Irreparable Rotator Cuff Tears: What to Do and When to Do It; the Surgeon's Dilemma

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Irreparable Rotator Cuff Tears: What to Do and When to Do It; The Surgeon’s Dilemma

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Irreparable rotator cuff tears are infrequent but well-defined lesions consisting of massive rotator cuff tears that are not reparable by conventional means. Rockwood and others defined irreparable tears as those that, because of their size and retraction, cannot be repaired primarily to their insertion onto the tuberosities despite conventional techniques of mobilization and soft-tissue releases. Goutallier et al. classified rotator cuff tears on the basis of the amount of muscle atrophy and fatty infiltration of the affected rotator cuff muscles demonstrated by computed tomographic scans. Often, these tears are associated with concomitant arthritis of the glenohumeral joint, making treatment options even more complex.

Patients with irreparable rotator cuff tears can present with a variety of manifestations. They may have no symptoms or mild symptoms, or they may be completely disabled and in severe pain. The true incidence of irreparable rotator cuff tears is not known; however, anatomic studies on cadavers and imaging studies of asymptomatic patients have demonstrated rotator cuff tears in 30% to 50% of older patients, especially those older than seventy years of age. Tempelhof et al. classified rotator cuff tears on the basis of the amount of muscle atrophy and fatty infiltration of the affected rotator cuff muscles demonstrated by computed tomographic scans. Often, these tears are associated with concomitant arthritis of the glenohumeral joint, making treatment options even more complex.

Look for this and other related articles in Instructional Course Lectures, Volume 56, which will be published by the American Academy of Orthopaedic Surgeons in February 2007: • “Technical Pearls on How to Maximize Healing of the Rotator Cuff,” by Kenneth J. Accousti, MD, and Evan L. Flatow, MD

Magnetic resonance imaging is probably more sensitive. Massive irreparable rotator cuff tears occur in two physiologically distinct patient groups, but they can present in all age and activity groups. Most often, these tears occur in physiologically older, lower-demand patients (older than seventy years of age and usually female) who have been asymptomatic until minor trauma created symptoms. The second group consists of physiologically younger, more active patients, often in the sixth decade of life, who present with dramatic symptoms of pain and disability after an acute event or with a history of rotator cuff surgery or of chronic rotator cuff injury.

In addition to different clinical presentations, irreparable rotator cuff tears also occur in two distinct anatomic patterns. Complete tears of the supraspinatus, infraspinatus, and teres minor tendons are posterosuperior failures and are more common. Complete tears of the supraspinatus and subscapularis tendons, sometimes with damage or disruption of the long head of the biceps tendon, are anterosuperior fail-
ures. Both anatomic patterns often result in severe disability and poor function. Loss of the coracoacromial arch combined with anterosuperior instability may lead to escape of the humeral head, a potentially devastating clinical situation.

Pathomechanics
The rotator cuff comprises four muscles whose tendons form a histologically confluent sleeve of tissue around the humeral head that inserts into the tuberosities of the proximal part of the humerus. This anatomic arrangement allows the cuff to provide a wide range of active motion as well as stability by concavity compression at the glenohumeral joint. In this way, the rotator cuff acts as a dynamic stabilizer, resisting upward motion of the humeral head during contraction of the deltoid muscle. When there is an irreparable rotator cuff tear, the stabilizing force couple is lost, allowing the humeral head to displace superiorly during contraction of the deltoid. This is associated with a loss of elevation and, in some cases, with superior shoulder instability.

Patient Presentation
Clinical Findings
The presenting history, chief symptom, and results of physical examination of a patient with an irreparable rotator cuff tear can be a confusing picture. Patients can have variable amounts of pain, unpredictable deficits in both the active and the passive range of motion, and inconsistent levels of disability. The physical examination reveals atrophy of the scapular muscles in patients who have had longstanding lesions. In more severe cases, crepitus and hemarthrosis may also be evident. Patients can have varying degrees of weakness and loss of motion, ranging from little or no deficit to a complete loss of active motion.

