Review Article

Tendon transfers to help you avoid reverse shoulder replacement

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Abstract: Treatment of irreparable rotator cuff tears (RCTs) with minimal degenerative changes in an active, high demand patient remains challenging. While reverse shoulder replacement is an option, durability in the setting of high demand use remains unknown. Alternatively, tendon transfers are an attractive alternative that require no long term restrictions on use. The latissimus dorsi and pectoralis major are typically described as treatment options for irreparable posterior superior and anterior superior RCTs respectively. Recently, anatomic and biomechanical studies have questioned the use of these transfers suggesting that the lower trapezius may be the ideal transfer for posterior superior tears. Similarly, the latissimus dorsi is a more anatomic transfer to reconstruct anterior superior tears. As such, the lower trapezius and latissimus have become our standard treatment options for posterior superior and anterior superior irreparable tears respectively. Tendon transfers represent an attractive alternative to reverse shoulder replacement when treating a patient with an irreparable tear and minimal arthritis.

Keywords: Irreparable rotator cuff tear (irreparable RCT); massive rotator cuff tear (massive RCT); tendon transfer; lower trapezius; latissimus dorsi

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Introduction

Although reverse shoulder arthroplasty reliably improves function and relieves pain in irreparable rotator cuff tears (RCTs), the long-term outcomes in active, high demand patients remains unknown. Non-arthroplasty options represent a challenging but attractive alternative as no long term restrictions are required. Attempted repair has been associated with retear rates exceeding 90%, challenging the utility of repair in this scenario (1). Several additional non-arthroplasty treatment options have been described with variable success including biceps tenotomy or tenodesis (2), subacromial decompression (3,4), partial rotator cuff repair (5), superior capsular reconstruction (6) and tendon transfer (7-9). Tendon transfers provide durable and dynamic treatment option for the active high demand patient with an irreparable RCT.

Stable glenohumeral motion requires an intact force couple provided by the rotator cuff to compress the humeral head into the glenoid. In the axial plane, the subscapularis and infraspinatus/teres minor couple to compress the glenohumeral joint. The deltoid and supraspinatus represent the coronal force couple stabilizing the humeral head in abduction (10). In the absence of a balanced force couple, the shoulder is unable to withstand the superiorly directed force of the deltoid frequently leading to pain, functional impairment and glenohumeral degeneration.

Non-arthroplasty options must restore the missing force couples to reestablish glenohumeral kinematics. Additionally, by preventing eccentric glenoid loading and restoring near normal kinematics, the progression of osteoarthritis may be slowed. As such, tendon transfer is an ideal solution, both alleviating pain and restoring force couple through a dynamic rather than static reconstruction (7-9).

The basic principles of tendon transfer surgery around the shoulder mirror those of tendon transfers of the hand and wrist. These principles include: (I) the donor muscle should be expendable, (II) the donor must have similar excursion and strength as loss of one grade in strength can be expected, (III) one muscle one function, and (IV) the donor line of pull should mirror the recipient muscle (11).

History and physical examination

Active range of motion is highly variable between patients with irreparable RCTs, running the gamut from pseudoparalysis to full motion. Patients often note a recent traumatic event with loss of function, representing disruption of their remaining force couple despite an underlying chronic RCT. Examination should begin with an inspection of the shoulder girdle for signs of atrophy often noted in the supraspinatus and infraspinatus fossae. The Jobe test (supraspinatus) and external rotation lag in adduction (infraspinatus) and 90° abduction (teres minor) should be performed to assess the posterior superior rotator cuff. The lift off, belly press and bear hug can be used to examine the anterior superior rotator cuff. Radiographs should be inspected for degenerative changes to the glenohumeral joint as well as superior migration of the humeral head with loss of "Shenton's Line" of the shoulder on the anteroposterior image. Magnetic resonance imaging should also be obtained to determine the tear size, level of retraction, fatty infiltration as described by Goutallier *et al.* (12), and status of the articular cartilage.

