Tendon Transfers for Irreparable Rotator Cuff Tears

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Massive, irreparable rotator cuff tears present a challenging problem for the orthopaedic surgeon. These large tears are associated with persistent defects, weakness, and poor outcomes. Massive tears are classified as either anterosuperior or posterosuperior, each with a unique frequency, clinical presentation, examination findings, and prognosis. These tears can cause an uncoupling of forces across the glenohumeral joint, resulting in unstable shoulder kinematics. Physical examination, depending on chronicity of the tear, can reveal a variety of findings, ranging from periscapular atrophy and profound weakness to pain with preserved function due to deltoid compensation. Nonoperative management has yielded inconsistent results and has been particularly unsuccessful for patients with symptoms lasting more than 6 months. Operative treatment options for massive rotator cuff tears are limited if a direct repair cannot be accomplished. The use of tendon transfers to reconstruct the biomechanics of the rotator cuff may be a viable treatment option for patients with irreparable rotator cuff tears. In this article, we will discuss the classification, pathomechanics, and clinical evaluation of massive rotator cuff tears, as well as review the treatment of tendon transfers and associated outcomes for irreparable rotator cuff tears.

Classification

Rotator cuff tears are defined based on their size, chronicity, the number of tendons involved, and the pattern of tear. With regards to rotator cuff tear size, different investigators have proposed various classification systems to identify massive tears. Cofield, for example, defined massive tears as those tears which have an anterior-posterior dimension greater than 5 cm. The size of the individual, and in turn, the size of the overall tendon, was not taken into consideration. Nobuhara and colleagues subsequently defined the size of a tear by measuring the amount of exposed humeral head. Many investigators currently define massive tears as those involving at least two tendons and also identify the amount of tendon remaining attached to tuberosity, which may correlate more consistently with function, prognosis, and surgical outcome.

Massive rotator cuff tears can also be described based on the tendons involved. Most tears appear to follow two distinct anatomic patterns of posterosuperior or anterosuperior.
The function was observed.

Without a balanced force couple to maintain the humeral head against the glenoid, a considerable loss of shoulder kinematics resulted in unstable kinematics. To establish balanced shoulder motion, there must be equilibrium of forces and moments about the glenohumeral joint. During shoulder motion, the rotator cuff muscles act in concert to centralize the humeral head against the glenoid fossa (Fig. 1). With massive rotator cuff tears, there is an uncoupling of these forces, resulting in altered kinematics and the potential for instability. Burkhart and colleagues evaluated 12 shoulders with massive, irreparable rotator cuff tears, radiographically, and described three patterns of glenohumeral motion: stable, unstable, and captured kinematics. Function was preserved as long as the force coupling was intact. However, if tears extended into the anterior (subscapularis) or posterior (infraspinatus/teres minor) cuff tissue, this resulted in unstable kinematics. Without a balanced force couple to maintain the humeral head against the glenoid, a considerable loss of shoulder function was observed.

Pathomechanics

To establish balanced shoulder motion, there must be equilibrium of forces and moments about the glenohumeral joint. During shoulder motion, the rotator cuff muscles act in concert to centralize the humeral head against the glenoid fossa (Fig. 1). With massive rotator cuff tears, there is an uncoupling of these forces, resulting in altered kinematics and the potential for instability. Burkhart and colleagues evaluated 12 shoulders with massive, irreparable rotator cuff tears, radiographically, and described three patterns of glenohumeral motion: stable, unstable, and captured fulcrum kinematics. Function was preserved as long as the force coupling was intact. However, if tears extended into the anterior (subscapularis) or posterior (infraspinatus/teres minor) cuff tissue, this resulted in unstable kinematics. Without a balanced force couple to maintain the humeral head against the glenoid, a considerable loss of shoulder function was observed.

Clinical Presentation and Evaluation

It has been demonstrated in multiple studies that there is an increasing incidence of rotator cuff tears with age. Therefore, the majority of massive tears tend to occur in the elderly group of patients. The physical examination of patients with chronic massive rotator cuff tears can be quite remarkable. It is important to evaluate the patient for other possible diagnoses for chronic shoulder pain and weakness, particularly conditions affecting the central nervous system and brachial plexus. After performing a thorough cervical spine examination, inspection of the shoulder may reveal periscapular atrophy and possible deltoid atrophy or deficiency. These patients may also demonstrate gross deformity about the biceps muscle, consistent with a chronic proximal tendon rupture. In cases of coracoacromial arch incompetency, some patients may have evidence of anterior-superior humeral head escape where the contour of the bone is observed in the anterior aspect of the shoulder.

Most patients with a massive rotator cuff tears will present with a decrease in active shoulder motion. If this weakness has been persistent for a long period of time, the patients may also exhibit mild limitations in passive shoulder motion as well. All patients will likely demonstrate weakness of supraspinatus strength with a positive Jobe empty can test. Depending on the location of the tear and the involved tendons, the other deficit, however, may differ significantly.

