Massive Tears of the Rotator Cuff

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**Spanish translation**

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Massive rotator cuff tears present a particularly complex and difficult challenge for the orthopaedic surgeon. Operative repair of these tears is technically difficult and is associated with a recurrence rate that is distinctly higher than that associated with repairs of smaller tears. Technical challenges include inelastic and often poor tendon quality, scarring and adhesions to the retracted tendon, muscle atrophy, and fatty infiltration. In addition to the technical limitations of the procedure, a poor biological milieu and relative hypovascularity of the tendons can further impair tendon-to-bone healing. These technical and biological challenges have raised questions regarding the appropriate treatment strategy for symptomatic massive rotator cuff tears.

Definition and Prevalence

There is no consensus regarding the definition of a massive rotator cuff tear. Both anatomic and functional characteristics have been used to classify rotator cuff tears, but each methodology has limitations. Cofield et al. defined a massive tear as a tear with a diameter of ≥5 cm, while Zumstein et al. defined a tear as massive if there was complete detachment of two or more tendons. Others have proposed classification systems based on the area of the defect. Tauro proposed an index calculated by multiplying the anteroposterior by the mediolateral dimension of the tear. Burkhart proposed a classification of rotator cuff tears based on the tear pattern and the mobility of the tear margins. Crescent-shaped tears are the classic standard type, and they have excellent medial-to-lateral mobility. These tears can be repaired directly to bone with minimal tension. In contrast, u-shaped tears extend much farther medially, with the apex of the tear being adjacent to or medial to the glenoid rim. Recognizing this tear pattern is critical because side-to-side “margin convergence” sutures to decrease tensile forces are necessary before the tendon can be repaired directly to bone. However, all of these classification systems are vulnerable to error due to variation in patient size, arm position at the time of measurement, and the techniques used to measure the degree of tendon retraction.

The prevalence of massive tears reported in the literature has ranged from 10% to 40% of all rotator cuff tears. Harryman et al. reported that 28% (fifty-three) of all (191) surgically repaired rotator cuff tears in a five-year period were massive posterosuperior tears. Massive anterosuperior tear configurations involving the supraspinatus and subscapularis tendons are less common, ranging from approximately 5% to 20% of all rotator cuff tear patterns.

It is critical to recognize that massive rotator cuff tears are not necessarily synonymous with irreparable tears. While the
repair of massive tears can often be technically challenging, many are reparable\(^2\). An acute traumatic tear or an avulsion injury may be >5 cm in dimension but have a good-quality elastic tendon stump and be anatomically reducible without placing excessive tension on the repair. Signs of irreparability include static superior migration of the humeral head, a narrowed or absent acromiohumeral interval, and fatty infiltration affecting ≥50% of the rotator cuff musculature (Figs. 1-A and 1-B)\(^{22,23,27,28}\).

**Biomechanics of Massive Cuff Tears**

The deltoid and rotator cuff muscles work synergistically to maintain a balanced force couple for the glenohumeral joint in both the coronal and the transverse plane. The deltoid and rotator cuff inferior to the humeral head equator maintain a balanced coronal force couple, while the subscapularis and infraspinatus/teres minor complex balance each other in the transverse plane. In this capacity, the rotator cuff muscles function as primary dynamic stabilizers to maintain a concentric reduction during rotation of the humeral head on the glenoid\(^{20,29-33}\). Massive cuff tears can disrupt this force couple and ultimately compromise the fulcrum that is necessary for normal glenohumeral mechanics. For this reason, Burkhart defined a large rotator cuff tear that does not impair function as one involving the supraspinatus tendon and the superior half of the infraspinatus tendon, since balanced force couples are maintained in this setting\(^{20,34}\). When the tear also compromises...
the inferior half of the rotator cuff, however, the balanced force couple in the coronal plane is lost and the massive cuff tear impairs function.

**History, Physical Examination, and Imaging**

Symptomatic massive rotator cuff tears are frequently painful, particularly at night and during activities of daily living. Patients may report varying degrees of weakness and varying losses of the range of motion. On physical examination, patients with a long-standing tear may have visible atrophy of the supraspinatus and/or infraspinatus muscles. Functional deficits often correlate with the location of the tear. Posterosuperior cuff disruption typically causes decreases in abduction, forward flexion, and active external rotation. Patients may have weakness in external rotation and a positive external rotation lag sign, which is the inability to hold one's arm in a position of maximum external rotation. Patients with a larger tear, with complete loss of external rotation strength, may exhibit a positive hornblower sign—i.e., they may be unable to externally rotate the shoulder (the motion required for a hornblower to get the horn to the lips with the arm at the side). An inability to complete this action without abducting the arm to avoid active external rotation reflects deficiency of teres minor function. Walch et al. found this sign to be 100% sensitive and 93% specific in terms of identifying irreparable tears of the teres minor. Walch et al. found this sign to be 100% sensitive and 93% specific in terms of identifying irreparable tears of the teres minor.

