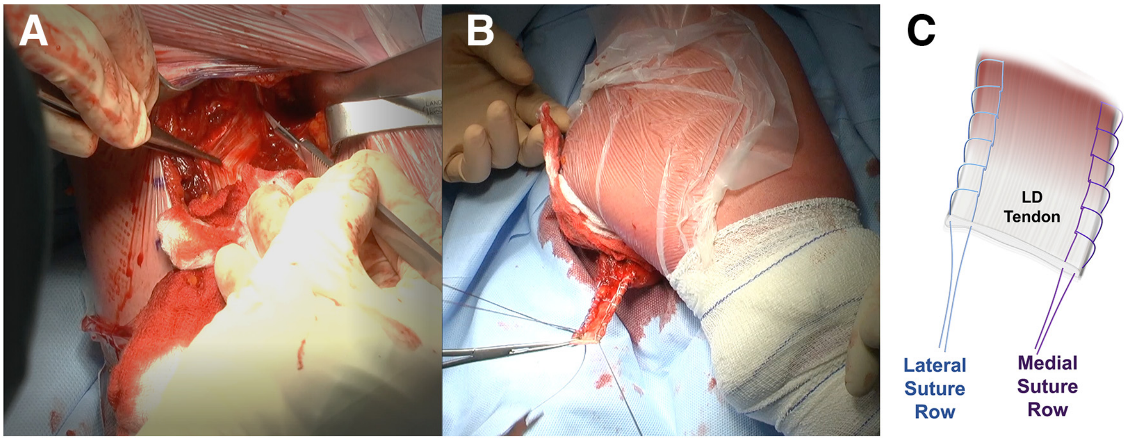

Fig 4. Latissimus dorsi (LD) tenotomy and suture placement using the axillary approach in a right shoulder in beach-chair position. (A) LD tenotomy with the shoulder placed in maximum internal rotation and complete forward elevation. A blunt retractor was carefully placed on the humerus to protect the radial nerve. (B) The shoulder was placed in adduction and internal rotation. Two rows of Krakow stitches were placed on the LD tendon, one medial and one lateral. The medial row was placed on the superior border of the LD and was identified with a colored suture. (C) Illustration of the final appearance of the harvested and prepared LD with Krakow stitches while maintaining the shoulder in adduction and internal rotation. The lateral row of stitches was placed on the inferior border of the LD. In the following steps, the medial and lateral rows of sutures would fix the transfer to the medial and lateral edge of the rotator cuff footprint using knotless anchors.

