Review

Treatment options for massive rotator cuff tears: a narrative review

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Abstract. The treatment of massive rotator cuff tears poses a challenge to orthopedic surgeons. The prevalence of massive rotator cuff tears is 40% of all rotator cuff tears. Compared with smaller tears, massive rotator cuff tears are often complicated by structural failure and poor outcomes and present a higher rate of recurrent tearing after surgical repair. Several management options are available but the selection of the most appropriate treatment for each patient can be challenging. To achieve the best outcomes, the orthopedic surgeon should have a good understanding of the indications, the pathomechanics and the clinical outcomes of the various treatment modalities. Treatment options include non-operative management, arthroscopic debridement with a biceps tenotomy or tenodesis, complete or partial repair, patch augmentation, superior capsular reconstruction, muscle/tendon transfer and reverse total shoulder arthroplasty. The purpose of this article is to review treatment options and clinical outcomes for the management of massive rotator cuff tears. (www.actabiomedica.it)

Key words: massive, rotator cuff, tear, shoulder, treatment

Massive rotator cuff tears: introduction

The treatment of massive rotator cuff tears poses a challenge to orthopedic surgeons.

The prevalence of massive rotator cuff tears is 40% of all rotator cuff tears (1). The size of the rotator cuff tears has an important effect on clinical outcomes after surgery. Compared with smaller tears, massive rotator cuff tears are often complicated by structural failure and poor outcomes and present a higher rate of recurrent tearing after surgical repair (2). Massive rotator cuff tears require surgical treatment either if they occurs in an acute pattern or after rehabilitation failure in chronic-degenerative lesions.

It is important to understand what an irreparable rotator cuff tear is, since nowadays this concept is not clear (3). Some authors do not consider rotator cuff tear as irreparable, arguing that all rotator cuff tears are reparable (4). On the other hand Collins et al. and Denaro et al. affirm that some lesions are not reparable or should not be repaired (5). In reparable massive tears risk of rerupture depends on age, tear size, repair technique used, inappropriate rehabilitation; most important factors are muscle atrophy and fatty degeneration (6).

Several management options are available but the selection of the most appropriate treatment for each patient can be challenging. To achieve the best outcomes, the orthopedic surgeon should have a good understanding of the indications, the pathomechanics and the clinical outcomes of the various treatment modalities. Many classification systems have been proposed to help in the treatment choice. DeOrio and Cofield classified massive rotator cuff tears as tears sized more than 5 cm in either the anterior-posterior or medial-lateral dimension (7), Gerber defined them as those involving complete tears of at least 2 tendons (7), whereas Davidson and Burkhart proposed a classification system linking rotator cuff tear patterns to treatment and prognosis (8). No consensus exists regarding the best classification system, thus it is essential to understand the tear pattern according to the patient's clinical situation (9).

Further complexity in the treatment of massive rotator cuff tears comes from the fact that structural failure does not always means clinical failure (10-11).

Numerous surgical management options are available including non-operative management, arthroscopic debridement with a biceps tenotomy or tenodesis, complete or partial repair, patch augmentation, superior capsular reconstruction, muscle/tendon transfer and reverse total shoulder arthroplasty (12). Double-row techniques have demonstrated biomechanical advantages in controlled cadaveric studies, but have yet to demonstrate clear clinical efficacy over more simple repair techniques. When repairs for massive rotator cuff tears fail, options include revision repair or superior capsular reconstruction, which is an option to bridge the tissue gap with human dermal allograft or fascia lata autograft in the attempt to contain the humeral head from superior migration thus trying to delay rotator cuff arthropathy. Although latissimus transfers remain a reasonable option for massive, irreparable rotator cuff tears in appropriate patients, clinical results are often unpredictable. Older patients with chronic, massive rotator cuff tears with pseudoparalysis can achieve predictable, often excellent clinical results with a reverse total shoulder arthroplasty.

The purpose of this article is to review treatment options and clinical outcomes for the management of massive rotator cuff tears.