Indications for tendon transfer

The ideal candidate for tendon transfer with an irreparable RCT should be active and high demand with minimal if any evidence of glenohumeral degenerative changes. Additionally, presence of a significant functional deficit such as an external rotation lag is an ideal indication for tendon transfer rather than a static reconstruction such as a superior capsular reconstruction in our opinion. True pseudoparalysis is not a contraindication to tendon transfer in our opinion, but preoperative range of motion is frequently predictive of postoperative range of motion.

Several tendon transfers have been described for irreparable posterosuperior and anterosuperior RCTs. The biomechanical basis for each deficit, possible tendon transfer, and clinical outcomes are reviewed.

Pectoralis major for anterosuperior RCTs

Classically, transfer of the pectoralis major is described for treatment of irreparable anterosuperior RCTs (8,13-15). The pectoralis major has two heads, the clavicular head which originates on the medial clavicle, and the sternal head that originates from the upper sternum and second through fourth ribs. The clavicular and sternal heads converge and rotate around one another inserting at the lateral bicipital groove (16). The pectoral branch of the thoracoacromial artery provides the main blood supply, and medial and lateral pectoral nerves innervate the pectoralis major.

As initially described by Wirth and Rockwood, the pectoralis major was transferred superficial to the conjoined tendon (14). Satisfactory outcomes were reported in 10 of 13 patients at 5 year follow-up. Subsequently, improved line of pull has been noted with subcoracoid transfer (8,16,17). In a cadaveric study, Konrad *et al.* compared glenohumeral kinematics following transfer above or below the conjoined tendon (18). Although both transfers restored abduction and superoinferior translation, subcoracoid transfer restored more normal shoulder kinematics. The authors hypothesized that these findings were due to a more direct line of pull with subcoracoid transfer. Use of a split tendon transfer has also been suggested to diminish the risk of musculocutaneous nerve injury with subcoracoid transfer (16). However, even a split subcoracoid transfer of the sternal head utilizing the clavicular head as a pulley cannot recreate the posterior pull of the intact subscapularis.

Despite several descriptions of improved pain following pectoralis major transfer, functional outcomes have proven more variable (8,13,17). Elhassan *et al.* noted inferior outcomes among patients with anterior subluxation of the humeral head and those undergoing transfer for subscapularis rupture following shoulder arthroplasty (13). Improved outcomes have been noted in patients with intact supraspinatus function (8).

Latissimus dorsi for anterosuperior RCTs

In contrast to the pectoralis major, the latissimus dorsi more anatomically recreates the posterior line of pull of the intact subscapularis. Furthermore, the latissimus dorsi can be transferred to a more proximal and lateral position near the greater tuberosity for patients with superior migration or supraspinatus involvement (*Figure 1*). The latissimus dorsi

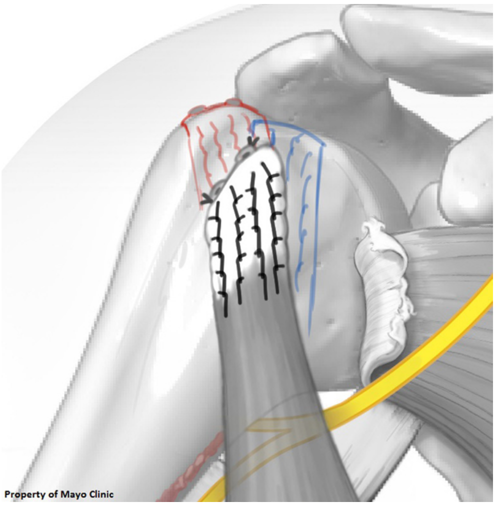

Figure 1 Schematic representation of latissimus dorsi attachment sites for anterior superior rotator cuff tears. In the presence of superior migration as well as supraspinatus involvement, the latissimus can be attached in a superior and lateral position (blue and red). For isolated subscapularis pathology the latissimus can be inserted at the lesser tuberosity (black).

