



Restoring the Anteroposterior Shoulder Force Couple: Arthroscopic-Assisted Lower Trapezius Tendon Transfer With Partially Augmented Rotator Cuff Repair for Irreparable Massive Rotator Cuff Tears

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Abstract: Lower trapezius transfer presents a highly encouraging therapeutic approach for addressing posterosuperior irreparable massive rotator cuff tears. Based on studies on the balance of force couples of the rotator cuff, more scholars believe that attention should be paid to the reconstruction of the force couples of the rotator cuff. This study proposes a modified surgical approach that integrates an arthroscopic-assisted lower trapezius transfer with autologous hamstring tendon and partially augmented rotator cuff repair for irreparable massive rotator cuff tears, with a focus on restoring the anterior-posterior shoulder force couple.

Irreparable massive rotator cuff tears (IMRCTs) pose a significant clinical challenge for shoulder surgeons, accounting for up to 40% of all cases of operated rotator cuff tears.¹ Tendon transfers are a viable option for the reconstruction of IMRCTs, achieved by transferring the latissimus dorsi, teres major, or lower trapezius.²⁻⁹ The balance between the subscapularis and infraspinatus/teres minor complexes in the transverse plane is called “the transverse force couple.”¹⁰ Lower trapezius transfer (LTT) can achieve excursion and vectors more akin to those of the infraspinatus and teres minor muscles, which can provide a better balance of anterior-posterior forces across the entire shoulder joint.^{11,12} It may be recommended for younger patients with massive rotator cuff tears.¹³

Numerous techniques for LTT have been suggested, encompassing both open and arthroscopic-assisted

approaches.^{8,9} Elhassan et al.⁸ used acromial osteotomy to expose the proximal humerus. To circumvent complications such as acromial nonunion and preserve the deltoid insertion, minimally invasive and arthroscopic-assisted techniques were developed.¹⁴ This Technical Note introduces a surgical approach that integrates an arthroscopic-assisted LTT with partially augmented rotator cuff repair for the treatment of IMRCTs. This technique promotes the restoration of the equilibrium between the anteroposterior aspects of the shoulder.

Surgical Technique

The indications and contraindications are listed in [Table 1](#). The whole procedure of the surgery is shown in [Video 1](#). The surgical steps, tips, pearls, and pitfalls are shown in [Table 2](#). The advantages, risks, and limitations are shown in [Table 3](#). The surgical procedure and arthroscopic findings are shown in [Figure 1](#). The final construct is shown in [Figure 2](#).

Patient Preparation, Arthroscopic Portals, and Diagnostic Examination

The surgical intervention is executed under general anesthesia. The skin is demarcated to identify the scapula spine, medial border of the scapula, and origin of the trapezius ([Fig 1A](#)). Initially, a routine diagnostic arthroscopic examination of the shoulder is performed using 3 distinct approaches. The supraspinatus and

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2212-6287/24420

<https://doi.org/10.1016/j.eats.2024.103176>

Table 1. Indications and Contraindications

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|--|
| Indications |
| 1. Irreparable massive posterosuperior rotator cuff tears |
| 2. Infraspinatus fatty infiltration grade ≥ 3 (Goutallier classification), infraspinatus muscle atrophy \geq moderate (Warner classification) |
| 3. Positive external rotation lag sign |
| Contraindications |
| 1. Rotator cuff tear arthropathy: stage 5 (Hamada classification) ²¹ |
| 2. Irreparable subscapularis tendon tear |
| 3. Deltoid deficiency |
| 4. Neurogenic pseudoparesis |
| 5. Recurrent dislocation of the shoulder |
| 6. Fracture around the humeral head and glenoid |
| 7. Infection around the shoulder |
| 8. Fatty infiltration of teres minor (grade ≥ 3) represents only a relative contraindication |

infraspinatus tendon ruptures are determined by arthroscopy (Fig 1B).

Autologous Hamstring Tendon Preparation

A 2- to 3-cm oblique incision is performed at the medial and inferior border of the tibial tuberosity on the ipsilateral side of the patient's affected shoulder, and the semitendinosus tendon and gracilis tendon are removed with a tendon stripper (Smith & Nephew Endoscopy). The tendon is folded in half and combined into 2 strands, with the circular end being drawn with a No. 5 Ethibond suture (Ethicon) and the free end being braided and sutured with a No. 2 Ethibond suture (Ethicon). Unequal length folding is performed when the length is insufficient (Fig 1C).