Biomechanical consequences of rotator cuff tears

The muscles of the rotator cuff play an important role in normal gleno-humeral motion and stability. The rotator cuff muscles act together as dynamic stabilizers of the anatomically unstable gleno-humeral joint. The supraspinatus initiates abduction, the infraspinatus and teres minor are responsible for external rotation and the subscapularis is the main internal rotator of the shoulder. The deltoid and supraspinatus muscles act as the coronal force couple, compressing the humeral head to the glenoid during shoulder abduction. The subscapularis and infraspinatus muscles represent the axial force couple, providing joint stability by a compressive joint reaction force in the axial plane (13).

A cadaveric model showed how massive rotator cuff tears adversely affect normal shoulder biomechanics resulting in increase in maximum internal rotation in posterosuperior tears, maximum external rotation in anterosuperior tears and total rotation range of motion at all abduction angles (14). Disruption of the muscle-tendon units that contribute to active external rotation (infraspinatus and teres minor) leads to weakness in active external rotation and an increase in passive internal rotation, whereas massive rotator cuff tears involving the subscapularis lead to weakness in active internal rotation and increased passive external rotation.

To restore normal kinematics in patients with massive tears of the posterosuperior rotator cuff tendons, greater forces are required by both the deltoid and the intact muscle-tendon units of the rotator cuff, particularly the subscapularis, to achieve stable abduction (15). The progression of a rotator cuff tear to disrupt the axial force couple leads to superior subluxation of the humeral head and dysfunction of the shoulder. Forces required to move the arm increase with tear size and can contribute to the anterior or posterior extension of the tear. Torn tendons cannot participate in load sharing, therefore increasing the tensile load on the remaining fibers. This can lead to tear propagation, especially in poor quality residual tendons. In addition, a recent study by Collin et al found that disruption of the entire subscapularis or of three rotator cuff muscles to be risk factors for shoulder pseudoparalysis (16), which has been defined as a patient's having less than 90° of active anterior elevation with full passive range of motion and the lack of neurologic impairment.

Large retracted tears have also been shown to cause traction on the suprascapular nerve and may contribute to the progression of atrophy and fatty infiltration of the supraspinatus and infraspinatus muscles (17). Repair of the massive tear with or without associated suprascapular nerve neurolysis may relieve tension on the suprascapular nerve, allowing recovery of the nerve and improvement in function (18).

Medial extension of supraspinatus tears can also disrupt glenohumeral kinematics. At the beginning of abduction, muscle weakness or tendon retraction may determine superior migration of the humeral head, leading to increased cuff impingement between the greater tuberosity and acromion (19). Usually, a massive rotator cuff tear involving at least 2 torn tendons is needed to provoke superior migration of the humeral head (7).

Assessment: physical examination of the shoulder and imaging

The examination of shoulders with rotator cuff tears should begin with an assessment of range of motion and a neurovascular examination to assess for the integrity of axillary and suprascapular nerve function. Inspection may reveal deltoid atrophy or periscapular atrophy of the infraspinatus. Massive tears involving the infraspinatus will typically present with increases in passive internal rotation as well as an external rotation lag sign. Similarly, massive tears involving the subscapularis will often present with an increase in passive external rotation and an internal rotation lag sign. Furthermore, supraspinatus tears may demonstrate a drop arm sign. Palpation of the long head biceps tendon (LHBT) within the bicipital groove is essential during the examination, as lesions to the LHBT are strongly associated with rotator cuff tears. The surgeon must also assess for concomitant symptomatic acromioclavicular joint arthritis. Strength testing of all rotator cuff muscles is imperative. Special attention should be paid to the subscapularis, as lesions to the upper part of its tendon are often correlated with biceps tendon lesions and LHBT instability. Tests for the subscapularis include the belly press test, the lift-off test, and the bear hug test.

The surgeon must assess the function of each tendon and for the presence of pseudoparalysis, which indicates a lack of compensation for the detached rotator cuff tendons. A pseudoparalytic shoulder without a functional subscapularis is a contraindication to a latissimus transfer and the presence of symptomatic arthritis would necessitate an arthroplasty (20).

For all patients with suspected rotator cuff pathology, at least 3 radiographic views of the shoulder (anteroposterior, axillary lateral, outlet) are needed to look for narrowing of the acromio-humeral interval and superior migration of the humeral head, which are key factors to diagnose underlying rotator cuff disease. Gleno-humeral arthritis is often more clearly identified on the axillary lateral radiograph. The outlet view is used to assess the acromial morphology.