Patients with posterosuperior disruption of the rotator cuff often have decreased abduction, forward flexion, and active external rotation, giving rise to two classic physical findings. One is a positive external rotation lag sign, which is the inability to externally rotate the arm against resistance or to hold the arm in external rotation against resistance. With complete loss of external rotation power, the patient may have the second classic finding: a positive hornblower’s sign (Fig. 1). The hornblower’s sign has been shown to have 100% sensitivity and 93% specificity with regard to indicating irreparable tears of the teres minor.

Patients who have an anterosuperior failure often have decreased abduction and forward flexion. They can have increased passive external rotation as well as positive belly-press and lift-off signs. The lift-off sign was described by Gerber and Krushell. The patient places the dorsum of the hand against the lumbar spine. If he or she can lift the hand off the back, the subscapularis is functioning. When the patient cannot internally rotate the shoulder enough to place the hand behind the back, a belly-press test can be used. A belly-press test is considered to be positive (also indicating loss of subscapularis function) when the patient cannot keep the wrist straight and the elbow away from the side when he or she presses the palm against the abdomen. Patients with complete loss of rotator cuff function may only be able to shrug the shoulder.

Radiographic Findings
Imaging studies including plain radiographs, computed tomography scans, and magnetic resonance imaging scans can help to guide both the diagnosis and the treatment of irreparable rotator cuff tears. The position of the humeral head, evidence of degenerative arthritis of the glenohumeral joint, and disorders of the acromioclavicular joint are seen on plain radiographs. Computed tomography scans have been used to assess rotator cuff muscle atrophy and fatty infiltration. Goutallier et al. classified the quantity of fatty infiltration as 0 (no fat within the muscle), 1 (minimal fatty infiltration), 2 (more muscle than fat), 3 (fat content equal to muscle content), or 4 (more fat than muscle). Magnetic resonance imaging is the most effective modality used to assess the involved shoulder, and it has replaced computed tomography scanning as the imaging modality of choice for the assessment of rotator cuff lesions. Magnetic resonance imaging can demonstrate rotator cuff tears with 100% sensitivity and can be used to estimate the width of a tear (with up to 77% accuracy) and retraction (within 5 mm) 63% of the time. More importantly, magnetic resonance imaging can be
used to assess fatty infiltration more effectively, as described above (Fig. 2).

The amount of fatty infiltration of the rotator cuff muscles is directly related to the likelihood of a retear and to the functional outcome. When the muscle has Type-3 or 4 fatty infiltration, it is of poor quality and will not improve after surgical repair. The extent of fatty infiltration of the rotator cuff muscles has proven to be a valuable preoperative guide for assessment of the potential reparability of a massive rotator cuff tear.

Management
Treatment of symptomatic irreparable rotator cuff tears is extremely challenging because, at present, there are no perfect solutions to this complex and sometimes disabling problem. Treatment depends on the presenting symptoms (pain and/or disability), age, and functional level. Other issues such as medical comorbidities, the presence of an intact coracoacromial arch, and possible concomitant glenohumeral arthritis are also factors that must be considered in the treatment plan. The treatment options range from conservative (nonoperative) to surgical intervention. Surgical options include débridement with or without partial rotator cuff repair, tendon transfer, muscle tendon slide procedures, the use of rotator cuff allografts and synthetic grafts, arthrodesis, and shoulder arthroplasty, including the use of reverse ball prostheses.

No one treatment is best for all irreparable rotator cuff tears. The surgeon needs to select the type of procedure that will provide the best outcome as dictated by the specific patient’s needs. Unfortunately, there have been no evidence-based, prospective, matched-patient studies comparing the different nonoperative and surgical options, to our knowledge.

Nonoperative Management
Many chronic irreparable rotator cuff tears can be treated successfully without surgery. A nonoperative approach to relieve pain and create “biomechanically compensated” function by muscle substitution with use of the remaining rotator cuff, deltoid, and periscapular muscles is often the best method of initial treatment.