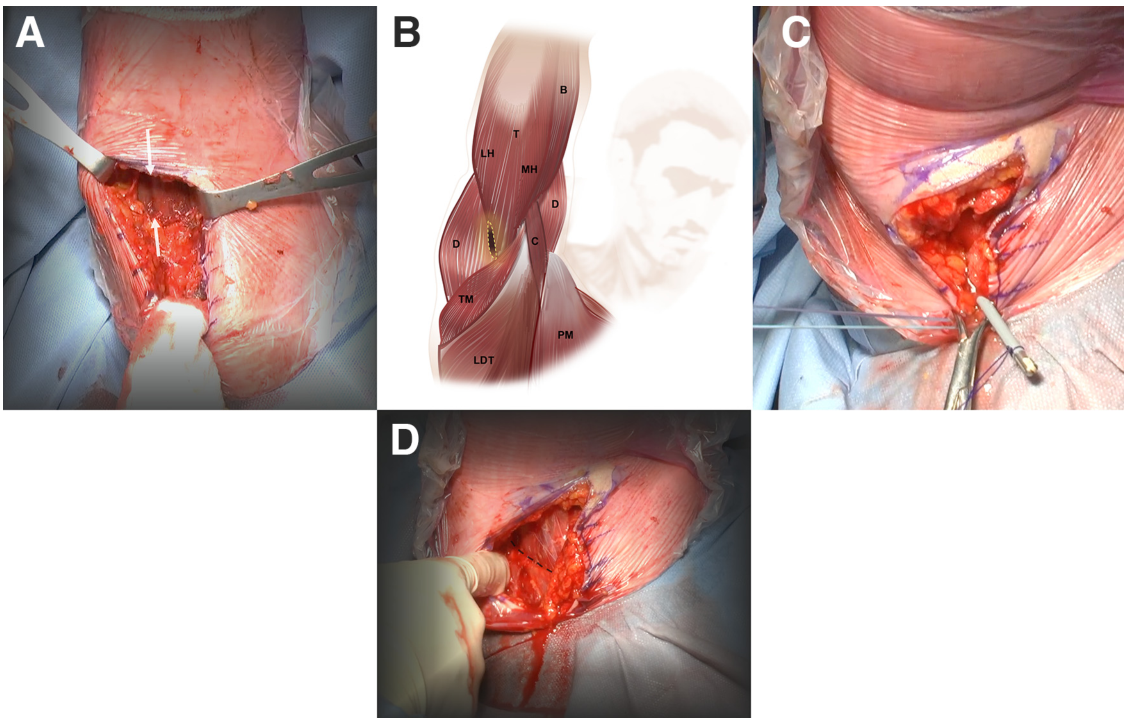

Fig 5. Transfer of the latissimus dorsi tendon to the subacromial space in a right shoulder in beach-chair position. The shoulder is placed at maximum forward elevation. (A and B) An intermuscular plane is created above the teres major (TM), between the long head of the triceps (LH) and the deltoid (D) muscle (white arrows and yellow dotted lines). B, biceps, C, coracobrachialis; PM, pectoralis major. (C) In previous steps, under arthroscopic visualization (not illustrated), the radio frequency is introduced in the posterior portal to exit via the axillary approach through the previously created intermuscular plane (yellow dotted lines). A PDS #1 loop is tied to the tip of the RF to transport the latissimus dorsi tendon (LDT) sutures. (D) The LDT is transported by pulling the sutures from the posterior portal. The surgeon's finger is used to verify the excursion of the muscle. The dotted black line marks the superior border of the latissimus dorsi.