Although ultrasonography can be successfully used to diagnose rotator cuff disease, it is highly user-dependent, whereas magnetic resonance imaging can better evaluate the structural integrity of the rotator cuff and can be used to assess the size and location of the tear, the quality of the tendon, and the chronicity of the tear. The sagittal T1 image may show atrophy or fatty infiltration of the involved musculature, providing prognostic informations. Axial views can evaluate the integrity of the subscapularis as well as associated LHBT tendinosis, tears, or static instability (16).

Treatment options and clinical outcomes

Nonsurgical treatment

Non-operative management should be proposed to patients with massive tears and associated activity-related pain without evidence of pseudoparalysis, indicating a well-compensated force couple. It typically involves activity modification, corticosteroid injections and strengthening of the deltoid and periscapular musculature (21,22). It begins with guided physical therapy to strengthen the intact portion of the rotator cuff, the deltoid and the periscapular musculature and prevent progressive rotator cuff arthropathy. A subacromial corticosteroid injection could decrease the inflammation during the rehabilitation process. A randomized clinical trial revealed comparable therapeutic efficacies of sodium hyaluronate and dexamethasone (18).Although some studies have shown promising early clinical results in elderly patients with rotator cuff tears after a series of infiltrations with hyaluronic acid followed by rehabilitative treatment (23), Zingg et al retrospectively evaluated 19 patients with massive rotator cuff tears involving 2 or 3 tendons who were treated nonoperatively (24). At a mean 4-year follow-up, despite maintenance of shoulder function and mild pain symptoms, there was a significant progression of glenohumeral arthritis and narrowing of the acromiohumeral interval. Moreover, significant progression in tear size and fatty infiltration occurred and 50% of the tears were deemed irreparable at final follow-up. The authors concluded that in selected patients, satisfactory shoulder function can be maintained despite progression of arthropathy and widening of the tear.

Another study involving 10 elderly patients with massive irreparable rotator cuff tears evaluated a physiotherapy approach focused on anterior deltoid strengthening and functional rehabilitation. After 3 months, Oxford Shoulder Disability Questionnaire and the pain scores of the 36-Item Short Form Health Survey showed a mean improvement of 9 and 22 points respectively (25).

Yamaguchi et al followed the natural history of 45 patients with initially asymptomatic rotator cuff tears during a 5-years period. They demonstrated that 51% of these patients became symptomatic after a mean of 2.8 years, with a high risk for tear size progression over time (26).

Although patients may benefit from nonoperative treatment in the setting of massive rotator cuff tears, the likelihood of tear progression and cuff tear arthropathy often limits the use of this modality to the most low-demand patients, those medically unfit for surgery or those wishing to avoid surgery.

Based on recent studies reported by Jeanfavre et al (27), the non-operatively treated cohorts reported the respective outcomes: 78% improved in pain, 81% improved in ROM, 85% improved in strength, 84% improved in functional outcomes. Dissatisfied outcomes occurred in 15% of patients, who then transitioned to surgery. In conclusion, the current literature indicates GRADE B recommendation (28) (moderate strength) to support the use of exercise therapy in the management of full-thickness rotator cuff tears with and without additional physical therapy or medical management interventions. There is further need for well-designed randomized controlled trials.

Surgical treatment

Although a multitude of surgical options exists for management of massive rotator cuff tears, rotator cuff repair for reparable tears and superior capsular reconstruction (SCR) for irreparable tears appears to be the most consistent regarding clinical outcomes (16). Debridement and biceps tenotomy or tenodesis may be a viable option in the most elderly, low-demand patients with limited functional goals (1). Latissimus transfers for irreparable posterosuperior rotator cuff tears have demonstrated some promising results in the literature regarding improvements in range of motion and clinical outcome scores. Unfortunately, results are often unpredictable and are associated with progression of glenohumeral arthritis and superior migration of the humeral head (61). Worse outcomes after latissimus transfer are typically seen in patients with an incompetent subscapularis, in patients with teres minor atrophy or in the setting of revision surgery. Results of latissimus transfer appears to be unpredictable, therefore SCR is preferred for management of irreparable posterosuperior rotator cuff tears. For elderly patients and those with signs of rotator cuff arthropathy and pseudoparesis, reverse total shoulder arthroplasty (rTSA), given the predictable outcomes and often excellent results. Beltrame A. et al. reported good or excellent results in terms of satisfaction in 90.3% of patients after rTSA due to eccentric osteoarthritis (29).