Nonoperative treatment includes nonsteroidal anti-inflammatory medications, steroid injections, and local therapeutic modalities to relieve pain. Early restoration of the passive range of motion and activity modification are imperative initially. Once pain relief has been obtained and the range of motion has been restored, specific strengthening exercises for the remaining rotator cuff, deltoid, and scapular muscles can be started in order to recreate a stable fulcrum for deltoid function. Strengthening exercises for the internal and external rotators of the shoulder should include resistive exercises below chest level initially. Deltoid strengthening exercises begin with the patient supine and are then progressed to antigravity positions such as sitting and standing. It may take more than three months for conservative treatment to be successful.

There have been few specific reports on the outcomes of conservative treatment of irreparable tears. In one study, on the nonoperative management of fifty-three patients, Bokor et al. found that thirty-nine patients had no to slight pain at the time of follow-up. The success rate correlated directly with the duration of symptoms prior to treatment. Patients with symptoms for less than three months did better than those who had had symptoms for longer than six months. The final result was usually evident after six months of nonoperative management.

Surgical Management
The surgical management of irreparable rotator cuff tears includes a number of procedures of varying degrees of complexity. These procedures include subacromial débridement and acromioplasty with or without partial repairs, tendon transfers, and the use of conventional or reverse prostheses. The choice of procedure depends on the patient’s age, activity level, joint stability, and concomitant arthritic changes.

Fig. 2
T1-weighted magnetic resonance imaging scan demonstrating severe fatty deposition (arrow) and muscle atrophy in an irreparable rotator cuff tear. (Image used with permission from Theodore Miller, MD, North Shore-Long Island Jewish Health System.)
**Subacromial Debridement, Partial Repair, Cuff Débridement, and Biceps Tenotomy: Open and Arthroscopic**

In some cases, subacromial decompression and rotator cuff débridement alone may relieve symptoms in patients with a massive irreparable tear of the rotator cuff. Subacromial débridement is indicated in healthy, lower-demand patients whose primary symptom is pain. The best results are in patients who have active elevation and control of the descent of the shoulder as well as glenohumeral stability. Patients in whom a subacromial injection relieves symptoms and improves function are good candidates for this procedure.

These procedures have been carried out both arthroscopically and through open techniques. An arthroscopic débridement has the advantage of not violating the deltoid insertion. The procedures can include all or any of the following: limited, nondestabilizing acromioplasty (smoothing the acromion without release of the coracoacromial ligament); bursectomy; débridement of the rotator cuff edge; and release of a damaged long head of the biceps tendon. A tuberoplasty of the greater tuberosity and acromioclavicular joint resection may also be indicated depending on the presenting symptoms.

Burkhart et al. described the advantage of a partial repair of the posterior and anterior portions of the tear without transposition or transfer in selected patients. They described a "suspension bridge model" whereby continuity between the anterior and posterior tendons resulted in a fibrous frame reconstruction close to the equator of the humeral head, creating a force to stabilize the humeral head against the glenoid and enabling the deltoid to raise the arm. Burkhart et al. reported that thirteen of fourteen patients had pain relief and improvement of function after such a partial repair. According to the UCLA Shoulder Rating Scale, which assigns a maximum of 10 points for pain, 10 points for function, and 5 points each for the range of motion, strength of forward flexion, and overall patient satisfaction, the mean score improved from 9.8 to 27.6 points.

**Reports of the clinical experience with débridement have been anecdotal and retrospective. In 1995, Rockwood et al. reported decreased pain and improved function in forty-four of fifty-three shoulders at an average of six and a half years after open acromioplasty, débridement, and rotator cuff débridement. Gartsman reported that twenty-six of thirty-three patients had decreased pain and an improved range of motion but decreased strength at an average of five years after an open repair. In a study by Ellman et al., arthroscopic débridement resulted in pain relief in nineteen of twenty-two shoulders with an irreparable tear but there was no significant increase in strength or the range of motion. Burke described good pain relief and function in ten of eleven patients who had undergone arthroscopic débridement alone for treatment of a biomechanically stable irreparable rotator cuff tear. In later reviews, however, Zvijac et al. and Kempf et al. noted substantial deterioration in pain relief, strength, and functional outcome in short periods of time after arthroscopic débridement procedures.