For the more common posterosuperior tear, two provocative maneuvers can determine the extent of posterior cuff involvement. The external rotation lag sign is performed in the sitting position with the arm at the side, elbow flexed to 90°, and the arm passively externally rotated to maximum. If the patient cannot actively hold this position, the infraspinatus is likely to be torn. In a similar manner, the horn blower’s test to identify teres minor involvement is performed with the patient in the sitting position. After abducting the arm to 90° and flexing the elbow to 90°, the patient is asked to hold the arm that is externally rotated to 90°. Walch and associates demonstrated high sensitivity and specificity of the horn blower’s test in identifying an irreparable teres minor tear. In patients with anterosuperior tears, significant weakness of the subscapularis will be noted. The lift-off test mainly evaluate the lower subscapularis muscle, while the belly-press assesses the upper muscle belly. In addition to the results of these provocative maneuvers, patients may also demonstrate increased passive external rotation.

Radiographic Evaluation

Plain radiographs are a valuable component to the evaluation, providing information on the glenohumeral joint, acromial morphology, and evidence for superior escape. A complete evaluation includes an anteroposterior, an axillary, and an outlet or scapular Y views. Chronic massive tears may cause proximal migration of the humeral head. Thus, these radiographs will frequently demonstrate a decrease in the distance between the humeral head and undersurface of the acromion, or the acromiohumeral interval (AHI). Hamada and coworkers identified five radiographic grades of massive tears and reported 79% to 86% correlation between grade and size of tear, with predictable radiographic progression if untreated.
The most commonly utilized imaging modality to identify and characterize rotator cuff tendon tears is magnetic resonance imaging (MRI), which can reliably identify the presence and the extent of the tear. Originally, Goutallier and colleagues actually utilized computerized tomography to characterize the status of the rotator cuff muscles by describing four stages of fatty degeneration (Table 1, Fig. 2). More recently, multiple studies have adapted this staging system for the MRI and correlated retear rate and prognosis with the degree of fatty degeneration. Mellado and associates, for example, found that if there is stage 3 or 4 fatty infiltration, with the fat content exceeding muscle, there is no functional improvement with attempted repairs. This staging of fatty infiltration within the muscle belly has also proven to be a strong predictive factor of postoperative retearing as well. More recently, ultrasound has become a popular modality in evaluating rotator cuff pathology due to its low cost and noninvasive nature. It has proven to be quite reliable in identifying the presence of a tear, even during the postoperative period. Unfortunately, ultrasound is notoriously dependent on the technician’s experience. In addition, since the ultrasound cannot predictably penetrate through bone, it cannot provide much information about massive rotator cuff tears where the tendon edges have retracted medial to the acromial border.

Tendon Transfers

The treatment options for patients with massive rotator cuff tears include nonoperative management, surgical debridement via open or arthroscopic means, and partial or complete surgical repair or reconstruction. Nonoperative management of massive tears is mainly reserved for elderly patients whose primary symptoms do not involve significant pain. Improved function may be obtained with activity modification, judicious use of steroid injections, and physical therapy with an emphasis on training of the anterior deltoid muscle. However, the reports on the success of nonoperative management of massive rotator cuff tears have been mixed. Open or arthroscopic debridement is another option for elderly patients with the predominant symptom of pain. Though this procedure may relieve pain and associated symptoms, it does not restore strength or function to the debilitated shoulder. In addition, the pain relief gained from this procedure has not been reproducibly maintained. In order to achieve maximal functional restoration, a surgical repair of the rotator cuff tear should be attempted. However, if a tear cannot be repaired primarily to the tuberosities despite all mobilization techniques, then the patient may require a salvage-type reconstruction in order to restore some level of function and reduce pain. For select patients, a tendon transfer procedure may maximize the likelihood of a functional recovery. The ideal patient for this procedure is a young, active patient with an irreparable tear whose main complaint is weakness with minimal pain.

Many tendon transfer techniques with various donor tendons have been described to treat patients with massive irreparable rotator cuff tears, including the subscapularis, latissimus dorsi, teres major, pectoralis major, deltoid, triceps, and trapezius. The usefulness of the donor muscle is determined by three factors: relative length of the muscle; its line of action relative to joint rotation; and its amplitude. Rotator cuff muscles have relatively short amplitudes compared to large muscles like the latissimus dorsi or pectoralis major. The goal is to restore rotation and force coupling about the humeral head in order to produce stable overall kinematics.

Posterosuperior Tears

Based on a biomechanical study analyzing the moment arm, muscle length, and force of muscle transfers for posterosuperior tears, Magnermans and coworkers concluded that the teres major is the best candidate to improve function. However, due to the small amount of tendon and poor excursion of the teres major, most surgeons rarely transfer this muscle by itself. Considering the overlap of tendon averages 39% between the teres major and the latissimus dorsi muscles,
the latter is ideally suited to contribute to the transfer. Hence, these muscles are typically isolated and the tendons are transferred together.