Debridement procedures of the rotator cuff are usually labeled “salvage procedures” or “limited goals surgery”. They are indicated for elderly patients with irreparable tears and limited functional expectation, after failure of nonoperative management. Ideally, the patient should have a competent deltoid muscle and an intact coraco-acromial arch (30,31) and neither pseudoparalysis nor severe cuff tear arthropathy (32).

The main goals of surgery are to alleviate pain and to improve range of motion.

Rockwood et al (24) demonstrated an 83% satisfaction rate in a cohort of 50 patients with massive irreparable tears 6.5 years after open debridement and subacromial decompression. Mean active forward flexion improved from 105° preoperatively to 140° postoperatively in their cohort. These findings were supported by Gartsman (33), who reported a 79% satisfaction rate in patients with irreparable rotator cuff tears after open debridement and subacromial decompression. Pain decreased, range of motion and the ability to perform activities of daily living increased, but the elevation strength significantly decreased after surgery.

Walch et al (34) reported a satisfaction rate of 87% in a series of 307 patients with massive rotator cuff tears treated by biceps tenotomy only. Boileau et al (26) confirmed that both arthroscopic biceps tenotomy and arthroscopic biceps tenodesis effectively reduced pain and dysfunction caused by irreparable rotator cuff tears associated with a biceps lesion. There was no difference in outcomes of patients who received a tenotomy or a tenodesis. Outcomes were inferior in case of teres minor atrophy, true preoperative pseudoparalysis and severe cuff tear arthropathy.

Of interest, a comparative study between arthroscopic debridement alone and debridement plus tenotomy of the long biceps tendon (35) found significant clinical improvement 2.5 years post-operatively compared with the preoperative baseline, but no significant differences were found between the 2 groups.

1. Rotator cuff repair

Advancements in surgical skills, techniques and equipment have facilitated the arthroscopic repair of massive rotator cuff tears. The ideal rotator cuff repair restores biomechanics, decreases pain, improves function and achieves a strong fixation that allows a more aggressive rehabilitation process and promotes healing (36,37). Where possible, complete anatomic repair should be performed. However, the outcomes of massive rotator cuff tears after repair are less predictable and associated with a higher re-tear rate at postoperative follow-up than smaller cuff tears. Factors that contribute to the re-tear rates are increased fatty infiltration of tissue, decreased acromio-humeral distance, smoking, size of the rotator cuff tear and increased tension on the repair (38).

Clinical outcomes tend to be better when the rotator cuff repair has healed and the tendon is intact (39). If the tendon does not heal, the patient is at increased risk of progressive superior humeral head migration and rotator cuff arthropathy. Unfortunately, the preoperative MRI does not always allow to define the repairability of the lesion. Di Benedetto et al. (40) used an index with 9 parameters (fatty Infiltration, Patte Stage, tear size measured in medial-lateral and anterior-posterior dimension, Tangent Sign, Occupation Grade, Acromion-Humeral Distance, Inferior Gleno-Humeral Distance, Glenoid Version Angle) on preoperative MRI shoulder imaging to assist orthopedists in surgical planning of rotatator cuff tears repair. Seven out of the nine parameters have showed statistical significance: Fatty Infiltration (FI grade ≥3), Patte stage (PS grade= 3), tear size measured in ML (ML>36 mm), Positive Tangent Sign (sensitivity 95,3%, specificity 83,6), Occupation Grade (OG<0,46), Acromion-Humeral Distance (AHD<7 mm), Inferior Gleno-Humeral Distance (IGHD>5 mm).