Walch et al. reported relief of pain in seventy-four of eighty-seven patients who had undergone a tenotomy of the long head of the biceps tendon for the treatment of an irreparable rotator cuff tear, but there was no effect on the range of motion or strength. One-third of these patients also had an arthroscopic acromioplasty, which clouded the true results of the tenotomy.

Fenlin et al. described tuberoplasty in twenty patients, nineteen of whom had a successful result. They carried out the procedure through an open surgery, but it could be done arthroscopically, and it included shaving and reshaping of the overhang on the greater tuberosity to create a reconstructed subacromial space that would articulate smoothly with the undersurface of the acromion.

From this review of the literature, certain principles emerge. Débridement is best carried out in elderly low-demand patients with irreparable rotator cuff tear for which other muscles have compensated. There are no real differences between the results of open and arthroscopic procedures; however, arthroscopic techniques are less invasive and do not violate the deltoid insertion. Loss of the coracoacromial arch is associated with severe failures; therefore, decompression should include flattening and reshaping of the acromion as opposed to a true release of the coracoacromial ligament in this patient population. Débridement does not consistently improve function in patients with pain and poor function. In such cases, other surgical reconstructive options should be considered, especially in younger and more active patients.

**Rotator Cuff Reconstructive Procedures: Tendon Transfers and Graft Procedures**

The approaches used to reconstruct irreparable massive rotator cuff tears include transfers of the existing rotator cuff tendons, tendon transfers from other periscapular muscles, and repair of tissue with grafts or synthetic substitutions. In the past, the upper third of the subscapularis tendon was transferred to repair a residual anterosuperior defect in the rotator cuff. Unfortunately, transfer of the subscapularis tendon risks loss of power of internal rotation and creation of a possible internal rotation contracture. For this reason, the procedure is no longer advocated.

Tendon transfers from other periscapular muscle groups are useful in young, active patients with an irreparable rotator cuff tear and profound functional weakness as the primary symptom. These patients must have good deltoid function. The tendons that have most commonly been transferred include the latissimus dorsi for posterosuperior rotator cuff tears and the pectoralis major for irreparable anterosuperior tears.

In 1992, Gerber reported the early results of latissimus dorsi transfer for treatment of massive rotator cuff tears. The latissimus dorsi muscle is used to restore external rotation and head depression forces that were lost as a result of the massive tear. Gerber
found good-to-excellent results in thirteen of sixteen patients, and the results were stable for more than ten years. He noted that the results were better when the subscapularis tendon was intact (Fig. 3).

Miniaci and MacLeod\textsuperscript{36} reported satisfactory results in fourteen of seventeen patients who had undergone a latissimus dorsi transfer after a failure of a previous surgical repair of a massive rotator cuff tear. In their series, primary latissimus transfer was rarely indicated for irreparable massive rotator cuff tears, and they recommended primary repair, débridement, or partial repair as the initial surgical procedure.

Iannotti et al.\textsuperscript{37} described improvements with regard to pain relief and function in nine of fourteen patients who had been treated with a latissimus dorsi transfer. All patients had active electromyographic activity within the transferred latissimus dorsi with adduction of the arm or with resisted isometric external rotation with the arm at the side. No patient had electromyographic activity of the transfer with active forward elevation, and no patient had electromyographic activity with external rotation in more than one plane of motion. Twelve of the fourteen patients had a clear demonstration of the tendon transfer on magnetic resonance imaging studies. This study supports the concept of a tenodesis effect with some active functional role of the latissimus transfer.