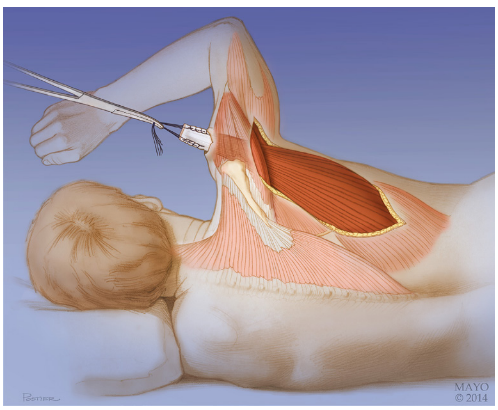

Figure 2 Illustration of latissimus dorsi harvest for posterior superior rotator cuff tears. Note the vertical line of pull relative to the posterior superior rotator cuff.

has a broad origin across the sacrum, iliac crest and spinous processes of T7–L5, and inserts onto the intertubercular groove of the proximal humerus. The latissimus adducts, internally rotates and extends the humerus. The blood supply of the latissimus comes from the thoracodorsal artery, and innervation comes from the thoracodorsal nerve (C6–8) of the posterior cord.

Elhassan *et al.* evaluated the feasibility of the latissimus dorsi transfer in a cadaver study (19). No impingement of the radial or axillary nerves was noted with transfer of the latissimus dorsi an average of 4.0 cm proximally. However, risk of nerve impingement was increased with combined latissimus and teres major transfer to a proximal position on the lesser tuberosity (19). In a consecutive series of 24 patients, Mun *et al.* reported outcomes of latissimus dorsi transfer for irreparable subscapularis tears (20). The latissimus dorsi was transferred to the proximal lesser tuberosity through a standard deltopectoral approach. Improvements in subjective outcome measures including Constant (46 to 69) and American Shoulder and Elbow Surgeon scores (40 to 70) were noted. Furthermore, forward elevation improved from 135° to 166° and internal rotation improved for L5 to L1 (20).

Latissimus dorsi for posterosuperior RCTs

The latissimus dorsi with or without teres major has been frequently described in the treatment of posterosuperior RCTs (9,21-23). The latissimus can recreate a force couple with an intact deltoid and subscapularis, providing a posterior and inferior force (22). Following transfer for posterior superior RCTs, the latissimus acts as a humeral head depressor and external rotator (*Figure 2*). Improvements in pain have been noted by several authors; however functional gains remain less predictable following transfer of latissimus dorsi for posterior superior RCTs (21,24-26). The latissimus dorsi is not a synergistic transfer as it is an internal rather than external rotator. Furthermore, there is debate whether the latissimus merely provides a tenodesis effect rather a true external rotation moment (27,28). Finally, unlike the infraspinatus and teres minor, the latissimus has a vertical line of pull functioning more as a humeral head depressor (*Figure 3*).

Werner *et al.* demonstrated the importance of an intact subscapularis for successful latissimus dorsi transfer in a cadaveric study (29). In the absence of a functioning subscapularis, latissimus contraction resulted in anterior and inferior subluxation of the glenohumeral joint. Furthermore, there is concern that the excursion of the latissimus may lead to increased contact pressures during abduction (30). These findings may explain the progression of glenohumeral degeneration noted in many series (24,25).

Multiple surgical techniques including single incision, double incision and arthroscopic assisted have been described for latissimus dorsi transfer (22,24,31). Gerber *et al.* demonstrated 74% good or excellent results at 10 year

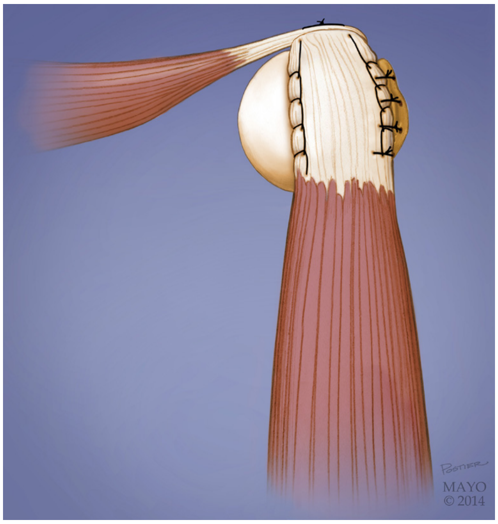

Figure 3 Illustration of latissimus dorsi transfer for posterior superior rotator cuff tears. Again note the vertical line of pull, thus functioning predominantly as a humeral head depressor.