Arthroscopic Autologous Hamstring Tendon Passage and Fixation

The supraspinatus tendon is repaired with an anchor (DePuy Synthes) using a conventional technique. Biceps tendon fixation with the same anchor is performed if the anterosuperior area does not have enough tissue for partial repair. An anchor (DePuy Synthes) is inserted close to the cartilage margin, along with a third anchor (Smith & Nephew) between the superior margin of the pectoralis major and the trochlear exit of the biceps tendon (Fig 1D). A bone groove is made at the corner of the greater tuberosity. If there is a residual tendon in the infraspinatus tendon that can be partially repaired, the tail line is passed through the repairable part of the infraspinatus tendon (Fig 2).

Under arthroscopic supervision, the exchange rod is threaded through the anterolateral approach and then along the infraspinatus tendon surface and the subdeltoid space (located beneath the spinae scapulae) toward the subcutaneous projection of the lower trapezius tendon. The graft tendon lead is retrieved through the same tunnel, and the woven graft tendon reverse fold end is introduced into the joint. The graft tendon bypasses through the middle of the suture securing the stump of the infraspinatus tendon, as well

as through the prefabricated groove of the greater tuberosity, ultimately reaching the exit of the intertubercular groove (Fig 1E). The reverse end of the graft is secured with the other thread of the biceps tendon anchor.

The suture passing through the stump of the infraspinatus muscle is tied across the transplanted tendon. If the infraspinatus tendon cannot be partially pulled to the proximal humeral imprint area, a suture is first used to cross the graft tendon for fixation, and another suture is used to tensely braid the retracted infraspinatus tendon to the graft tendon. The medial margin of the supraspinatus tendon is also sutured side to side with the graft tendon if tension is allowed (Fig 1F).

Lower Trapezius-Autologous Hamstring Tendon Attachment

After fixation, an arthroscopic dorsal scapular manipulation is performed. A blunt puncture head is threaded oblong upward to the spine of the scapula. A radiofrequency knife is used to create an operating space on the musculofascial surface of the scapular spine to further expose the tendon graft, scapular tuberosity, and middle and lower trapezius bundles at the insertion area of the scapular spine (Fig 1G). The traction of the transplanted tendon is relaxed, allowing the transplanted tendon near the lower edge of the inferior trapezius bundle. Using the Livatec thread-crossing device, a 0-size Puttis thread is used to suture 3 times with a side-to-side noose. The reliability of the graft tendon and the traction and tension of the inferior trapezius bundle are examined under an arthroscope. The insertion of the lower trapezius bundle is then released from the spine of the scapula (Fig 1H).

Postoperative Protocol

The shoulder is protected in a brace for the first 6 weeks. Patients are allowed to start voluntary exercise involving the elbow, wrist, and hand of the affected limb on the first postoperative day. From 3 to 6 weeks, the patients can remove the brace intermittently for passive shoulder exercises, including forward flexion, abduction, and external rotation. From 6 to 12 weeks, active motion of the shoulder joint is permitted, while respecting pain-free range-of-motion limits and avoiding any activation of the LTT. Three months later, the patients are allowed to perform shoulder abduction and external rotation with scapular retraction.

Discussion

According to the suspension bridge model theory,^{15,16} the axis of rotation of the glenohumeral joint can be stabilized by rebalancing the anterior and posterior force couple, leading to less shoulder impingement and less inflammation. The absence of the rotator cuff and superior capsule may disrupt the shoulder force couple