Anterosuperior rotator cuff failure can result in decreased abduction and forward flexion of the shoulder. With subscapularis involvement, the physical examination may reveal positive belly-press and lift-off tests as well as increased passive external rotation. In the belly-press test, the patient's inability to push down on the belly without the elbow dropping behind the plane of the body is indicative of deficiency of the upper portion of the subscapularis muscle. In the lift-off test, subscapularis dysfunction is indicated by an inability of the patient to push away the examiner from an internally rotated “behind the back” position. Barth et al. recently described the bear-hug test for subscapularis tendon tears. The test is performed by placing the palm on the affected side on the contralateral shoulder with the fingers extended and the elbow positioned anteriorly. The patient then holds this position while the physician tries to pull the patient’s hand away from the shoulder by applying an external rotation force perpendicular to the forearm. While all tests had a specificity of >90%, the authors found the bear-hug test to have greater sensitivity (60%) than the belly-press and lift-off tests. Chao et al. recently completed electromyographic studies to correlate physical examination findings with subscapularis function. The bear-hug test performed at 45° of forward flexion and the belly-press test demonstrated peak electromyographic activity in the upper part of the subscapularis muscle, while the bear-hug test performed at 90° of forward flexion demonstrated peak activity in the lower part of the subscapularis muscle.

Imaging studies play a critical role in both the diagnosis of, and the selection of the correct treatment for, massive cuff tears. A decreased acromiohumeral distance can provide evidence of a massive cuff tear. Computed tomography scans are now used less frequently than magnetic resonance imaging, but they can be performed to assess rotator cuff atrophy and fatty infiltration. Magnetic resonance imaging and ultrasonography are the most common imaging modalities used to diagnose rotator cuff lesions. While the specificity and sensitivity of ultrasonography is highly operator-dependent, the test is dynamic and permits evaluation of the shoulder during provocative maneuvers that reproduce symptoms. It is also particularly useful in the presence of proximal humeral fracture-fixation implants or a shoulder prosthesis, as compared with magnetic resonance imaging in these settings are limited by metallic artifact-induced image distortion. Limitations of ultrasonography as compared with magnetic resonance imaging include difficulty with defining complex tear patterns, with grading of the severity of fatty infiltration of muscle, and with identifying coexistent intra-articular pathological involvement of the labrum or biceps tendon. In recent studies, magnetic resonance imaging has been shown to be 100% sensitive in terms of diagnosing rotator cuff tears, and it can be used accurately to estimate tear size, retraction, and fatty infiltration.

**Treatment Options**

We are not aware of any randomized controlled trials comparing nonoperative with operative treatment or of any studies directly comparing the various surgical options, which range from simple debridement to tendon transfer. In addition, patients with massive rotator cuff tears demonstrate substantial heterogeneity with regard to the severity of the tear, tissue...
TABLE I Grades of Recommendations for Treatment of Massive Rotator Cuff Tears

<table>
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<th>Grade of Recommendation*</th>
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*A = good evidence (Level-I studies with consistent findings) for or against recommending intervention, B = fair evidence (Level-II or III studies with consistent findings) for or against recommending intervention, C = poor-quality evidence (Level-IV or V studies with consistent findings) for or against recommending intervention, and I = there is insufficient or conflicting evidence not allowing a recommendation for or against intervention.

Nonoperative Treatment

Some authors have suggested that repairs of massive rotator cuff tears are followed by a prohibitively high recurrence rate and that it may be preferable to treat such tears nonoperatively or with simple debridement. Several studies have shown that patients with a massive tear have good motion and the ability to perform activities of daily living. Using a cadaver shoulder model, Hansen et al. demonstrated that stable glenohumeral abduction without excessive superior humeral head translation could be maintained in the setting of a massive tear but requires the generation of higher forces in the deltoid and the remaining intact portion of the rotator cuff. Subscapularis forces were increased 30% to 85% depending on the tear size. Some individuals with a massive tear, even those with a tear that involves the inferior infraspinatus and teres minor tendons, can maintain active shoulder abduction and good function with low-demand daily activities. One hypothesis is that contraction of the deltoid muscle superioresly translates the humeral head underneath the coracoacromial arch and allows pivoting around this abnormally superior center of rotation.

Bokor et al. noted improvement in 50% to 85% of fifty-three patients after nonoperative treatment of a full-thickness rotator cuff tear. The duration of symptoms correlated with the long-term success of nonoperative management, with patients with symptoms for longer than six months having inferior outcomes. Levy et al. recently described an effective system for rehabilitation and "re-education" of the anterior deltoid muscle to compensate for a deficient rotator cuff. This approach is supported by recent biomechanical studies that have demonstrated an important role for the anterior deltoid muscle in preventing superior humeral head migration and compressing the glenohumeral joint in the presence of a large cuff tear. Seventeen patients with a radiographically confirmed, massive chronic rotator cuff tear were prospectively evaluated for a minimum of nine months following a twelve-week anterior deltoid rehabilitation program. The mean Constant score improved from 26 to 60 points and the mean forward flexion improved from 40° to 160° after completion of the program.