Jost et al (41) studied the long-term outcomes of patients who had a structural failure of open rotator cuff repairs. At a mean of 7.6 years after the operation, 19 out of 20 patients continued to be satisfied with the outcome. The size of re-tears did not progress between 3.2 years and 7.6 years of follow-up, indicating that re-tears may not have the same natural history as primary tears, which usually progress in size over time. Adverse signs of progressed structural deterioration in the failed repairs included a decrease in acromio-humeral distance, progression of osteoarthritis and progressive fatty degeneration of the infraspinatus.

In an effort to identify factors associated with healing, Chung et al (32) investigated 108 patients who underwent arthroscopic repair of massive cuff tears at a minimum of 1 year of follow-up. Anatomic failures occurred in 39.8% of patients. This is a comparable retear rate to that reported by Zumstein et al (35) (57%) and Kim et al (48) (42.4%). All patients had significant improvement in pain as measured by several outcomes scores; however, functional outcome was poor in 38 of 108 patients as they had an American Shoulder and Elbow Surgeons (ASES) score less than 80. Fatty infiltration of the infraspinatus was found to be an independent prognostic factor for poor structural healing. Further analysis of failed structural healing revealed that a postoperative acromio-humeral distance of <4.1 mm was associated with poor functional outcomes. Zumstein et al (42) indicated that open repair of massive rotator cuff tears yielded excellent results at a mean follow-up of 9.9 years. A wide lateral extension of the acromion has been identified as a risk factor for re-tearing.

A study conducted by Ames et al (43) found that patients with a larger acromial index were more likely to have an increased number of rotator cuff tendons torn as well as a larger number of anchors used in the repair.

Biomechanical studies have shown superiority of the double-row rotator cuff repair on the basis of increased load to failure and better restoration of the tendon footprint (44). Similarly, a meta-analysis of level I randomized clinical trials comparing arthroscopic single-row versus double-row rotator cuff repair conducted by Millett et al (45) found that single-row repairs had significantly higher re-tear rates compared with double-row repairs, especially with regard to partial-thickness re-tears. In particular, the trans-osseous equivalent double-row technique has demonstrated greater tendon-bone contact area and pressure as well as better healing compared with other double-row techniques (16, 46, 47).

Another interesting study evaluated the use of anchors in PEEK (polyether ether ketone) versus bio-composite suture anchor (glycolic polylactic acid anchors, beta-tricalcium phosphate and calcium sulphate) proving that the degree of bone growth in PEEK anchors was comparable to that of anchors with biocomposite material in the healing phases. Shoulder function improved after complete repair of the rotator cuff, regardless of material (48).

In a case-control study Di Benedetto et al (49) showed that the Cascade Autologous Platelet System did not result in improved ROM, strength, Constant score, NRS, tendon fat degeneration and muscle atrophy after surgical arthroscopical repair of supraspinatus small tears. Only its tendon thickness and signal intensity were improved.

The optimal postoperative rehabilitation strategy to promote healing has yet to be determined. The ideal protocol protects the repair construct during the healing process while minimizing the risk of postoperative stiffness. A study conducted by Iannotti et al (50) investigated the time to failure after rotator cuff repair of full-thickness tears ranging from 1 to 4 cm. The investigators found that the majority of re-tears occurred between 6 and 26 weeks postoperatively, suggesting that rehabilitation should focus on protecting the repair for a longer time.

2. Partial rotator cuff repair

A complete anatomic repair of massive rotator cuff tears is not always surgically possible as a result of poor tissue quality, tendon loss, severe retraction, or increased tension of the repair (51). In these cases, partial repairs of the tendons have been used successfully. Burkhart introduced the concept of partial repair on the basis of restoring biomechanical force couples and increasing acromio-humeral distances, therefore improving function and pain (52, 53).

The outcomes of partial repair have subsequently been studied by many investigators (44, 54-60). Overall, functional outcomes showed significant improvement over pre-operative levels. Several studies have investigated differences in term of outcome between complete and partial repair. Moser et al (50) observed that active external rotation was significantly better in the complete repair vs. partial repair; however, differences in subjective pain and function were not statistically significant. Iagulli et al (47) found that both partial repair and complete repair groups exhibited significant improvements in the University of California–Los Angeles shoulder score after surgery at a mean follow-up of 24 months; however, there was no significant difference in score between the 2 groups. Kim et al (48) compared clinical outcomes at 2 years between complete arthroscopic repair with aggressive cuff release and partial repair with margin convergence. Again, no statistically significant differences were found with respect to functional outcomes between the 2 groups at the time of follow-up. It was furthermore analyzed the relationship between clinical and surgical findings and the arthroscopic reparability of rotator cuff tears (42) and both partial and complete repair groups demonstrated improved function and level of disability.

