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Review Article

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The Utility of Lower Trapezius Transfers in Massive Irreparable Posterior-Superior Rotator Cuff Tears

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Abstract

Massive irreparable rotator cuff tears (RCT) present a challenging problem when they occur in the young, active patient population. One treatment option involves tendon transfer, which traditionally has involved the latissimus dorsi transfer (LDT). However, the lower trapezius transfer (LTT) has emerged as an effective alternative with its own set of advantages, such being a tendon transfer that is "in line" and "in phase" with the shoulder functions it restores. Moreover, biomechanical and clinical studies have supported the LTT as an effective treatment option that restores the shoulder function to a great degree with successful outcomes. In this review, we discuss the indications, biomechanics, open and arthroscopic assisted surgical techniques, and outcomes of LTT for massive irreparable RCTs.

Keywords: Lower trapezius transfer; Massive irreparable rotator cuff tear, Latissismus dorsi transfer, Shoulder

Abbreviations: RCT: Rotator Cuff Tear; LDT: Atissimus Dorsi Transfer; LTT: Lower Trapezius Transfer; TMT: Teres Major Transfer; ERMA: External Rotation Moment Arm; ISI: Infraspinatus Insertion; TMI: Teres Minor Insertion; SHH: Superolateral Humeral Head; LHD: Lateral Humeral Diaphysis; VAS: Visual Analogue Scale; SVV: Subjective Shoulder Value; DASH: Disabilities of the Arm, Shoulder, and hand ASES: American Shoulder and Elbow Society ADLER: Activities Of Daily Living That Require Active External Rotation; oLDT: open Latissimus Dorsi Transfer aLDT: Arthroscopically Assisted Latissimus Dorsi Transfer; SANE: Single Assessment Numeric Evaluation

Introduction

Massive irreparable rotator cuff tears (RCT) represent challenging problems in both the primary and revision setting. These patients typically present with severe pain and loss of shoulder function, and if left untreated undergo a predictable progression of arthritic changes [1-3]. The definition of "irreparable" remains unclear, but multiple factors are considered including patient comorbidities, tear chronicity, imaging, and previous surgeries [4]. After a trial of conservative management, a wide array of surgical options exists for massive irreparable RCTs, which include rotator cuff debridement, partial rotator cuff repair, biceps tenotomy and tenodesis, tendon transfers, superior capsule reconstruction, subacromial balloon, and reverse shoulder arthroplasty [4].

When a massive irreparable RCT occurs in a young, active patient, tendon transfers represent a viable treatment option [5-8]. Compared to shoulder

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arthroplasty, tendon transfers have no concern for implant failure or implant longevity, making tendon transfers an optimal treatment option in this specific patient population [9]. The common tendon transfers described for RCTs include the latissimus dorsi transfer (LDT) and the lower trapezius transfer (LTT). Moreover, the teres major transfer (TMT) has also been described both in isolation and in conjunction with the LDT, as well as pectoralis major and pectoralis minor transfers [10].

The LDT was first described by L'Episcopo [11] in obstetric brachial plexopathy in 1934 and then utilized for massive irreparable RCTs by Gerber et al. in 1988 [12]. The latissimus dorsi originates broadly from the iliac crest, thoracolumbar fascia, and spinous processes of the lower thoracic and lumbar vertebrae to then insert on the bicipital groove floor of the humerus. The LDT involves the transfer of the latissimus dorsi tendon from its original insertion to the greater tuberosity, which converts the latissimus dorsi into an external rotator and a flexor of the glenohumeral joint [10]. The LDT has been shown to result in good to excellent pain relief, but the functional outcomes have been less predictable [9]. Moreover, the latissimus dorsi muscle contracts "out-of-phase" with the function of musculature it is meant to restore, the LDT may lead to altered glenohumeral kinematics and joint reactive forces predisposing to glenohumeral osteoarthritis, and several factors have been shown to lead to poorer outcome with LDT, such as subscapularis deficiency, teres minor deficiency, deltoid dysfunction, prior rotator cuff repair, glenohumeral osteoarthritis, acromioclavicular osteoarthritis, and critical shoulder angle >35° [4,9,13-15]. While LDT represents a potential treatment option, these disadvantages have led surgeons to investigate other tendon transfer options for massive irreparable RCTs in young, active patients [16].