Zingg et al. reported on the clinical and structural midterm outcomes of nonoperative management of massive rotator cuff tears. Nineteen consecutive patients with a massive rotator cuff tear and low functional demands were managed nonoperatively, and the mean duration of follow-up was forty-eight months. At the time of final follow-up, the mean absolute Constant score was 69 points (range, 41 to 94 points on a 0 to 100-point scale) and the mean Subjective Shoulder Score was 68 points (range, 30 to 95 points on a 0 to 100-point scale). Patients maintained good shoulder function and preserved their active range of motion. Despite clinical improvement, however, glenohumeral osteoarthritis progressed, the acromiohumeral distance decreased, and fatty infiltration of the involved muscles increased by approximately one Goutallier grade. The risk of rotator cuff arthropathy and irreversible fatty infiltration of muscle may limit future treatment options and must be considered when counseling patients.

Debridement and Subacromial Decompression

Arthroscopic debridement has been reported to have satisfactory short-term outcomes in patients with a massive rotator cuff tear. This procedure is primarily indicated for elderly, low-demand patients with pain but good preservation of active motion and an intact coronal and transverse force couple about the glenohumeral joint. Although shoulder strength does not improve after this intervention, function is usually enhanced because of relief from pain caused by mechanical impingement. Preoperative relief from a subacromial injection is a favorable prognostic finding for improvement after this operation. If operative debridement and subacromial decompression is performed, it is critical that the coracoacromial ligament be preserved in the setting of a massive rotator cuff tear. The coracoacromial ligament is an important static stabilizer against anterosuperior escape of the humeral head (Fig. 3).

Mixed results have been reported after open or arthroscopic subacromial decompression and debridement of massive rotator cuff tears. Augereau and Apoil reported poor long-term results after open subacromial decompression and resection of the coracoacromial ligament. Rockwood et al. reported decreased pain and improvement of function and strength in forty-four (88%) of fifty patients after tear debridement and decompression. Gartsman et al. reported modest results of open debridement and subacromial decom-
expression, with decreased pain relief and improved function but decreased strength as compared with the preoperative condition\textsuperscript{41,51}. Zvijac et al. reported deterioration of function and strength over time\textsuperscript{53}, and Kempf et al. reported only modest improvement in the overall Constant score after the treatment of massive tears with arthroscopic debridement and long-term postoperative rehabilitation\textsuperscript{54}.

In order to maintain the integrity of the coracoacromial arch in the setting of a massive rotator cuff tear, alternative decompressive procedures have been described. Fenlin et al. described open debridement and tuberoplasty for massive irreparable rotator cuff tears to reshape the greater tuberosity for smooth articulation with the acromion\textsuperscript{55}. In a study of twenty patients followed for twenty-seven months, 95\% reported satisfactory results and the improvement in the mean UCLA score was from 9.3 to 27.7 points\textsuperscript{55}. Scheibel et al. described a so-called reversed arthroscopic subacromial decompression, a procedure that includes arthroscopic debridement of the subacromial space and glenohumeral joint, and an arthroscopic tuberoplasty with or without biceps tenotomy\textsuperscript{56}. Twenty-three patients were followed for a mean of forty months, and the age-adjusted Constant score increased from 66 to 91 points. The average acromiohumeral distance only decreased from 5.1 to 4.5 mm, and the integrity of the coracoacromial arch was preserved\textsuperscript{56}.

**Biceps Tenotomy**
The function of the long head of the biceps tendon, particularly in the setting of a massive rotator cuff tear, is controversial. Some studies have shown the biceps to function as both a dynamic and a static humeral head depressor and shoulder stabilizer\textsuperscript{57,58}. Recent electromyographic studies have shown the long head of the biceps to be quiescent in patients with a massive cuff tear during active abduction, suggesting that its stabilizing role is likely more passive than active\textsuperscript{59}.

There is evidence suggesting that the long head of the biceps tendon may be a source of pain and contribute to the discomfort associated with symptomatic massive cuff tears. Walch et al. reported the outcomes after biceps tenotomy in patients with an irreparable massive rotator cuff tear\textsuperscript{60}. Three hundred and seven biceps tenotomies were performed in patients with an irreparable rotator cuff tear or in those who were not willing to participate in the rehabilitation required after rotator cuff repair. At a mean of fifty-seven months postoperatively, the average Constant score increased from 48 points preoperatively to 68 points postoperatively. Concomitant acromioplasty was associated with better subjective and objective results in patients with a preserved acromiohumeral distance of >6 mm. Fatty infiltration of the rotator cuff, however, had a negative influence on both functional and radiographic outcomes\textsuperscript{60}.