Subcoracoid pectoralis major transfer has been reported at a number of centers\textsuperscript{33,34}. In each series, the upper portion of the pectoralis major was passed under the conjoined tendon and sutured to the lesser tuberosity (Fig. 4). Resch et al.\textsuperscript{33} reported on a series of twelve patients, six of whom had a negative belly-press test postoperatively; all four patients with preoperative instability had resolution of that symptom. Overall, the improvement was good to excellent in eight of the twelve patients. Wirth and Rockwood\textsuperscript{35} reported satis-
factory results in ten of thirteen patients who had undergone a pectoralis major transfer.

Warner and Gerber reported the use of a split pectoralis major tendon transfer or split pectoralis major-teres major transfer in complicated cases of unstable anterosuperior rotator cuff deficiency. Twenty patients underwent these procedures, and in eleven of them the split pectoralis tendon transfer alone was used. All patients in the series were evaluated with the system described by Constant and Murley, which consists of individual scores for pain (15 points), activity (20 points), active mobility (40 points), and strength (25 points). The mean improvement in the Constant score was from 42 to 61 points, with the nine patients treated with a combination of a split pectoralis major and teres major transfer having a mean improvement from 34 to 55 points. These results were in patients who had complicated disorders with limited functional goals. Tests for subscapularis insufficiency remained positive after the surgery for all patients.

Aldridge et al. reported the use of a pectoralis major and latissimus dorsi tendon transfer to treat massive cuff defects in eleven patients with minimal pain and a limited range of motion and function. On the average, active elevation increased from 42° to 86°; active external rotation, from 0° to 13°; strength in elevation, from 2.3 to 3.1 lb (1.0 to 1.4 kg); and strength in external rotation, from 2.1 to 2.7 lb (0.95 to 1.2 kg). Four patients reported feeling no better, two had slight improvement, and five had substantial improvement.

Tendon transfers are complex surgical procedures that require a long period of rehabilitation. They are not indicated for older, more debilitated patients since the amount of muscle reeducation determines, to some degree, the amount of success. For this reason, patients who are not willing to undergo extensive long rehabilitation programs should not undergo these procedures.

Tissue substitution with synthetic materials and with autogenous...
and allograft tissue implants has been attempted, but there are limited published data on these procedures. Neviser et al. reported good to excellent results in fourteen of sixteen patients treated with a freeze-dried allograft for a massive, but probably not irreparable, tear. Synthetic allograft patches have been utilized to augment rotator cuff repairs. Unfortunately, these tendon substitutes can create foreign body reactions leading to rejection and then cannot replace the atrophic or weakened rotator cuff muscle. These muscles must function if functional improvement is to be expected.

**Glenohumeral Arthrodesis**

Glenohumeral arthrodesis is usually used when the deltoid and rotator cuff muscles are not functional. Arthrodesis is the best treatment for some high-demand patients disabled by an irreparable cuff tear who require a strong, stable shoulder girdle for function. Patient treated with a glenohumeral arthrodesis can expect a strong shoulder girdle but limited rotation. As with any arthrodesis, nonunion as well as postoperative limitations of motion and function are substantial concerns following a glenohumeral arthrodesis.

**Fig. 6-A** Preoperative radiograph demonstrating advanced osteoarthritis.  **Fig. 6-B** Postoperative radiograph demonstrating the reverse ball prosthesis.

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![Flowchart](image.png)

**Patients with Irreparable Cuff Tears**

**Younger Patients**
- Pain
- Severe Disability
- Good Deltoid

**Attempt Repair**
- Partial
- Full

**Tendon Transfers**
- Latissimus Dorsi
- Pectoralis Major
- Combined

**Failed Therapy**
- Arthroscopic Débridement
- Tuberosity
- LHB Tenotomy
- Partial RTC Repair

**Older Patients**
- Significant Pain
- Reasonable function

**OA Present**
- Minimal Pain
- +/- Function

**Stable +/- Function**
- Hemiarthroplasty
- Ext coverage head

**Pseudoparalytic**
- Reverse ball prosthesis

**Non-Operative**
- NSAIDS
- ROM
- Strengthening

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*Fig. 7*

Treatment algorithm for patients with an irreparable rotator cuff tear. LHB = long head of the biceps, RTC = rotator cuff, NSAIDS = non-steroid anti-inflammatory drugs, ROM = range of motion, and OA = osteoarthritis.
Conventional and Reverse Arthroplasty