In conclusion, partial repair of massive rotator cuff tears is an acceptable treatment option for patients in whom a complete repair is not possible. Patients can expect good clinical and functional outcomes after surgery.

3. Patch augmentation

Failures of rotator cuff repairs led to the investigation of patch augmentation materials to enhance the strength of the repair and the healing potential, thus serving as an alternative technique to tendon transfers in active patients with massive rotator cuff tears with minimal glenohumeral arthritis. Many varieties of patch augmentation have been developed, including nondegradable structures, extracellular matrix–based patches and degradable synthetic scaffolds. When a patch augmentation device is used, the rotator cuff is repaired to nearly normal status either arthroscopically or with an open approach. The patch is then either implemented into the repair construct or sutured over the top of the repaired tendon by an arthroscopic, mini-open or open technique.

Studies had showed that a patch-reinforced repair with an augmentation material decrease gap formation at the tendon-bone repair site (62,62) Since increased gap formation has been implicated as a factor associated with decreased healing (63), these studies suggest that patch augmentation may facilitate healing of the rotator cuff tendon.

Favorable clinical outcomes have been reported in several studies using different patch materials with the outcome influenced by the type of patch used. Iannotti et al (64) reported no improvement of healing for the surgical repair of large and massive chronic rotator cuff tears augmented with porcine small intestine submucosa in a randomized clinical trial. Mori et al (65) investigated the clinical outcomes of patients who underwent arthroscopic partial repair or a patch graft procedure to repair large or massive rotator cuff tears with low-grade fatty degeneration of the infraspinatus. The group of patients who underwent the patch graft procedure had significantly better mean postoperative Constant scores and ASES scores compared with the partial repair group at a mean follow-up of 35 months. The re-tear rate of the infraspinatus in the patch graft group was 8.3% whereas the rate was 41.7% in the partial repair group as detected by MRI, suggesting that the patch graft procedure can improve healing and clinical outcomes (56).

Additional studies are needed to better understand the cellular factors associated with the healing of rotator cuff repairs and how to further stimulate these factors with augmentation material. Future studies comparing partial repair and patch augmentation may be of particular interest to determine the appropriate treatment of patients in whom complete repair is not achievable.

4. Superior capsular reconstruction (SCR) and bridging reconstructions

Superior capsular reconstruction using a human dermal allograft or autograft fascia lata has been suggested as an alternative for managing massive irreparable rotator cuff tears, defined as the inability of the torn rotator cuff tendon to reach the original footprint (66).

Since the superior capsule attaches to a significant portion of the greater tuberosity (67), it is often disrupted when complete tears of the supraspinatus or infraspinatus occur. A biomechanical study determined that superior capsular defects led to increased gleno-humeral translation in all directions, particularly with superior translation at 5° and 30° of abduction (68). Biomechanically, reconstruction of the superior capsule with a patch graft attached medially to the superior glenoid and laterally to the greater tuberosity restored superior translation to physiologic conditions (69).

Early biomechanical and clinical results have demonstrated the ability of SCR to contain the humeral head from superior migration and, in several cases, to reverse a pseudoparalytic shoulder (59). Mihata et al (59) investigated clinical outcomes of superior capsular reconstructions in 24 shoulders with irreparable tears. A fascia lata autograft was used as the augmentation material to reconstruct the superior capsule. All average clinical outcomes scores significantly improved at a minimum 2-year follow-up period with a restoration of anterior and posterior force couples (59) and no evidence of surgical complications related to the procedure. Similarly, Thorseness et al (16) reported no evidence of gleno-humeral arthritis in patients younger than 65 years.

Gupta et al (70) suggested a bridging interposition reconstruction of irreparable massive rotator cuff tears, sewing a human dermal allograft into the native tendon and anchoring it laterally onto the greater tuberosity. They reported promising results in a prospective observational study of 24 patients with an average 3-year follow-up (60).However, patch augmentation devices are not FDA approved to span a gap in the rotator cuff repair greater than 1 cm.