The LTT was initially described by Elhassan et al. in 2009 also for a brachial plexopathy patient with lost shoulder external rotation [17]. The lower trapezius originates from the T4 to T12 vertebrae and inserts on the medial portion of the scapular spine. The LTT involves transferring the lower trapezius' insertion from the medial spine to the greater tuberosity with the use of a tendon autograft or allograft sutured into the lower trapezius tendon to allow the LTT to reach the greater tuberosity [10]. The LTT offers many advantages when utilized for massive irreparable RCTs compared to LDTs. First, the LTT is "in-line" with the vector of the infraspinatus muscle it is meant to replace [4,5]. Second, biomechanical studies have found the LTT to have better abduction and external rotation moment arms in addition to better restoring the anterior-posterior shoulder girdle force couple [9,18,19]. Third, the lower trapezius muscle activates and is "in-phase" with the shoulder motions of external rotation, elevation, and abduction, which makes rehabilitation of the LTT easier and quicker [4,5]. These advantages have led some surgeons to utilize the LTT for massive irreparable RCTs [5-8,20].

In this review, we discuss the indications, biomechanics, open and arthroscopic assisted surgical techniques, and outcomes of LTT for massive irreparable RCTs, as it has emerged as an effective alternative to previous tendon transfer operations.

Indications for a Lower Trapezius Transfer

The ideal candidate for a LTT for massive irreparable RCT is a young, motivated patient with the chief complaint of pain and weakness particularly with external rotation [5,10,16]. LTT is further indicated in patients with chronic changes regarding their rotator cuff, such as atrophy (Thomazeau grade ≥2), fatty infiltration (Goutalier grade ≥2), tendon retraction (Patte grade ≥2), and tendon length <1cm [4,10,16,21,22]. Contraindications include multiple medical comorbidities with contraindications to surgery, advanced age (≥70-75 years old), infection, inability to comply with postoperative rehabilitation and instructions, advanced glenohumeral osteoarthritis, rotator cuff arthropathy (Hamada grade ≥3), osteoporosis, stiff glenohumeral joint, trapezius deficiency, subscapularis deficiency, and deltoid deficiency in addition to forward flexion <60 being a relative contraindication [4,16].

Of these indications and contraindications, some of the most important considerations include the integrity of the subscapularis, the integrity of the deltoid, and the absence of glenohumeral osteoarthritis and/or rotator cuff arthropathy. An intact, or at least reparable, subscapularis is required since the LTT dynamically stabilizes and restores the shoulder girdle force couple. With the LTT stabilizing the force couple of the shoulder from the posterior aspect, an intact subscapularis is needed to dynamically stabilize the shoulder girdle from the anterior aspect. An intact deltoid is required as the deltoid provides the majority of the power for active elevation. In the absence of a functioning deltoid, the LTT will be able to restore external rotation, but a healthy deltoid is needed to achieve full abduction and elevation following the procedure. Finally, the absence of glenohumeral osteoarthritis and rotator cuff arthropathy is required as the soft tissue procedure of a LTT cannot properly address this arthritic pathology as it is a joint preserving procedure [4].

As stated, LTT can be indicated for RCTs when they are massive and irreparable. However, the definition of a massive irreparable RCT and what exactly deems as "irreparable" remains debated, but many factors are considered. Patient comorbidities such as diabetes, smoking, older age, inflammatory arthritis, osteoporosis, and an immunocompromised state have all been shown to lead to an increased rate of a rotator cuff repair retear [23-29]. The chronicity of the RCT also plays a role with rotator cuff repairs occurring within 6 months of the traumatic event having the best outcome [4,30-32]. Within the first year after an RCT, the muscle shortens and retracts, and within 2-4 years, muscle fatty infiltration and tendon shortening occurs [33,34]. All of these chronic changes affect the reparability of the RCT, as tendon retraction to the level of the glenoid (Patte grade 3) and tendon length <15mm lead to poorer clinical outcomes and higher re-tear rates, and combining these factors with advanced muscle fatty infiltration creates a specificity of 98% for an irreparable tear [22,35,36]. Moreover, muscle atrophy (Thomazeau grade ≥2) and an acromiohumeral interval <7mm are metrics indicative of an irreparable rotator cuff tear [37,38].

The LTT is also indicated for massive irreparable RCTs because it adheres to the foundational principles of when to consider a certain tendon transfer. These principles include 1) similar excursion between the transferred and recipient muscles, 2) the transferred muscle is expendable and won't compromise function, 3) similar line of action and adequate strength between the transferred tendon and the recipient muscle, and 4) each tendon transferred only replaces one function of the recipient [4,5].