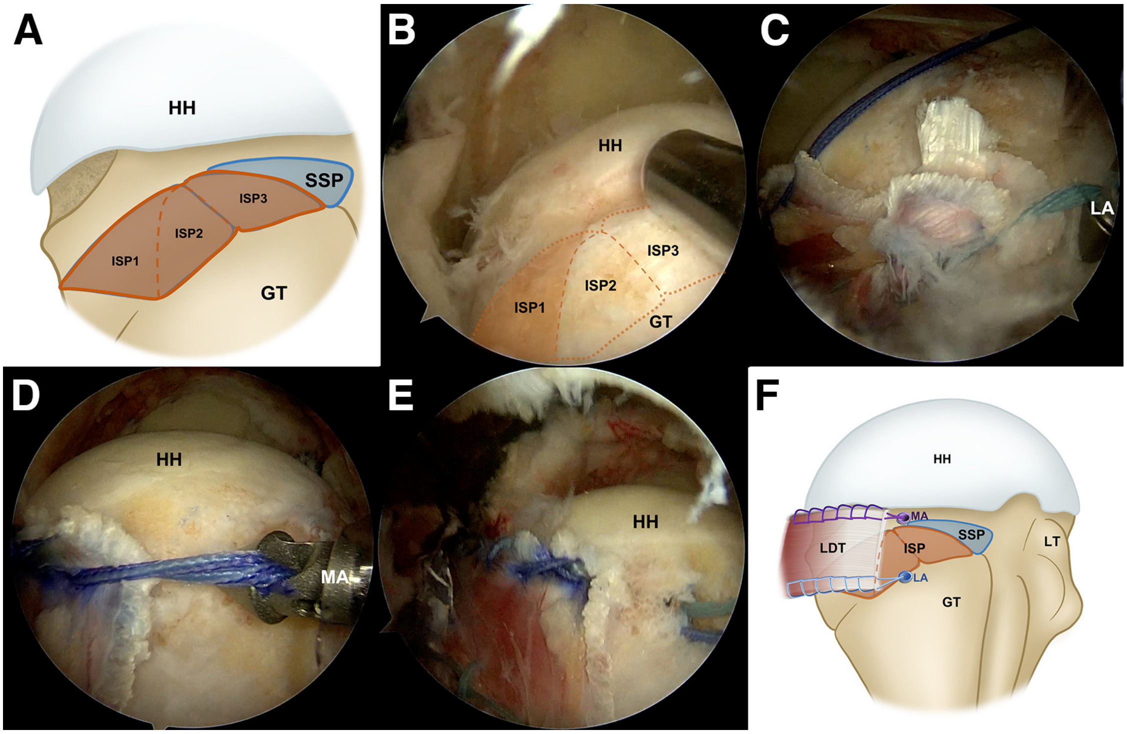

Fig 6. Arthroscopic view and illustrations of latissimus dorsi tendon (LDT) fixation in a right shoulder in beach-chair position. A 30° arthroscope was used from the lateral viewing portal. (A) Tendon footprint of the supraspinatus (SSP) and infraspinatus (ISP). The ISP was subdivided into three parts: lower (ISP1), middle (ISP2), and upper (ISP3). The goal was to place the anchors on ISP2 so that the tendon heals on ISP1. (B) Debridement and skeletonization of the greater tuberosity with a motorized shaver. (C) The lateral suture row is fixed using the lateral knotless anchor (LA) in the lateral aspect of the greater tuberosity (GT). (D) The medial suture row is fixed using a medial knotless anchor (MA) near the humeral head (HH) cartilage. (E) Final view of the LDT transfer. (F) Schematic illustration shows the anchor fixation points in the footprint and the target bone-tendon contact area in ISP1.

acromial undersurface were significantly reduced after SBS insertion, indicating that the use of SBS provides less wear to the cuff repairs and may potentially prevent reruptures of subacromial reconstruction procedures.[17] These findings and several clinical studies suggest that SBS may be a bridge option for the RSA procedure in patients with MIRCTs.[16,18]

This surgical procedure addresses the bidirectional deficiency of the rotator cuff with an arthroscopy-assisted LDTT followed by SBS implantation (Fig 8). The dynamic effect of

LDTT, produced by the fixation on the middle portion of the infraspinatus footprint,[19] is used to restore the external rotational coupling of the shoulder.

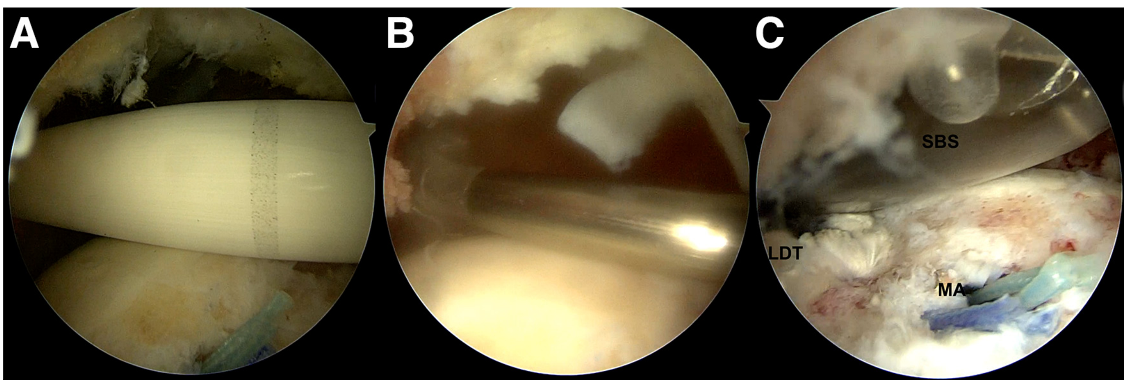

Fig. 7. Arthroscopic view of the implantation of the subacromial balloon spacer (SBS) in a right shoulder in a beach-chair position. A 30° arthroscope was used from the lateral viewing portal. (A) Probe placement and positioning of the laser mark on the greater tuberosity near the cartilage margin. (B) The balloon is rolled before being filled with irrigation fluid. (C) The final position of the SBS between the latissimus dorsi tendon (LDT) and the medial anchor (MA).