5. Tendon transfers

Many different tendons, most commonly latissimus dorsi, pectoralis major and trapezius may be involved in tendon transfers. The primary goal is to restore the anterior and posterior biomechanical force couples of the glenohumeral joint, thus providing pain relief and improving function. However, it is most suitable for young, active patients with good tissue quality, minimal glenohumeral arthritis and severe functional limitations (71).

6a. Latissimus dorsi transfer

Transfer of the latissimus dorsi with or without the teres major is most commonly used for massive irreparable posterosuperior tears. The latissimus dorsi has a large muscle excursion, making it a good candidate for muscle transfer (72), whereas the teres major has a small muscle excursion and small tendon, thus if it is transferred, it is usually done in conjunction with the latissimus dorsi. Several surgical techniques have been used for latissimus dorsi transfer, including single-incision, double-incision and arthroscopically assisted transfer (73,74).

Normal function of the latissimus dorsi muscle-tendon unit on the humerus includes adduction, internal rotation and extension. When it is transferred, the muscle no longer serves as an internal rotator but rather is an external rotator and humeral head depressor (75). Transferring the muscle-tendon from its insertion on the midbicipital groove anteriorly to the greater tuberosity postero-superiorly restores the posterior force couple and therefore improves glenohumeral function. The humeral head depression induced by the transferred tendon contributes to improving biomechanics of the glenohumeral joint by centering the humeral head on the glenoid, creating a better fulcrum. A more posterior placement results in more external rotation, whereas more superior placement results in more humeral head depression (76).

A systematic review conducted by Namdari et al analyzed 10 studies between 1992 and 2010 to determine the expected outcomes, predictive factors for success, and complications of latissimus dorsi transfers (61). Frequency-weighted mean follow-up was 45.5 months. The frequency-weighted mean adjusted Constant score improved from 45.9 preoperatively to 73.2 postoperatively. Frequency-weighted mean active forward elevation improved from 101.9° preoperatively to 137.4° postoperatively, active external rotation improved from a frequency-weighted mean of 16.8° to 26.7°, active abduction improved from a frequency weighted mean of 91.4° preoperatively to 130.7° postoperatively. The overall reported complication rate was 9.5%, which included infection, neurapraxia, tears of the transferred tendon, failures of deltoid repair, hematomas and wound dehiscence. In addition, in more than half of the shoulders, glenohumeral arthritis progressed and there was superior migration of the humeral head. Further analysis of the data led the authors to conclude that poor functional outcomes are more likely after revision surgery, with advanced teres minor fatty muscle atrophy, and in patients with a deficient subscapularis.

Moursy et al investigated the effect of removing a small piece of bone with the latissimus dorsi when doing the transfer with respect to detachment of the tendon from the greater tuberosity compared with sharp separation of the tendon from the insertion on the humerus (64). The ASES score, mean Constant score, range of motion, and strength were all significantly better in the group that had the tendon harvested along with a bone chip. In addition, MRI showed detachment of the tendon in 4 out of 22 patients (18%) in the sharp separation group and 0 out of 20 patients (0%) in the bone chip group (64). Inclusion of a bone chip when harvesting can decrease transferred tendon ruptures, one of the factors associated with failure.

The short-term results of arthroscopically assisted latissimus dorsi transfer were similar to those of previous studies (77). Less strength in forward elevation and lower Constant scores were observed for revision surgeries relative to primary surgeries. There was significant improvement in pain and range of motion in external rotation as well. Arthroscopic latissimus dorsi transfer at short-term follow-up has results comparable to those of open procedures and provides an alternative technique to traditional methods.

In conclusion, latissimus dorsi transfer is a reasonable surgical option in young patients with poor tissue quality and massive posterosuperior rotator cuff tears. Improvements in pain and function facilitate daily living activities and a higher quality of life, but a proper selection of patients is important for the success of this technique.

6b. Pectoralis major transfer

Irreparable anterosuperior rotator cuff tears can be surgically treated with a transfer of the pectoralis major tendon. This technique is particularly useful in treating patients with recurrent anterior instability resulting from subscapularis insufficiency (78).