**Partial Repair**
Partial repair has been shown to yield a good outcome in some patients who have a massive rotator cuff tear, and this method should be considered in the setting of good tissue quality. Often, isolated repair of the infraspinatus tendon to bone can
significantly improve external rotation strength and functional outcomes, even if the supraspinatus tendon cannot be repaired.\textsuperscript{28-32} It is important for the treating surgeon to recognize that complete closure of the defect is less important than restoration of a stable fulcrum of the glenohumeral joint.\textsuperscript{28-30,32,33} In this capacity, margin convergence sutures that improve the mechanical advantage of the rotator cuff can restore the balance of coronal and transverse force couples (Fig. 4).

Duralde and Bair retrospectively reviewed the results of partial open repair of a massive rotator cuff tear in twenty-four patients in whom a complete repair to bone was not achievable.\textsuperscript{61} At a mean of forty-three months postoperatively, good-to-excellent results were achieved in 67\% of the patients and 92\% were satisfied with the result. The mean active elevation improved from 114° preoperatively to 154° postoperatively, and no patient lost strength after the operation.\textsuperscript{61} Burkhart et al. reported similar outcomes in fourteen patients after partial repairs of massive tears and noted that the mean active forward flexion improved from 60° preoperatively to 150° postoperatively.\textsuperscript{41,62,63}

**Complete Repair**

Even if a direct repair of tendon to bone is achievable, it is often difficult to reliably achieve long-term healing with a structurally intact repair. These tears have had an unfavorable treatment history and repair is technically difficult, with a retear rate that is distinctly higher than that associated with smaller tears.\textsuperscript{3,5,13,18,64,65,67-69} Despite improvements in functional outcome scores, Galatz et al. reported recurrence of the tear in seventeen of eighteen patients at an average of thirty-six months after arthroscopic rotator cuff repair of tears measuring >2 cm in their transverse dimension.\textsuperscript{65,66}

**Operative Technique**

Tendon loss, retraction, and scarring are common and must be addressed to achieve a satisfactory repair of a massive rotator cuff tear. Regardless of whether the repair is performed arthroscopically or open, subacromial and subdeltoid adhesions should be released and bursal tissue should be excised first to clearly visualize the tear pattern.\textsuperscript{62-64} Adhesions superficial to the supraspinatus and infraspinatus muscles should be bluntly released.\textsuperscript{28,73-75} In a series of ninety-four massive rotator cuff tears, Lo and Burkhart reported that 90\% could be primarily repaired to bone after an adequate lysis of adhesions with use of a margin convergence technique.\textsuperscript{26} Occasionally, capsular releases may also be required to address particularly contracted or immobile tendons in massive tears. Bigliani et al.\textsuperscript{57,68} described an open anterior interval release of the coracobrachial ligament to the base of the coracoid process.

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**Fig. 4**

Partial repair of a massive rotator cuff tear. Margin convergence sutures have been placed between the limbs of a massive L-shaped tear, advancing the tissue laterally and decreasing tension on the free edge of the tear. Even though the free edge cannot be anatomically repaired to its native footprint, this type of partial repair can substantially improve humeral head coverage and balance the coronal force couple of the glenohumeral joint.
and Tauro described an arthroscopic release of the rotator interval to improve the mobility of a retracted supraspinatus tendon. A second posterior interval slide, or blunt release between the supraspinatus and infraspinatus tendons, may occasionally be required to further improve mobility and allow differential tensioning of the infraspinatus and supraspinatus tendons.

The optimal repair technique and anchor configuration for massive rotator cuff tears is not clearly established and may be affected by a number of variables, most importantly tear configuration and tissue quality. Performing a double-row repair has been advocated by several authors, who have cited superior biomechanical characteristics and an increased tendon-bone contact area for healing compared with those associated with single-row configurations. In the setting of a massive tear, however, double-row configurations may result in overtensioning of the repaired rotator cuff. For this reason, Snyder et al. advocated performing a medialized repair with a single row of sutures placed at the articular margin. Hersche and Gerber studied long-standing ruptures of the supraspinatus and found passive tension in these tendons to be 45 N greater than that in the intact musculotendinous unit. Using a biomechanical cadaver model, Domb et al. demonstrated that a double-row construct fared significantly better than a single-row construct in terms of displacement in the first cycle, stiffness in the final cycle, and ultimate load-to-failure. Park et al. corroborated these findings clinically, demonstrating that the American Shoulder and Elbow Surgeons (ASES) and Constant scores following double-row repairs were significantly improved compared with those after single-row repairs of tears of >3 cm. However, in a randomized controlled trial comparing single-row with double-row suture anchor repairs of rotator cuff tears in sixty patients, Franceschi et al. reported no significant differences in the range of motion or the mean UCLA scores at two years postoperatively despite the mechanical superiority of the double-row construct.