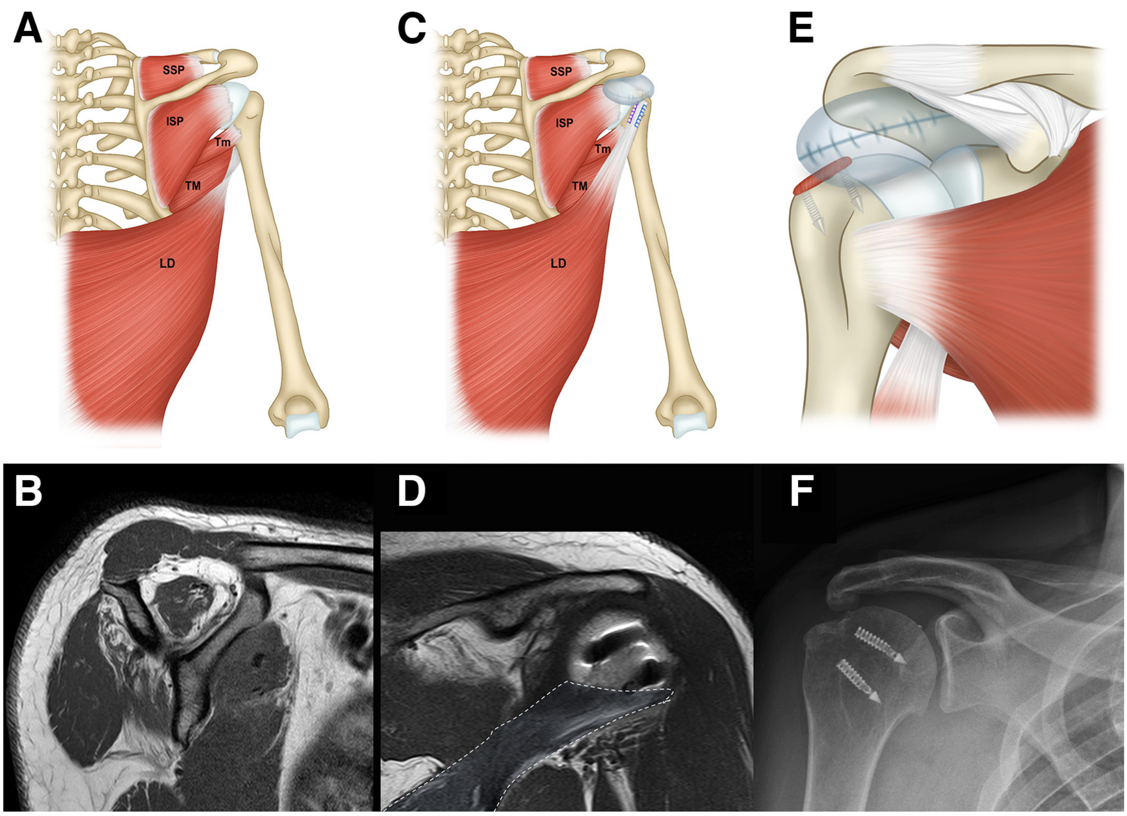

Fig. 8. Latissimus dorsi (LD) transfer combined with subacromial balloon spacer for massive irreparable rotator cuff tears (MIRCT). (A) Posterior view of the periscapular musculature with a MIRCT involving supraspinatus (SSP), infraspinatus (ISP), and teres minor (Tm). (B) Preoperative parasagittal T1-weighted image showing combined atrophy and fatty infiltration in SSP, ISP, and Tm in a patient who lost active forward elevation and active external rotation. (C) Illustration of the posterior periscapular musculature after surgery. (D) Postoperative T1-weighted coronal image showing LD transfer (white dotted lines). (E) Illustration of the shoulder after the procedure. (F) Postoperative anteroposterior radiograph of the shoulder showing the anchorage.

Furthermore, the SBS is intended to improve the mechanics of glenohumeral contact by centering the head and protecting the transfer of the tendon from subacromial compression stresses.

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