Biomechanics of a Lower Trapezius Transfer

There has been much work analyzing the biomechanical effects of the LTT in addition to comparing it to the other commonly utilized tendon transfers. Omid et al. [9] studied 8 fresh-frozen cadaveric shoulders and compared the biomechanics of the LTT to the LDT at 0°, 30°, and 60° of abduction, respectively. They found that when a massive posterior-superior RCT was induced in their cadaveric specimens, the shoulder at rest demonstrated increased internal rotation at all abduction angles ($p<0.05$), decreased glenohumeral compression forces at all abduction angles ($p<0.0001$), an anteriorly directed shift in force at 0° abduction ($p<0.05$), and a humeral head that migrated superiorly with maximal internal rotation at all abduction angles ($p<0.05$) and both superiorly and laterally at 0° and 30° of abduction. The 24N LTT restored the glenohumeral compressive forces to within the normal ranges at all abduction angles ($p<0.05$), whereas the LDT did not. The 12N and the 24N LTT restored the anterior-posterior forces on the glenohumeral joint at all abduction angles, whereas the LDT only did so at 30° of abduction ($p<0.05$). Finally, the 36N LTT restored the humeral head in its native position from its migration superiorly and laterally at 30° of abduction ($p<0.05$), whereas the LDT did not. Overall, Omid et al. [9] concluded that the LTT was superior to the LDT in their cadaveric model in regard to restoring glenohumeral kinematics and joint reactive forces.

Hartzler et al. [18] utilized 6 fresh-frozen cadaveric hemithoraces and compared the external rotation moment arm (ERMA) of the LTT, LDT, and the TMT when transferred to different locations on the humerus. More specifically, the LTT was either transferred to the infraspinatus insertion (ISI) or the teres minor insertion (TMI), the LDT was either transferred to the superolateral humeral head (SHH) or the proximal lateral humeral diaphysis (LHD), and the TMT was either transferred to the SHH or the LHD. With the shoulder at 0° of abduction, the LTT-ISI (28.1mm ERMA) and the LTT-TMI (22.3mm ERMA) demonstrated significantly higher ERMAs compared to the LDT-SHH, LDT-LHD, and the TMT-LHD. The TMT-SHH was not significantly different from the LTTs. At 90° of abduction, there were no significant differences between the LTTs compared to the LDTs and TMTs. However, the ERMA of the LTT-ISI and the LTT-TMI did significantly decrease at 90° of abduction compared to the LTT-ISI and the LTT-TMI at 0° of abduction. Overall, Hartzler et al. [18] concluded that the LTT results in superior external rotation when the arm is at 0° of abduction compared to LDT.

Reddy et al. [19] used a computerized shoulder model to virtually perform LTT and LDT on the supraspinatus, infraspinatus, and teres minor insertion sites, respectively. They found that the LTT had a significantly larger abduction moment arm compared to the LDT for the first 65, 150°, and 120° of abduction when inserted on the supraspinatus, infraspinatus, and teres minor footprints, respectively ($p<0.05$). Moreover, the LTT had a positive moment arm value throughout shoulder range of motion when inserted on either the supraspinatus and infraspinatus footprint, whereas the LDT moment arm values were generally of lower value and ranged from negative to positive values. The exceptions of this were with regard to forward flexion and external rotation at 90° abduction, in which the LDT had a significantly larger moment arm than the LTT when inserted on the infraspinatus and teres minor insertions ($p<0.005$). However, the LTT demonstrated a larger external rotation moment arm compared to LDT when the arm was at 20° of adduction for both the infraspinatus and teres minor insertions ($p<0.005$). Overall, Reddy et al. [19] concluded that the LTT resulted in improved abduction and external rotation moment arms when transferred to the infraspinatus insertion, and the LTT demonstrated a biomechanical advantage compared to LDT for tendon transfer due to its stronger abduction moment arms.

Surgical Technique of a Lower Trapezius Transfer

The LTT can either be performed through an open procedure or an arthroscopically assisted procedure [5,7,8,20,39]. Both procedures begin with the patient positioning, which can either be in the standard beach-chair position with a Spider arm holder (Tenet Medical) or the lateral