Outcomes
Zumstein et al. prospectively studied the outcomes in twenty-seven patients who had undergone an open, transosseous repair of a massive rotator cuff tear. At a mean of 3.1 years postoperatively, all of these patients reported a good-to-excellent result despite a retear rate of 37%. A wide, lateral extension of the acromion was identified as a risk factor for failure of the repair. At a mean of 9.9 years, twenty-three of these twenty-seven patients returned for a follow-up examination. Twenty-two patients remained satisfied with their outcome, although the retear rate had increased to 57%.

Lam and Mok reported on a retrospective series of seventy-four patients, sixty-five years of age or older, who had undergone a repair of a symptomatic massive rotator cuff tear. At a mean of forty-eight months postoperatively, 84% of the patients were satisfied and 93% had pain relief. Multivariate analysis revealed female sex and a duration of symptoms of
greater than thirty-four months before the operation to be prognostic for an inferior outcome.  

Björkenheim et al. reported that the results of repairs of large and massive rotator cuff tears were markedly inferior to the results of repairs of smaller tears. Jost et al. found that the clinical outcomes of patients with reperfusion after a massive rotator cuff repair correlated significantly with the size of the recurrent defect and the extent of fatty degeneration of the infraspinatus and supraspinatus muscles.

**Fatty Infiltration**

Fatty infiltration of the involved rotator cuff muscles has been identified as a negative prognostic factor for the reparability of a massive cuff tear and the outcome after such a repair. Warner et al. studied patients with massive rotator cuff tears of similar sizes and found a correlation between the appearance of fatty infiltration on magnetic resonance imaging and overall shoulder biomechanics and function. A correlation between the severity of fatty infiltration and poor tendon-tissue quality was observed intraoperatively. The pennation angle (the mean angle formed by the individual muscle fibers with the line of action of the muscle) decreases, and an increased amount of fat fills the space between muscle fibers in chronic rotator cuff tears.

While fatty infiltration may compromise the results of repair of a massive tear, satisfactory functional outcomes may still be achievable in the short to mid-term. Burkhart et al. reported on a retrospective series of twenty-two patients with a massive rotator cuff tear and Goutallier stage-3 or 4 fatty degeneration of the infraspinatus. The mean UCLA score improved from 12 points preoperatively to 30 points at a mean of thirty-nine months postoperatively. However, the five patients with Goutallier stage-4 degeneration had substantially less improvement in both the subjective and the objective outcomes.

**Suprascapular Nerve**

The effects of massive tears and their subsequent repair on the suprascapular nerve remain unclear. Massive posterosuperior tears can place excessive traction on the suprascapular nerve and result in neuropathy with pain and weakness. This occurs because of the relatively fixed position of the nerve beneath the transverse scapular ligament, rendering it vulnerable to traction injury with muscle retraction. Mallon et al. reported that, of eight patients with a massive cuff tear, all had suprascapular neuropathy, as demonstrated by electrodiagnostic studies, with severely limited motion and pain. Vad et al. noted a 28% prevalence of peripheral neuropathy, usually involving the supraspinatus and axillary nerves, in a series of twenty-five patients with a full-thickness tear of the rotator cuff with atrophy. Costouros et al. reported that, of seven patients who had a partial or complete repair of a massive rotator cuff tear associated with isolated suprascapular neuropathy, six demonstrated partial or complete recovery of the suprascapular nerve function on electrodiagnostic studies at six months postoperatively. The study demonstrated that suprascapular neuropathy and its associated pain and dysfunction may be reversible with repair of a massive tear.

**Repair with Scaffolds or Tissue Augmentation**

The high failure rate associated with repairs of massive tears has prompted investigation of scaffolds and other tissue augments to substitute for deficient tissue and achieve a tension-free repair. Scaffolds provide mechanical support and have biological properties that may favorably influence cell proliferation and differentiation, hopefully improving tendon-to-bone healing. Currently, scaffolds derived from dermis, small intestinal submucosa, skin, fascia lata, and pericardium have been processed and marketed for augmentation in the repair of massive tears. Flaps of the deltoid and autogenous biceps tendon have also been utilized to bridge a residual defect during massive cuff tear repair.

**Dermis-Based Patches**

Bond et al. reported outcomes following arthroscopic repairs of massive rotator cuff tears with use of a graft derived from human dermis. Fifteen of sixteen patients were satisfied with the result, and the mean Constant score increased from 54 points preoperatively to 84 points after a mean duration of follow-up of twenty-seven months. Thirteen patients had full incorporation of the graft into the native tissue as documented by magnetic resonance imaging. Burkhead et al. conducted a follow-up study of seventeen patients in whom a massive tear had been treated with an open repair and augmentation with graft derived from human dermis. At a mean of 1.2 years postoperatively, 24% of the repairs demonstrated some evidence of a recurrent tear. However, the mean UCLA scores improved from 9 points preoperatively to 26 points postoperatively. Badhe et al. presented the results in a retrospective case series of ten patients in whom a massive posterosuperior rotator cuff tear had been treated with open repair and augmentation with an acellular, porcine dermal xenograft patch. The mean Constant score improved from 41 points preoperatively to 62 points at a mean of fifty-four months postoperatively. Neither of these studies, however, demonstrated any reversal of preoperative atrophy or fatty infiltration. Only Metcalfe et al. reported favorable results after dermis-based-patch augmentation of repairs. However, the conclusions from these case series must be interpreted with caution, as none included a control group.