Table 2. Surgical Steps, Tips, Pearls, and Pitfalls

| Surgical Steps | Tips and Pearls | Pitfalls |
|---|--|--|
| Patient positioning | <ol style="list-style-type: none"> 1. The patient is positioned laterally with a 15° upper back tilt, 40° shoulder abduction, roughly 15° of forward flexion, and 4 kg of longitudinal traction. 2. The ipsilateral lower leg is prepared simultaneously. | Anatomic orientation and positioning are more challenging in the lateral decubitus position than the beach-chair position. |
| Diagnostic arthroscopic examination | <ol style="list-style-type: none"> 1. Five distinct approaches: the posterior approach, the anterior approach, the lateral acromial approach, the anterolateral acromial approach, and the anterior acromioclavicular joint approach. 2. The posterior approach is performed to evaluate the intra-articular and subacromial conditions, with acromioplasty being carried out as needed. 3. The lateral acromial approach is employed to examine the rotator cuff, biceps tendon, intertubercular groove surface, and subscapular tendon. | |
| Autologous hamstring tendon preparation | <ol style="list-style-type: none"> 1. A 2- to 3-cm oblique incision is performed at the medial and inferior border of the tibial tuberosity, and the semitendinosus tendon and gracilis tendon are harvested full length from the insertion site with a tendon stripper. 2. The 2 tendons are combined and then folded unequally to guarantee a length of 16 cm for men and 15 cm for women, with the circular end being drawn with a No. 5 Ethibond (Ethicon) and the free end being braided and sutured with a No. 2 Ethibond suture. 3. The length of the graft tendon is controlled at 16 cm. 4. The tibial side's thick end is merged and retained at the longer end, while the 4-strand portion is sutured to achieve a wide and flat configuration. | <p>Unequal length folding is performed to ensure enough length.</p> <p>More time needed to harvest autograft.</p> <p>Complications at the donor site.</p> |
| Arthroscopic autologous hamstring tendon passage and fixation | <ol style="list-style-type: none"> 1. The supraspinatus and infraspinatus tendon insertions are prepared with the shaver, creating a bleeding bone surface. 2. An anchor is inserted near the cartilage edge of the supraspinatus footprint and the supraspinatus tendon is partially repaired using a conventional technique. If there is insufficient tissue in the anterosuperior area for partial repair, biceps tendon fixation using the same anchor is conducted. A second anchor is positioned near the cartilage margin on the lower-half footprint of the infraspinatus, while a third anchor is placed in the intertubercular sulcus between the superior margin of the pectoralis major and the trochlear exit. 3. A bone groove of approximately 5 × 5 mm is made at the corner of the greater tuberosity on the line between second and third anchors. 4. If there is residual tendon in the infraspinatus tendon that can be partially repaired, the sutures of the second anchor are passed through the remaining infraspinatus tendon in a mattress way. If a repairable subscapularis tear is present, the use of a fourth anchor is necessary for proper repair. 5. The exchange rod is threaded through the anterolateral approach and then along the infraspinatus tendon surface and the subdeltoid space (located beneath the spinae scapulae) toward the subcutaneous projection of the lower trapezius tendon, followed by a 1-cm incision at the apex of the subcutaneous exchange rod. 6. The graft tendon lead is retrieved through the same tunnel with a wire grabber, and the woven graft tendon reverse fold end is introduced into the joint from the posteromedial side to the anterolateral side. 7. The graft tendon bypasses through the middle of the suture, securing the stump of the infraspinatus tendon, and through the prefabricated groove of the greater tuberosity, ultimately reaching the exit of the intertubercular groove, where the biceps tendon anchor is fixed. 8. The reverse end of the graft is secured with the other thread of the biceps tendon anchor. 9. The dorsal graft tendon leads are suspended and pulled with a hammer to maintain tension in the graft tendon. | <p>Insufficient graft tension can lead to inadequate external rotation.</p> <p>The best location for the tendon channel is under the deltoid muscle on the infraspinatus surface. The height of penetrating the skin should be parallel to the scapular spine, preferably approximately 2 cm below the scapular spine.</p> |

(continued)

Table 2. Continued

| Surgical Steps | Tips and Pearls | Pitfalls |
|--|--|--|
| Lower trapezius-autologous hamstring tendon attachment | 10. A suture is first used to cross the graft tendon for fixation, and another suture is used to tensely braid the retracted infraspinatus tendon to the graft tendon. | Identifying and releasing the lower trapezius tendon can be difficult. The lower trapezius should be sutured with higher tension than usual to connect the graft tendon, with the shoulder abducted at 40° during the suture. |
| | 11. The medial margin of the supraspinatus tendon is also sutured side to side with the graft tendon. | |
| | 1. A 1-cm observation incision is made at the posterior apex of the posterior axillary line, and a blunt puncture head is threaded oblong upward to the spine of the scapula. | |
| | 2. A hammer is hung at the other limb of the tendon to maintain tension on the tendon and reduce distortion, and the graft tendon is sutured to the inferior trapezius bundle under tension. | |
| | 3. A 1-cm operating incision is made above the tuberosity of the scapular spine. | |
| | 4. Using the Livatec thread-crossing device, a 0-size Puttis thread is used to suture 3 times with a side-to-side noose. | |
| | 5. The insertion of the lower trapezius bundle is then released from the spine of the scapula. | |
| | 6. The reliability and tension of the connection between the graft and lower trapezius tendon are examined under an arthroscope by adduction and rotation of the arm. | |

and cause upper migration of the glenohumeral joint. However, the acromion blocks the humeral head, forming pseudarthrosis and reestablishing longitudinal couple balance. Therefore, subacromial pseudarthrosis acts as a compensatory structure (superior pseudarthrosis support) so that we can focus on posterior reinforcement repair. Hence, this technique is suitable for patients with Hamada grade 3 or 4.