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decubitus position. The relevant anatomy is marked, and the patient is draped. A horizontal incision is made just inferior to the scapular spine from 1cm medial of the medial edge of the scapula to 3-4cm lateral of the medial edge of the scapula. The medial aspect of the incision can be extended inferiorly if needed by creating a hockey-stick incision extension from the original incision. Then one dissects through the skin and subcutaneous tissues until the overlying fascia of the lower trapezius and infraspinatus are exposed. The inferior edge of the lower trapezius is bluntly dissected and mobilized from the underlying infraspinatus fascia. Then one traces the trapezius to its insertion [39]. Of note, the lower trapezius tendon has a triangular shape with a height of 23mm, length of 49mm, and a footprint on the medial scapular spine of 30mm [5]. The tendon is detached, and the lower trapezius is separated from the middle trapezius, as one can tell the distinction by the presence of a fat stripe. Of note, the neurovascular pedicle typically lies 2cm medial to the scapula on the undersurface of the lower trapezius. The lower trapezius tendon is then prepared with nonabsorbable sutures in a Krackow fashion for eventual transfer. The Achilles tendon allograft is then also sutured at its superior and inferior edges followed by an overlying suture tape [39]. After preparing the Achilles tendon allograft, the surgery can proceed with either an open technique or an arthroscopic technique to fix the graft to the greater tuberosity.

For the open procedure, a Saber incision is performed just medial to the lateral acromion and the interval between the anterior-middle deltoid and middle deltoid is developed. Next, an acromion osteotomy of 5mm thickness is performed at the portion of the acromion where the middle deltoid originates. The detached bone is then reflected laterally, and excellent exposure of the posterior-superior rotator cuff region is obtained. The torn rotator cuff tendon(s) are then intraoperative assessed and repaired either partially or fully based on intraoperative assessment. Moreover, a biceps tenodesis can be performed at this stage if biceps pathology is present. Next, the footprint of the supraspinatus and infraspinatus are debrided and prepared for the Achilles tendon allograft, which is fixed with multiple transosseous sutures and anchors to the medial and lateral edge of the footprint on the greater tuberosity [20].

On the other hand, to utilize the arthroscopic technique, the posterior, anterolateral, anterior, lateral, and posterolateral portals are created. Viewing from posterior portal and working from the anterior and lateral portals, the unhealthy rotator cuff is debrided and a subacromial decompression is performed. Any healthy rotator cuff is either partially repaired or secured with the LTT. Finally, a biceps tenodesis may be performed if a patient has concomitant biceps pathology. Viewing through the lateral portal and working through the posterolateral portal, the interval between the infraspinatus muscle belly is developed and the infraspinatus fascia is incised from the previous open incision to create a window for the LTT. Of note, during the interval development, one must stay medial to the axillary nerve. A grasping clamp is inserted through the anterolateral portal or lateral portal and passed through the medial open incision to grab the Achilles tendon allograft and transfer it into the joint. The graft is anchored into the superior and medial aspects of the greater tuberosity using the sutures and suture tape [39].

To finish the procedure in both techniques, the arm is positioned in maximal external rotation and 50° of abduction to fix the graft to the lower trapezius tendon. This is done by various techniques, but one technique involves splitting the graft in half and then sewing the inferior portion of the graft to the lower trapezius tendon in a Pulvertaft fashion, and then sewing the superior portion of the graft over the Pulvertaft weave and the lower trapezius musculotendinous junction. The incision is then closed with the graft in tension and a postoperative restriction and rehabilitation protocol is followed [39].

Outcomes of a Lower Trapezius Transfer

Elhassan et al. [5] reported their outcomes on 41 patients who underwent an arthroscopically assisted LTT for an irreparable posterior-superior RCT with an average follow-up of 14 months (range, 6—19 months). Of note, 27/41 (66%) of the study's patients had a previous rotator cuff repair that had failed. The authors utilized an Achilles allograft for excursion and anchored the tendon on the anterior aspect of the supraspinatus footprint. The authors found that 37/41 (90%) of the patients demonstrated significant improvements in pain and function by the outcome scores of visual analogue scale (VAS), subjective shoulder value (SVV), and disabilities of the arm, shoulder, and hand (DASH) ($p<0.001$). The shoulder range of motion was also significantly improved with forward flexion, abduction, and external rotation ($p<0.001$). However, internal rotation did not significantly change from preoperative assessment to postoperative follow-up. The authors stated that 38/41 (93%) of the patients demonstrated trapezius contraction at their latest follow-up indicative of no neurovascular injury. Moreover, 36/41 (88%) had significant improvement in external rotation strength. In their patient series, only 4 patients had poor outcomes with the LTT. 3 of these patients had preoperative arthritic glenohumeral changes, while the other patient had severe preoperative pseudoparalysis and weakness. The authors found that preoperative long-term symptoms of ≥2 years, rotator cuff arthropathy of Hamada grade ≥3, and pseudoparalysis significantly predicted negative clinical outcome scores ($p<0.05$). Overall, Elhassan et al. [5] concluded that arthroscopically assisted LTT can lead to good outcomes in patients with a massive irreparable RCT, even in patients with a prior failed rotator cuff repair.