**Small Intestinal Submucosa Patches**

In contrast to the results of the use of dermis-based scaffolds, unfavorable healing and clinical outcomes have been demonstrated in a number of series in which porcine small intestinal submucosa grafts had been employed to augment the repairs of massive rotator cuff tears. Sclamberg et al. found that ten of eleven repairs had failed at six months postoperatively and recommended discontinuation of the use of these grafts. Iannotti et al. performed a randomized controlled trial of thirty patients and reported a trend toward worse outcomes with porcine patch augmentation compared with those with repair alone. Walton et al. performed a randomized controlled trial of patients in whom a massive rotator cuff tear had been treated with conventional open repair or with repair with porcine grafts. The results of repairs of smaller tears correlated significantly with the size of the rotator cuff tear.
small intestinal submucosa xenograft augmentation\textsuperscript{113}. Poor results led to cessation of the study after four of nineteen patients experienced a severe inflammatory reaction in the acute postoperative period that necessitated open irrigation, debridement, and patch removal\textsuperscript{113}.

**Tendon Transfers**

Tendon transfer is a viable surgical option for patients with a massive cuff tear and primary symptoms of weakness, pain, and impaired active motion. The ideal candidate for this operation is a patient who does not have glenohumeral arthritis but has impaired function related to weakness and loss of external rotation. Manual laborers with a massive irreparable tear who require strength to perform occupational tasks often fall into this category. The selection of the donor muscle-tendon unit is based on the structural deficit and impaired function. The operation and associated rehabilitation are often extensive. Patients must have a clear understanding of the magnitude of the operative procedure, the anticipated discomfort in the postoperative period, and the expectations that will be placed on them in the rigorous rehabilitation program.

**Latissimus Dorsi Transfer**

Transfer of the tendon of the latissimus dorsi muscle to reconstruct a massive posterosuperior rotator cuff tear was originally proposed by Gerber et al.\textsuperscript{15,16} (Fig. 6). The subscapularis tendon and deltoid muscle origin must be intact for the transfer to establish balanced coronal and transverse force couples about the glenohumeral joint\textsuperscript{114}.

Miniaci and MacLeod reported that fourteen of seventeen patients who were treated with this transfer after a failed rotator cuff repair had a satisfactory result\textsuperscript{115}. Warner and Parsons reported a 73\% overall patient satisfaction rate in a series of twenty-two patients treated with latissimus dorsi tendon transfer but a 27\% rerupture rate and significantly worse outcomes in patients who had a salvage procedure after a failed rotator cuff repair as opposed to a primary procedure\textsuperscript{114}. Iannotti et al. reported a 64\% rate of satisfactory results in a series of fourteen patients and noted that female sex, poor preoperative shoulder function, and generalized muscular weakness were associated with an inferior clinical outcome\textsuperscript{116}. In a study of eighteen patients treated with a latissimus dorsi transfer as a salvage procedure following a failed repair of a

![Fig. 6](https://example.com/fig6.jpg)

massive cuff tear, Birmingham and Neviser reported that the mean ASES score improved from 43 points preoperatively to 61 points at a mean of twenty-five months postoperatively27.

**Pectoralis Major Transfer**
The pectoralis major tendon transfer has been described for patients with a massive irreparable tear of the subscapularis tendon. The proximity and direction of pull of the pectoralis major tendon can help to restore internal rotation and the transverse force couple in the setting of subscapularis deficiency without static anterosuperior escape. With our preferred technique, the sternal and clavicular heads of the pectoralis muscle are separated to allow detachment of only the tendon of the sternal head for the transfer49. The muscle split between the two heads is extended medially to allow the sternal head to be passed beneath the clavicular head, which acts as a fulcrum for the sternal head to guide the vector of pull in line with the subscapularis tendon118-120. Elhassan et al. reported on thirty patients treated with this technique who were divided into three groups18. Group I comprised eleven patients in whom a procedure for shoulder instability had failed, group II included eight patients with a failed shoulder replacement, and group III included eleven patients with a massive irreparable tear of the rotator cuff. At the time of the latest follow-up, pain had decreased in seven of the eleven patients in both group I and group III but in only one of the eight patients in group II. The Subjective Shoulder Score improved in seven patients in group I, in one in group II, and in six in group III. The rate of failure of the tendon transfer was also highest in group II and was associated with preoperative anterior subluxation of the humeral head. Wirth and Rockwood reported satisfactory results in ten of thirteen patients after pectoralis transfer for treatment of an irreparable subscapularis tear119. Resch et al. performed a pectoralis major transfer in twelve patients and reported a good-to-excellent result in nine of them, but the results were less predictable in the ten patients who had complex shoulder disorders and had undergone the pectoralis major transfer after a previous failed operation (Fig. 7)120. Jost et al. reported satisfactory results after twenty-four of thirty pectoralis major transfers and noted that the outcomes were better in patients who had had an isolated, irreparable subscapularis tendon tear. No difference in outcome was noted with passage of the tendon above or below the conjoined tendon12.

