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Gerald R. Williams, Jr., Charles A. Rockwood, Jr., Louis U. Bigliani, Joseph P. Iannotti and Walter Stanwood


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Rotator Cuff Tears: Why Do We Repair Them?*

BY GERALD R. WILLIAMS JR., MD, CHARLES A. ROCKWOOD JR., MD, LOUIS U. BIGLIANI, MD, JOSEPH P. IANNOTTI, MD, PHD, AND WALTER STANWOOD, MD

Rotator cuff tears are among the most common conditions affecting the shoulder. Despite their ubiquity, however, there is substantial debate concerning their management. Partial and complete rotator cuff tears are known to occur with increasing frequency with increasing age in asymptomatic people.1-3 The clinical results of rotator cuff repair in symptomatic patients who have been followed for as long as ten years are good to excellent in a high percentage of cases, even though rupture of the cuff is known to occur 20% to 65% of the time.4-7 Moreover, the presence of a massive, irreparable rotator cuff tear is not incompatible with good overhead function.8 These observations have traditionally made clinical decision-making in the treatment of symptomatic rotator cuff tears difficult. Historically, treatment recommendations have included rehabilitation, surgical repair, subacromial decompression without repair, tendon transfers, and tendon substitution techniques.6,8-21.

Controversy regarding the management of patients with symptomatic, full-thickness rotator cuff tears is largely the result of the heterogeneity of the patient population and the dearth of well-controlled comparative data. Much progress toward a more unified understanding of the surgical indications and outcomes of rotator cuff repair has been made in recent years, although there is still considerable confusion. The purposes of this symposium are to review the history and current controversies of rotator cuff tears and their management, to outline the indications and outcomes of both nonoperative management and surgical repair of rotator cuff tears, and to summarize the surgical options and outcomes in patients with irreparable rotator cuff tears.

History and Current Controversies
Rotator Cuff Injury
Injuries of the rotator cuff have been known to occur since the earliest of medical writings. A description of a rotator cuff injury appeared in Edwin Smith’s Surgical Papyrus, one of the oldest known pieces of medical writing.9 In addition, Hippocrates, the father of medicine, and Galen, the father of clinical anatomy and sports medicine, postulated that rotator cuff injury could accompany shoulder dislocations.10

The first illustration of a supraspinatus tendon tear appeared in 1788.22-24 The first series of seven rotator cuff tears was reported in 1834 by John Gregory Smith.22 During the middle to late twentieth century, several clinical and autopsy studies documented that asymptomatic, age-related partial or complete rotator cuff tears occurred in 10% to 90% of all individuals.1,2-7.25-27.

History of Rotator Cuff Repair

Although descriptions of rotator cuff repair in the context of glenohumeral instability appeared in the latter part of the nineteenth century, Codman provided the first detailed description of surgical repair of the rotator cuff.
repair of an isolated supraspinatus tendon tear. Although Codman originally described rotator cuff repair through a “saber” incision with an acromial osteotomy, in the later stages of his career he abandoned this technique in favor of a less invasive deltoid-splitting approach. He noted that, with rotation and proper positioning of the arm, the portion of the rotator cuff requiring repair could be visualized through this approach.

The role of the acromion in painful shoulder conditions was suspected in the early 1930s. Radical and lateral acromioplasties were advocated by many surgeons. Because of his dissatisfaction with radical acromiectomy and his realization that the anterior, rather than the lateral, acromion was important in the pathogenesis of impingement and rotator cuff tears, Neer described and popularized anterior acromioplasty. His objectives for rotator cuff repair are to establish (1) closure of the cuff defect, (2) elimination of impingement, (3) preservation of the deltoid, and (4) prevention of stiffness. His surgical technique of an open superior approach, acromioplasty, coracoacromial ligament excision, tendon mobilization, and tendon repair to bone remains the “gold standard” to which all contemporary methods of surgical treatment of rotator cuff tears must be compared.

Good clinical results with open rotator cuff repair have been reported by many surgeons. Important prognostic factors include patient age, tear chronicity, and tear size. In addition, some surgeons have reported improved postoperative clinical results when cuff repair is combined with acromioplasty, as suggested by Neer. Despite good clinical results, however, postoperative reperuture of the cuff is common. Rotation and tear size, tear chronicity, and patient satisfaction affect the timing of surgical repair, the method of surgical repair (i.e., arthroscopic, open, or mini-open repair), the need for acromioplasty, the need for coracoacromial ligament excision, and the management of irreparable defects (i.e., tendon transfers versus decompression and cuff debridement). It is not possible to explore all of these controversial areas in this symposium. Therefore, the focus of the following sections will be the indications for and the techniques and results of nonoperative and surgical management of both reparable and irreparable, full-thickness rotator cuff tears. The goal is to reach some level of consensus with regard to the management of rotator cuff tears with use of an evidence-based approach.