Fascia lata autograft,¹⁷ autologous hamstring tendon,^{6,18} and Achilles tendon allograft^{8,19} have been used for LTT. We prefer to use the hamstring tendon

autograft (semitendinosus and gracilis tendon), which facilitates fusion and reduces the risk of inflammatory reaction and disease transmission.²⁰ Allogeneic tendons are not readily available and expensive. The ipsilateral hamstring autograft is too short for folding, so asymmetrically folded tendon grafts are used to address this problem.

Side-to-side repair of the transplanted tendon is performed with the stump of the infraspinatus tendon and teres minor tendon to maximize the strength of the residual tendon. The rotator cuff stump is sutured

Table 3. Advantages, Risks and Limitations

Advantages

1. The main purpose of the technique is to restore the anterior-posterior force couple. There is no need to restore the rotator center of the humeral head in patients who already have pseudarthrosis beneath the acromion. So even patients with degeneration up to Hamada grade 4 are suited for this technique, with no concerns about the cuff on the top of the humeral head where the retear occurs most frequently.
2. The posterior shoulder force couple is reinforced by both lower trapezius transfer and a side-to-side margin repair between the tendon graft and the infraspinatus/teres minor complexes.
3. Surface fixation of the transferred tendon can be reliable and maximize the force moment.
4. Suture of the lower trapezius tendon and transferred tendon under arthroscopy is less invasive than during open approaches and can be copied easily for most shoulder-specific sports medicine surgeons.
5. The lateral decubitus position will be welcomed by many shoulder surgeons who are used to repairing the rotator cuff in this position.
6. Hamstring tendon harvest is safe and feasible for most surgeons.
7. Autograft facilitates fusion and reduces the risk of inflammatory reaction and disease transmission.
8. The procedure is not so time-consuming (approximately 60-90 minutes for the author) and is easy to copy for most shoulder-specific sports medicine surgeons.
9. Excellent cost-efficiency due to the less suture anchors needed (average 3 anchors) and autografts.

Risks

1. Additional approach for graft harvesting in the lower extremity may increase the risk of hematoma and thrombus in elderly patients.

Limitations

1. The hamstring autograft is not as wide and strong as the Achilles tendon allograft.
2. The reliability of function restoration of external rotation is still a challenge and long-term evidence is needed.
3. Healing and function recovery are time-consuming compared with the reverse shoulder prosthesis.