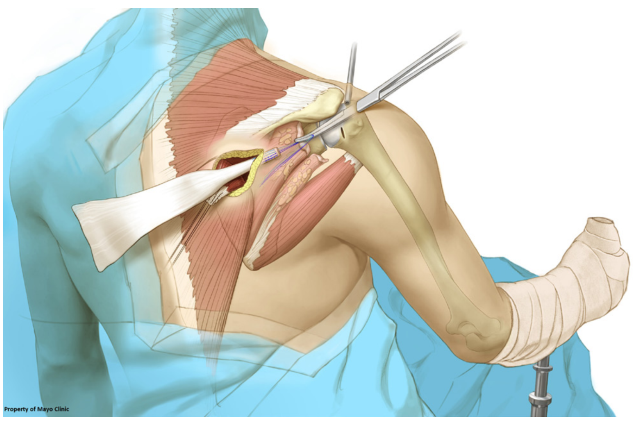

Figure 4 Arthroscopic assisted lower trapezius transfer with allograft. Note the symmetric vector of the lower trapezius relative to the torn posterior superior rotator cuff. Achilles tendon allograft is required to elongate the transfer.

follow up with a two incision approach (31). Subjective shoulder value (SSV) and Constant scores improved despite progression of radiographic degenerative changes. Inferior outcomes were noted in patients with subscapularis or teres minor insufficiency (9,31). A systematic review by Namdari *et al.* noted improved constant scores from 45.9 to 73.2 postoperatively (32). Active external rotation improved to 26.7° from 16.8° and active forward elevation improved to 137.4° from 101.9°. Several predictors of poor outcome were noted including revision surgery, fatty infiltration of the teres minor and subscapularis insufficiency. The use of a bone block rather than tendon alone has been noted to reduce the retear rate (24).

In order to reduce the risk of deltoid injury with a two incision approach, athroscopic assisted transfer has been advocated (33-35). Castricini *et al.* reported similar outcome of arthroscopic assisted transfer in a series of 86 patients with 3-year follow up, noting excellent or good outcomes in 82% (35). Predictors of poor outcome included prior rotator cuff repair or biceps tenodesis. Similarly, Grimberg *et al.* noted improved SSV as well as active forward elevation, abduction and external rotation (33).

Lower trapezius for posterosuperior RCTs

The trapezius muscle functions to elevate, retract, and externally rotate the scapula. The trapezius originates at the occiput and spinus process of C7–T12, and is divided into upper, middle and lower portions (11). The upper portion inserts over the lateral 1/3 of the posterior clavicle and the middle and inferior portions insert over the medial acromion and scapular spine. The trapezius is innervated by the spinal accessory nerve and receives its blood supply from the transverse cervical artery.

In contrast to the latissimus, the lower trapezius has a near identical line of pull to the infraspinatus fossa, making it a more anatomic reconstruction for posterior superior RCTs (36). Moreover, the lower trapezius externally rotates the scapula and is therefore a synergistic transfer for posterior superior RCTs, and has been shown to stabilize the humeral head even with an absent deltoid or subscapularis (37). However, the excursion of the lower trapezius is limited and requires elongation with a graft unlike the latissimus dorsi (*Figure 4*).

Using an open technique, Elhassan *et al.* reported encouraging outcomes in a series of 33 patients with mean follow-up of 47 months treated with lower trapezius transfer and achillies allograft elongation for irreparable posterior superior RCTs (7). Functional outcomes were improved with increases of 50° forward elevation, 50° abduction, 30° external rotation and no change in internal rotation. The greatest improvements in range of motion were in patients with at least 60° of preoperative forward elevation. Significant improvements were also noted in DASH and SSV scores. A modified arthroscopic assisted technique of lower trapezius transfer has also been described with similar success to the open technique (38).

Conclusions

Treatment of irreparable RCTs in active, high demand patients with functional impairment remains complex and debated. Tendon transfers can restore near normal glenohumeral kinematics, relieving pain and improving function. In contrast to classically described tendon transfers around the shoulder, the lower trapezius for posterosuperior RCTs and latissimus dorsi for anterosuperior RCTs offer improved biomechanics potentially leading to improved outcomes. These transfers represent an attractive alternative to reverse shoulder replacement for active high demand patients.

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Footnote

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