The deltopectoral approach is used for surgery and several surgical techniques have been described; however, the subcoracoid pectoralis major transfer most closely approximates the inferior and posterior force vector originally provided by the subscapularis (79). Gerber et al described a technique using split pectoralis major transfers to re-establish the posterior and inferior force vectors (80). This technique reduces the risk of injury to the musculocutaneous nerve by going underneath the conjoined tendon.

Reliable improvements in function and pain have been recorded in several studies for patients who underwent a pectoralis major transfer for isolated subscapularis tears and multi-tendon tears involving the subscapularis.

Jost et al noted that outcomes were less favorable in patients who had a concomitant irreparable supraspinatus tear (81).A systematic review of 8 studies (195 shoulders) noted an improvement in Constant scores from a mean preoperative value of 37.8 to 61.3 postoperatively (82). The Constant scores were significantly higher in patients who had a subcoracoid transfer of the pectoralis major tendon compared to those with a supracoracoid transfer, in agreement with the biomechanical observations of Konrad et al (83). Elhassan et al found that patients with irreparable ruptures of the subscapularis tendon after shoulder replacement had a high risk of failure of the pectoralis major transfer, especially in case of preoperative anterior subluxation of the humeral head (84).

In conclusion, pectoralis major transfer is a reasonable surgical option for the management of irreparable anterosuperior rotator cuff tears, particularly when the patient is experiencing anterior instability as a result of subscapularis insufficiency. Patients can expect a significant improvement in pain and function, with better outcomes if there is an isolated subscapularis tear.

6c. Trapezius transfer

Trapezius transfers are currently used to improve external rotation in patients with brachial plexopathy (85). A biomechanical investigation found that a lower trapezius transfer is more effective in restoring external rotation than the latissimus dorsi transfer (86). Consequently, there is increased interest in using trapezius transfers for treatment of massive irreparable posterosuperior rotator cuff tears. Additional biomechanical and clinical studies will be needed to see if this method may be useful in the management of massive rotator cuff tears.

6. Reverse total shoulder arthroplasty (rTSA)

A major indication for rTSA is cuff tear arthropathy, in which a massive rotator cuff tear goes along with secondary gleno-humeral joint damage (1). Although hemiarthroplasty has been considered the treatment of choice for cuff tear arthropathy for a long time, rTSA has been shown to yield better results concerning pain relief and function (87).

rTSAs are also frequently used for pseudoparalysis due to massive irreparable rotator cuff tears even in the absence of osteoarthritic degeneration of the glenohumeral joint (88). Additional indications for rTSA include comminuted proximal humeral fractures in elderly patients with poor bone quality and revision arthroplasty.

Reported rates for complications and revisions after rTSA have been as high as 50% and 33%, respectively (89). More recently, lower complication rates (7%) and revision rates (5.3%) have been reported (90). It is important to assess the integrity of the teres minor preoperatively as Simovitch et al reported inferior outcomes in patients with stage 3 or stage 4 fatty infiltration (91). Furthermore, Boileau et al noted that when the preoperative function of the teres minor was impaired as determined by the Hornblower sign, postoperative active external rotation decreased significantly (92).

Some studies have shown better improvement in terms of pain relief, function and satisfaction in patients younger than 65 years (78) or 60 years (93) ; however, high complication rates of 37.5% (78) and 25.0% (83), respectively occurred. Guery et al reported a survivorship 10 years after rTSA of 58%, therefore recommending that rTSA should be reserved for patients older than 70 years with low functional demands (94). This statement was supported by Favard et al, who reported a deterioration both clinically and radiologically over time, therefore recommending caution with indication for reverse shoulder arthroplasty, especially in younger patients (95).

Conclusion

The management of patients with massive rotator cuff tears remains challenging. A thorough knowledge of treatment options and indications is crucial to achieve the best outcomes for patients. Surgical advances including patch augmentation have improved the treatment of massive rotator cuff tears; however, long-term studies are needed to identify prognostic factors and ideal techniques and to optimize selection of patients.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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Received: 1 May 2021
Accepted: 13 May 2021
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