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Two studies directly compared LTT versus LDT with respect to clinical outcomes, which were conducted by Baek et al. [7] and by Woodmass et al. [8]. Baek et al. [7] performed a respective review on patients that underwent arthroscopic assisted LTT or arthroscopic assisted LDT for an irreparable posterior-superior RCT with a minimum 2-year follow-up. After meeting the selection criteria, 42 patients underwent LTT, whereas 48 patients underwent LDT. All operations were performed by a single surgeon. The authors found that both LTT and LDT improved the VAS, American Shoulder and Elbow Society (ASES) score, and activities of daily living that require active external rotation (ADLER) score when comparing the patients from preoperatively to 2-year follow-up ($p<0.001$). Moreover, the LTT and LDT both resulted in significantly increased range of motion from preoperatively to 2-year follow-up with regard to active forward elevation and active external rotation ($p<0.001$). When comparing LTT directly to LDT at 2-year follow-up, LTT resulted in significantly increased ASES scores and ADLER scores. Moreover, LTT led to significantly increased active forward flexion ($p<0.10$) and active external rotation ($p<0.05$) compared to LDT at final follow-up. Finally, the LTT resulted in significantly lower Hamada grades ($p<0.001$) and lower rates of progression to arthritic change ($p<0.035$) at 2-year follow-up compared to LDT. Baek et al. [7] concluded that while both LTT and LDT can improve the clinical outcomes in the setting of irreparable RCT in young patients, LTT is superior to LDT with respect to shoulder range of motion, shoulder function, and progression of arthritis.

Woodmass et al. [8] also directly compared arthroscopically assisted LTT to both open LDT (oLDT) and arthroscopically assisted LDT (aLDT) with minimum 2-year follow-up. 8 patients underwent LTT, 10 patients underwent oLDT, and 16 patients underwent aLDT. All of the surgeries were performed by 1 of 2 surgeons. When comparing the patients preoperatively to their 2-year follow-up, LTT and aLDT led to significantly improved ASES function scores, ASES index scores, single assessment numeric evaluation (SANE) scores, and forward flexion range of motion ($p<0.05$). The aLDT additionally led to increased external rotation range of motion ($p<0.05$). The oLDT did not lead to any significant changes. When directly comparing LTT to LDT, LTT led to a significantly improved ASES function scores, ASES index scores, and VAS scores compared to oLDT at both the 6 month and 2-year follow-up ($p<0.05$). When LTT was compared to aLDT, LTT led to significantly improved VAS scores at the 6-month follow-up ($p<0.05$). Woodmass et al. [8] concluded that the arthroscopic assisted techniques are superior to open techniques, and that the arthroscopically assisted LTT is a safe and effective alternative in the treatment of massive irreparable RCTs.

De Marinis et al. [6] conducted a systematic review regarding clinical outcomes, complication rates, and reoperation rates for LTT performed in patients with irreparable RCTs. The authors found 7 studies with 159 patients that met their selection criteria with a mean follow-up time ranging from 14 months to 47 months. At final follow-up, the LTT greatly improved shoulder range of motion with average forward elevation improving from 10° to 66° and average external rotation improving from 11° to 63°. Moreover, the LTT corrected the external rotation lag that was present in 78 patients preoperatively. The patient reported outcome measures of VAS, SSV, ASES score, and the Contant-Murley score were all improved at final follow-up. The authors found that LTT had a complication rate of 17.6% with the most common complication being harvest site seroma/hematoma (6.3%). The overall reoperation rate was 7.5% with the most common procedure being a conversion to a reverse total shoulder arthroplasty (5%). Overall, De Marinis et al. [6] concluded that LTT for irreparable RCTs results in improved clinical outcomes, restored external rotation, and has complication and reoperation rates comparable to other surgical alternatives for this patient population.

Conclusions

The LTT represents an emerging and efficacious treatment option in the setting of massive irreparable RCTs in the young, active patient population. As a tendon transfer, the LTT offers the advantages of being "in line" and "in phase" with the shoulder muscles it is meant to restore. Biomechanical studies have shown that the LTT restores the anterior-posterior shoulder girdle force couple, abduction and external rotation moment arms, and glenohumeral joint reactive forces. The LTT can be performed through either an entirely open approach or through an arthroscopically assisted approach. Finally, the LTT has demonstrated successful clinical outcomes in addition to acceptable complication and reoperation rates.

Conflicts of Interest: None

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