The latissimus transfer is described with the patient in the lateral position, with an anterior incision made first over the anterolateral aspect of the acromion. Next, bursal tissue is removed to create space for the latissimus tendon, and the torn, retracted rotator cuff is identified and debrided. Next, a posterior incision is made at the posterior axillary line in zigzag fashion to prevent scar contracture. Identification and isolation of the latissimus dorsi tendon is facilitated by placing the arm in flexion and internal rotation. The tendon is cut, tagged with heavy nonabsorbable suture, and transferred to the anterior aspect of the abraded greater tuberosity through bone tunnels. The medial latissimus tendon edge should be sutured to the retracted cuff edge (Fig. 3). It is important to position the shoulder in 45° abduction and 30° external rotation during fixation of the transferred tendon. The patient will maintain this position in a gunslinger brace for 6 weeks, followed by a 6- to 12-month muscle training and biofeedback program.21,26,27

Gerber and colleagues, in their most recent series of 69 patients with an average follow-up of 53 months, reported significantly improved scores and maintained increased range of motion with slight progression of osteoarthritis.26 Other investigators have also reported similarly good midterm results and improvement in function.28,29 Of note, Warner found a late rupture of the latissimus in 20% to 30% of his patients and has since recommended augmentation with tensor fascia lata.21 Pearle and associates performed and analyzed these transfers on 12 cadaveric specimens and found the radial nerve 2 to 3 cm away from the insertion site of the latissimus dorsi and teres major tendons,30 and Gerber and coworkers reported a neurapraxia rate of 5%.26

Anterosuperior Tears

For anterosuperior rotator cuff tears, the pectoralis major has been widely used for tendon transfers. It has sufficient amplitude for an effective transfer. However, its line of action is significantly anterior to the subscapularis origin. Consequently, subcoracoid (under the conjoint tendon) transfers of the pectoralis major have been recommended to change its line of action and better mimic the subscapularis (Fig. 4).21,31

The technique involves a delto-pectoral approach with identification of any remaining subscapularis or scar tissue in continuity with retracted tendon edge. The patient will maintain this position in a gunslinger brace for 6 weeks, followed by a 6- to 12-month muscle training and biofeedback program.21,26,27

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The technique involves a delto-pectoral approach with identification of any remaining subscapularis or scar tissue in continuity with retracted tendon edge. The patient should be tagged and the muscle belly mobilized. Care should be taken to identify and protect the axillary nerve during inferior dissection and mobilization of the subscapularis tendon. The pectoralis major tendon is identified and can be cut, tagged with heavy nonabsorbable suture, and mobilized. After preparing the lesser tuberosity, the tendon is passed deep to the conjointed tendon, avoiding injury to the
musculocutaneous nerve, and secured, either with suture anchors or transosseous sutures.

There are limited studies reporting results on pectoralis major transfers for massive anterosuperior rotator cuff tears. Galatz and colleagues reported 11 of 14 satisfactory results at a mean follow-up of 17.5 months. However, they achieved humeral head containment in only 50% of these patients at final follow-up. Outcome for patients with a diagnosis of isolated irreparable subscapularis tears have also been promising, with high patient satisfaction.

Aldridge and associates retrospectively reviewed 11 consecutive patients treated with a combined transfer of the latissimus dorsi and pectoralis major tendons for massive rotator cuff deficiency and reported mixed results. Due to limited numbers, they had difficulty identifying prognostic factors for success. Finally, Warner and Parsons, in a comparative analysis of primary and salvage transfers, found that the latter provide limited gains. These investigators attributed this poor result to increased fatty degeneration, deteriorating tendon quality, and recurrent insult to the deltoid.

**Miscellaneous**

Various other muscle transfers have been described to treat patients with massive rotator cuff tendon tears with limited outcome data. A report on the transfer of the long head of the triceps tendon as an interpositional flap for irreparable tears demonstrated improved University of California Los Angeles (UCLA) scoring at 1 year. There was, however, no significant improvement in strength or motion. Long-term results of 29 deltoid transfers for massive posterosuperior tears demonstrated outcomes comparable to that of latissimus transfers, with impressive MRI follow-up demonstrating 15/18 transfers intact at 10 years. The investigators attribute the success to the synergistic function of the deltoid and cuff, as well as to the preservation of the flap innervation and blood supply. Besides limited outcome data, concern over irreversible deltoid injury has caused a lack of enthusiasm for this transfer.

**Summary**

Irreparable rotator cuff tears are infrequent and can result in a debilitating loss of function for patients. These tears are classified as either anterosuperior or posterosuperior, each with its own unique frequency, clinical presentation, examination findings, and prognosis. Various tendon transfers have been described to improve function. Posterosuperior rotator cuff tears are best managed with a combined latissimus dorsi and teres major tendon transfer, as the teres major tendon has the best biomechanical profile to improve function, but is by itself too small, with poor excursion to accomplish an isolated transfer. For the anterosuperior tear, a pectoralis major transfer has been most widely utilized. Techniques transferring the sternal head in a subcoracoid fashion may improve results by closer mimicking the biomechanics of the subscapularis, reducing the bulk of the transfer and improving cosmesis. Multiple other transfers have been described with varying success and limited outcome data. Patient selection and
adherence to postoperative rehabilitation remains crucial to the success of these procedures, as well as to deltoid integrity and tendon quality.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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