**Hemiarthroplasty**
Neer et al. characterized rotator cuff arthropathy as superior subluxation of the humeral head, a decreased acromiohumeral distance with acetabularization of the acromion, and associated wear on the superior aspect of the humeral head and the greater tuberosity21 (Fig. 8). Hemiarthroplasty is a treatment option for patients with symptomatic rotator cuff arthropathy and modest functional goals122-126. Satisfactory function is typically obtained in the setting of an intact subscapularis tendon and a preserved axial force couple. However, static anterosuperior escape, in which the humeral head is no longer contained by the coracoacromial arch, is a contraindication24.

The reported clinical outcomes after hemiarthroplasty for cuff tear arthropathy have been mixed. Sanchez-Sotelo et al. reported on thirty-three shoulders in which glenohumeral arthritis and a massive irreparable tear of the rotator cuff had been managed with hemiarthroplasty122. While the mean pain score decreased from 4.2 points preoperatively to 2.2 points at the time of final follow-up at a mean of five years, nine patients had moderate pain at rest or with activity. In addition, seven shoulders that had undergone prior subacromial decompression developed anterosuperior instability after the hemiarthroplasty122. Overall, a successful result was reported in 67% of the cases.

Zuckerman et al. reported on a retrospective series of fifteen patients with cuff tear arthropathy treated with hemiarthroplasty123. The mean UCLA score increased from 11 points preoperatively to 22 points at a mean of twenty-eight months postoperatively, and thirteen of the fifteen patients expressed overall satisfaction with the result. However, the mean active forward flexion and external rotation improved only 17° and 14°, respectively123. Field et al. reviewed the results of hemiarthroplasty for cuff tear arthropathy in sixteen patients followed for a mean of thirty-three months124. Sixty-three percent of the patients had a satisfactory result, but six had an unsuccessful outcome and three of four patients who had a prior ac-
romioplasty developed anterosuperior subluxation after the hemiarthroplasty.\textsuperscript{124}

Williams and Rockwood reported on a series of twenty-one rotator-cuff-deficient arthritic shoulders treated with hemiarthroplasty.\textsuperscript{125} At a mean of four years, eighty-six percent of the patients had a satisfactory result, with the mean pain score improving from 2.9 points preoperatively to 0.6 point postoperatively. However, only twelve patients had no pain. It has been theorized that the deterioration of the results and the substantial prevalence of residual postoperative pain in these cases may be secondary to progressive glenoid and acromial erosion.\textsuperscript{122-126}

**Reverse Shoulder Arthroplasty**

Reverse total shoulder arthroplasty has recently emerged as a treatment for glenohumeral arthritis in the setting of advanced rotator cuff arthropathy. A standard shoulder replacement is contraindicated in the absence of a functional rotator cuff because loss of a balanced coronal force couple subjects the glenoid component to excessive shear forces with contraction of the deltoid. This so-called rocking-horse phenomenon leads to early failure secondary to glenoid loosening.\textsuperscript{127} Constrained prostheses were designed to address this issue but were associated with poor clinical results and high rates of failure.\textsuperscript{128,129} These designs shifted the axis of rotation laterally relative to its native position and increased the lever arm across the glenoid, resulting in loosening and failure of the glenoid component. With the reverse shoulder replacement, Grammont et al. modified these designs and increased the efficiency of the deltoid by (1) medializing the center of rotation and thereby decreasing shear forces on the glenoid, and (2) tensioning the deltoid by effectively lengthening the arm.\textsuperscript{130}