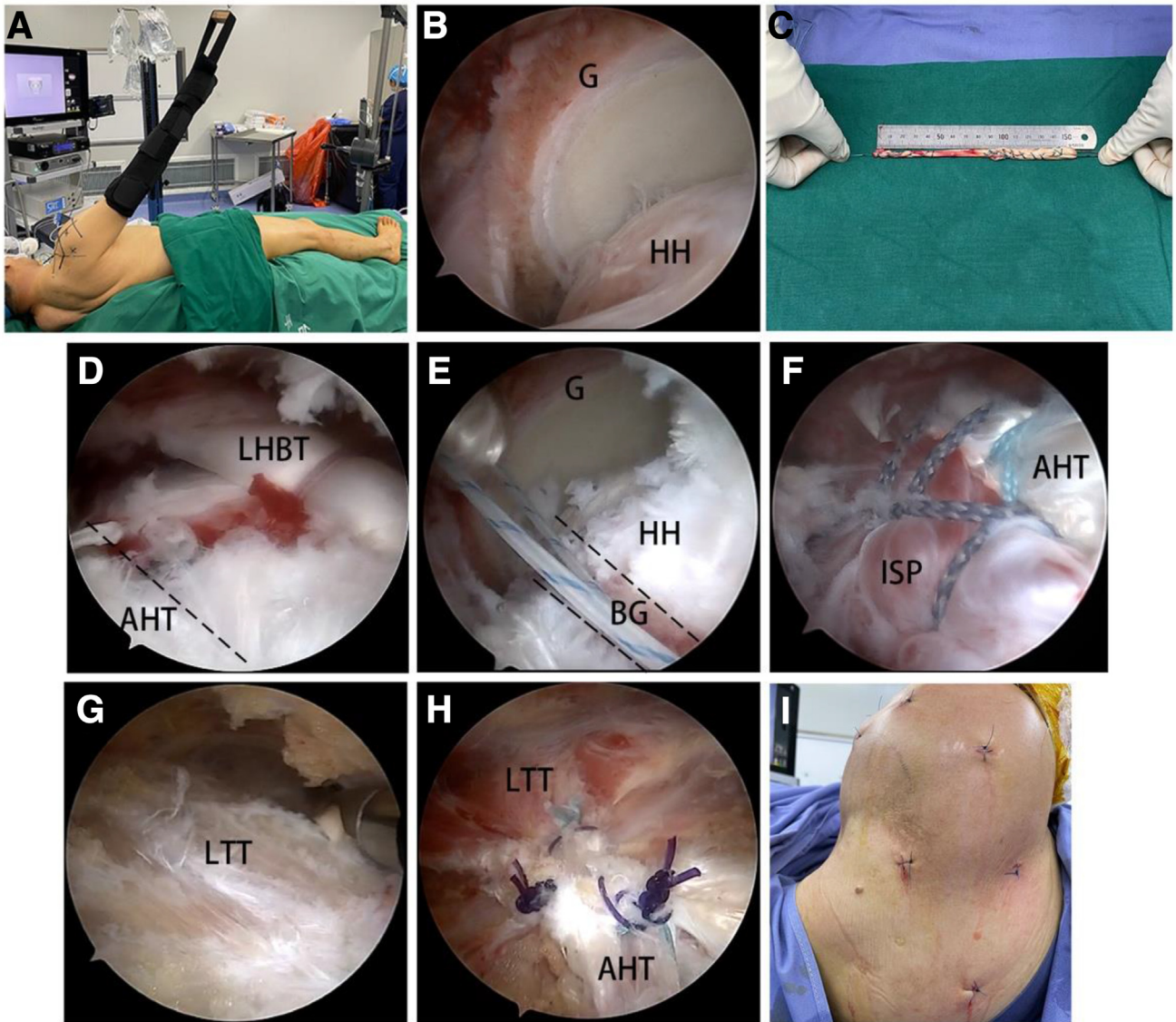


Fig 1. (A) Patient position and arthroscopic portals, right shoulder, lateral decubitus position. The patient is positioned laterally with a 15° upper back tilt, 40° shoulder abduction, roughly 15° of forward flexion, and 4 kg of longitudinal traction. The ipsilateral lower leg is prepared. The semitendinosus autograft is then extracted from the insertion of the pes anserinus. (B) According to the preoperative clinical and intraoperative findings, biceps tenodesis/tenotomy, posterosuperior rotator cuff repair, or subscapularis repair can be performed at the same time. A routine diagnostic arthroscopic examination of the shoulder is performed using 3 distinct approaches. The supraspinatus tendon can be pulled back to the footprint area or cannot be pulled back to the footprint area, and the infraspinatus tendon cannot be pulled back to the footprint area. Subacromial debridement is executed as a routine measure to excise a portion of the hyperplastic osteophytes located in the anterolateral acromial region while preserving the coracoacromial ligament's continuity. (C) The semitendinosus autograft is harvested with both ends sutured with No. 5 Ethibond (Ethicon). Unequal length folding is performed to ensure a length of approximately 16 cm. The tibial side's thick end is merged and retained at the longer end, while the 4-strand portion is sutured to achieve a wide and flat configuration. (D) Superior capsule reconstruction with long head of the biceps tendon if needed. If the supraspinatus muscle cannot be pulled back to the footprint area, the partial repair is performed as far as possible. If the long head of the biceps brachii tendon is available, a bone groove is made at the lateral corner of the greater tuberosity along the supraspinatus insertion to prevent the transposition of the biceps tendon from sliding forward. (E) The graft tendon bypasses the prefabricated groove of the greater tuberosity and is secured at the intertubercular groove. (F) The stump of the infraspinatus tendon and the teres minor tendon are sutured side to side with the transplanted tendon. (G) The transplanted tendon, scapular tuberosity, and middle and lower trapezius bundles are exposed under arthroscopy. (H) The graft tendon is bypassed under the inferior trapezius bundle and secured. (I) Postoperative small incision. (AHT, autologous hamstring tendon; BG, bone groove; G, glenoid; HH, humeral head; ISP, infraspinatus; LHBT, long head of the biceps; LTT, lower trapezius transfer.)