An arthroplasty may be the best treatment for some patients with an irreparable rotator cuff tear and concomitant arthritis or anterosuperior instability. Patients with an irreparable rotator cuff tear and glenohumeral arthritis but a competent coracoacromial arch have had successful results following hemiarthroplasty with or without an extended-coverage humeral head component (Fig. 5). These patients can expect pain relief with a reasonable return of function. Field et al. reported on the use of hemiarthroplasty for the treatment of cuff tear arthropathy and an irreparable rotator cuff tear in sixteen patients. Twelve patients had a good to excellent return of function and pain relief, but the procedure was unsuccessful in four patients. All patients with an unsuccessful result had had a previous acromioplasty and an unstable shoulder. Hemiarthroplasty should not be done in patients who have had previous surgery, including acromioplasty, or in those with anterosuperior shoulder instability.

Arntz et al. reported on twenty-three patients with disabling pain associated with an irreparable rotator cuff tear. Twelve patients were treated with a hemiarthroplasty and eleven patients, with an arthrodesis. The authors concluded that hemiarthroplasty was the better method for managing complex irreparable tears of the rotator cuff in shoulders in which the articular surface had been destroyed but only when the deltoid was functional. In their series, arthrodesis was better for patients who had both an irreparable rotator cuff tear and irreparable deficiencies of the deltoid muscle.

In a study by Williams and Rockwood, twenty-one shoulders underwent a hemiarthroplasty for cuff tear arthropathy. At the time of follow-up, eighteen of the twenty-one had mild or no pain and three had moderate pain. All patients had improved function and were satisfied with the result.

Hemiarthroplasty is not indicated for patients who have an irreparable tear with anterosuperior instability and glenohumeral arthritis. For such patients and those with pseudoparalysis of the shoulder, a reverse ball prosthesis is now recommended. This is a new prosthesis, and long-term results are not yet known. Initially described by Grammont and Baulot, the reverse ball prosthesis is based on a biomechanical design in which the center of rotation is located within the glenoid component, medializing the center of rotation and increasing the deltoid lever arm. The sheer force of the deltoid is converted into a compressive force, increasing the deltoid advantage (Figs. 6-A and 6-B). The reverse ball prosthesis has been utilized extensively in Europe. It has recently been approved for use in the United States for patients with rotator cuff tear arthropathy.

Reports from Europe have indicated that the reverse ball prosthesis provides better results than hemiarthroplasty in patients with an irreparable rotator cuff tear. Improvements in pain relief, anterior elevation, and function have been substantial in some midterm follow-up studies; however, these procedures are not without complications. Long-term glenoid loosening remains a concern, and increased rates of hematoma, infection, and instability have been reported.

Overview

Chronic irreparable rotator cuff tears can cause substantial shoulder pain and disability. As a result of the complex pathology in shoulders with irreparable rotator cuff tears, there are many different clinical scenarios and many available treatment options (Fig. 7). For this reason, careful patient evaluation and treatment selection are critical to ensure a good result. Many chronic irreparable rotator cuff tears can be treated nonoperatively, especially when the shoulder has reasonably good function. The goals of surgical reconstruction must be considered in terms of the patient’s individual needs, medical condition, and functional abilities.

Debridement and partial repair can be considered for some patients, whereas reconstruction of the rotator cuff is most useful in young active patients for whom functional restoration is important. Latissimus dorsi muscle transfer is the preferred treatment for active disabled patients with a posterosuperior irreparable cuff defect and good deltoid function. Anterosuperior irreparable defects can be treated with pectoralis and teres major tendon transfers but with less predictable results. A hemiarthroplasty can be considered for patients with severe disability, arthritis, and glenohumeral stability; however, in patients with unstable glenohumeral arthritis, the reverse ball prosthesis will provide more predictable pain relief and return of function, at least in the short term.