While short-term results have been encouraging, reverse total shoulder arthroplasty is associated with a substantial complication rate and the long-term results remain to be defined. In a multicenter study, Guery et al. reported the outcomes of eighty prostheses in seventy-seven patients followed for a minimum of two years.\textsuperscript{131} The average Constant score improved from 23 to 66 points, with active elevation improving from 73\(\degree\) to 138\(\degree\). The prosthetic survival rate was 91\% at five years and 75\% at seven years but declined substantially, to 30\%, at eight years.\textsuperscript{131} Werner et al. evaluated fifty-eight patients at a mean of thirty-eight months after reverse shoulder arthroplasty for the treatment of cuff arthropathy.\textsuperscript{132} The mean Constant score improved from 29 points preoperatively to 64 points postoperatively. The overall complication rate, however, was 50\%, and 33\% of the patients required a revision procedure.\textsuperscript{132} Frankle et al. reported the results of sixty patients at a mean of thirty-three months after treatment of rotator cuff arthropathy with reverse shoulder arthroplasty.\textsuperscript{133} Thirty-five patients had a primary procedure, and twenty-three procedures were performed following a failed rotator cuff repair or debridement procedure. The mean ASES score improved from 34 points preoperatively to 68 points postoperatively. The complication rate was 17\%, with revision surgery required in 12\% of the patients. Boileau et al. reported on forty-five patients treated for various diagnoses, twenty-one of whom had symptomatic rotator cuff arthropathy. The complication rate was 5\% in the group with rotator cuff arthropathy compared with 47\% in a group in whom the procedure was a revision.\textsuperscript{134}

The clinical results of reverse shoulder arthroplasty are inferior when there is dysfunction of the posterior aspect of the rotator cuff, specifically the teres minor.\textsuperscript{135,136} Guery et al. found worse clinical results in patients who had had deficient external.

![Fig. 8](image-url)

Anteroposterior radiograph of the left shoulder, demonstrating rotator cuff arthropathy. There is static superior subluxation of the humeral head, a decreased acromiohumeral distance (arrow) with acetabularization of the acromion, and associated wear of the superior aspect of the humeral head and greater tuberosity.
rotation and a positive hornblower sign preoperatively. Boileau et al. reported deficiency of the teres minor to be associated with inferior functional results, and multiple studies have demonstrated improved outcomes when a reverse shoulder arthroplasty was combined with a tendon transfer to restore weak external rotation.

Despite favorable short-term clinical results, the high rate of complications associated with this operation is a substantial concern. Wall et al. reviewed the results of reverse shoulder arthroplasty according to etiology and reported a 19% complication rate in 186 patients. The most common complications were dislocation (7.5%) and infection (4%). Glenoid fractures, humeral fractures, pain associated with implants, radial nerve palsy, and loosening of the glenosphere or baseplate occurred in five or fewer cases each. Importantly, the risk of complications in the setting of revision surgery was more than double that observed with primary surgery (37% and 13%, respectively). Instability can occur and may be related to undertensioning of the deltoid muscle, deltoid insufficiency or detachment, or medial impingement of the humeral component on the scapular neck. In addition, while the risk of injury to or detachment of the deltoid origin remains a theoretical concern with an anterosuperior exposure, to our knowledge no studies have documented a greater risk of instability with the anterosuperior, deltoid-splitting approach than with the conventional deltopectoral exposure. Over-tensioning of the deltoid muscle, however, can result in fracture of the acromion, particularly in elderly, osteoporotic patients. Given the dead space surrounding the prosthesis, there is a substantial risk of postoperative hematoma formation and deep infection. Scapular notching is also a concern and is related to impingement of the medial aspect of the humeral cup on the scapular neck in adduction. The clinical implications of notching are controversial. Guery et al. noted small notching to be inconsequential but reported large notches that extend beyond the inferior glenoid baseplate screw to have a negative impact on clinical outcome. Boileau et al., however, reported no adverse effect of notching regardless of size. Notching is clearly related to the surgical technique and can be decreased with inferior baseplate positioning and superior tilting of the glenosphere.

**Overview**

Massive rotator cuff tears can cause debilitating shoulder pain in many patients. These tears can present complex and difficult management dilemmas for the orthopaedic surgeon. Operative repair of massive tears is technically difficult and is associated with a rate of recurrence that is much higher than that associated with smaller tears. For this reason, careful patient evaluation is critical to develop an appropriate and individualized treatment plan. The patient's history, findings on physical examination, and imaging studies, when interpreted in the context of his or her functional goals, can help to guide the choice of treatment options. Nonoperative treatment may be indicated for asymptomatic patients with satisfactory function. However, the best available current evidence indicates that the majority of patients for whom nonoperative treatment has failed or who elect to have an operation will benefit from operative intervention. Arthroscopic debridement and partial repair can be considered for older, low-demand patients, but repair should be attempted in younger, symptomatic patients. If a complete repair is technically feasible, a double row of sutures is biomechanically favorable and may help to reduce the rate of recurrent tears. High-demand patients with an irreparable massive tear may be candidates for tendon transfers; however, the results have been inconsistent and have been evaluated only in small clinical series. When arthritic changes are present in the setting of a massive rotator cuff tear, prosthetic replacement should be considered. Hemiarthroplasty is a viable treatment option for patients with symptomatic rotator cuff arthropathy and either modest functional goals or preserved active elevation. In patients with advanced cuff tear arthropathy and/or painful pseudoparalysis, a reverse shoulder prosthesis can provide predictable pain relief and return of function but is associated with a substantial risk of complications.

**References**