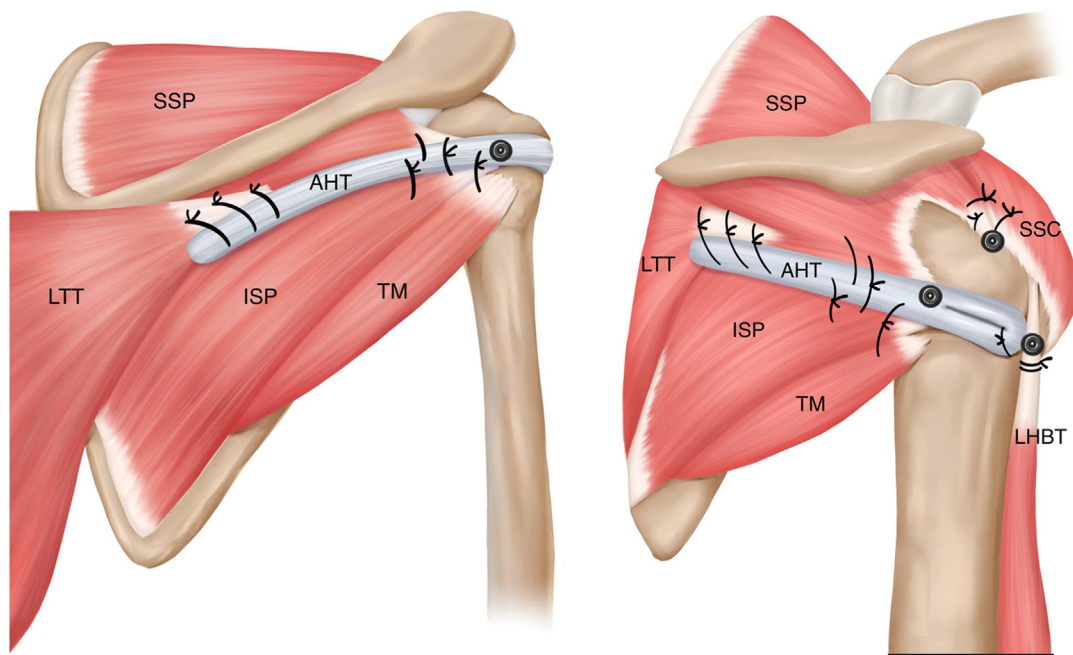


Fig 2. The final construct of the reconstruction. The graft tendon is routed around the prefabricated groove of the greater tuberosity and anchored at the intertubercular groove. The infraspinatus and teres minor tendons are then sutured in a side-to-side fashion with the graft tendon. The graft tendon is bypassed under the inferior trapezius bundle and secured. The rebalancing of the anterior and posterior shoulder force couple is achieved through the implementation of lower trapezius transfer and a side-to-side margin repair between the tendon graft and the infraspinatus/teres minor complexes.

considering the potentially low-force conduction of the inferior trapezius bundle. The tension of the transplanted tendon is weakened because of its long path; moreover, adhesion may develop around the graft tendon channel. Although the stump of the infraspinatus tendon and the stump of the teres minor tendon cannot be directly sutured to the humeral head due to fatty infiltration and contracture, it can be connected to the humeral head by bridging the tendon under tension.

Surface fixation is performed for the tendon-bone healing interface. Surface fixation appears less rigid than tunnel fixation but may present its advantages. Fixation is performed at 2 locations, which increases the reliability. The bone groove at the corner promotes healing and reduces the risk of impact and wear. A 2.5- to 3-cm contact surface is maintained between the cartilage edge of the infraspinatus tendon insertion to the intertubercular groove and the superior edge of the pectoralis major, providing ample adhesion interface and adhesion strength. In addition, an angled fixation is designed to increase the friction force.

The tendon graft is positioned onto the surface of the infraspinatus tendon to maintain sufficient distance from the joint, thereby reducing the impact of synovial fluid on the healing process. This placement ensures that the tendon graft follows a linear trajectory and achieves optimal rotational torque. The remaining

infraspinatus tendon and teres minor tendon are sutured under the transplanted tendon for the same reason as above.

Disclosures

All authors (J.Z., G.Z., Y.Y., Liwei Ying, Li Ying, Q.Z., X.Z.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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