Nonoperative Management

Indications

Important factors to consider when deciding whether to recommend surgery or nonoperative management for a patient with a symptomatic (e.g., night pain, pain with overhead activity, and functional loss with daily activities) full-thickness rotator cuff tear include age, expected activity level, the presence of retraction, and the presence of rotator cuff muscle atrophy and fatty replacement. Surgery is usually the rule for patients in the fourth or fifth decade of life with a history of a traumatic shoulder injury and who have sufficient tendon and muscle quality to yield a satisfactory initial repair, permanent tendon-to-bone healing, and restoration of function. This is particularly true in retracted tears. In older patients in the sixth, seventh, or eighth decade of life with chronic tears, the quality of the rotator cuff tendon and muscle tissue is often less than optimal and healing may not occur. These older patients often are not so much interested in having powerful overhead use of the shoulder as they are in eliminating the pain and having a functional range of motion. Moreover, they are also more likely to have larger tears with greater degrees of retraction, muscle atrophy, and fatty replacement. Therefore, a nonoperative treatment plan consisting of a well-organized stretching and strengthening program can be effective in eliminating pain and restoring function in older patients with more sedentary activity demands.

Methods

The important principles of a nonoperative treatment program are pain control, restoration of passive motion, and optimization of rotator cuff and periscapular muscle strength and coordination. These principles can be successfully applied with use of a supervised rehabilitation program, home-based exercises, or some combination of formally supervised and home-based exercises. Rockwood popularized the use of a specific, surgeon-administered, four-phase rehabilitation program that he calls “orthotherapy” because orthopaedic surgeons solely direct it. Surgeons personally instruct the patients in performing each phase of the rehabilitation program and make minor adjustments in the program to meet the specific needs and accommodate the limitations of each patient.

Patients are expected to perform the therapy program at home, at work, and on vacation. They are instructed to perform the exercises two or three times a day, seven days a week, until they are in the fourth phase, the so-called maintenance program. This type of rehabilitation is both time and cost-effective. The program is very simple and allows the patient to perform the routine in approximately thirty minutes each day. Each patient is given an inexpensive shoulder rehabilitation kit consisting of a fully illustrated manual, a pulley kit that mounts over the top of any door, a three-piece, 3-ft (91-cm)-long plastic stick, and six 3-in (7.6-cm)-wide Therabands (Hygenics, Akron, Ohio) of graduated strength. The illustrated manual presents and describes the various exercises that the patients are to do in each phase of the rehabilitation. A videotape that can be referred to anytime that the patient has a question regarding the therapy program is also included in the kit. The “orthotherapy” treatment program consists of the following four phases: Phase I, Pain Control; Phase II, Stretching Exercises; Phase III, Strengthening Exercises; and

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Phase IV, Maintenance Program.

Phase I: Pain Control
The goal of the initial phase of the program is to eliminate or diminish the pain in the affected shoulder. This phase emphasizes pain control through the use of rest, nonsteroidal anti-inflammatory drugs, moist heat, and occasional analgesics. Patients are told to avoid using the upper extremity in the impingement arc above 70° of forward flexion until the symptoms have subsided. The patients are then encouraged to use the involved arm for simple activities of daily living. Occasionally, because of persistent pain, the subacromial region may be injected with local anesthesia and steroids. The patients are encouraged to use moist heat, such as a hot shower or a moist heating pad, for periods of thirty minutes once or twice a day to decrease the symptoms. Patients are not advanced to Phase II until the pain is controlled.

Phase II: Stretching Exercises
Patients must first regain a functional range of motion before any strengthening exercises can be reliably performed. Stretching exercises should evoke a sensation of pulling at the terminal extent of the passive motion arc but should never be performed to the point of causing acute pain. The old adage of “no pain, no gain” has no place in shoulder rehabilitation. The home stretching program works best if it is preceded by a period of moist heat. This is followed by the Codman pendulum exercises for two or three minutes. Passive forward flexion, abduction, extension, and internal and external rotation stretching are then performed with use of the 3-ft (91-cm)-long stick as shown in the Appendix. Posterior capsular or muscular stiffness is addressed with use of cross-body adduction stretching exercises, and passive forward elevation is obtained through the use of a pulley system (see Appendix). The pulley, mounted over the top of any closed door, relies on the unaffected extremity as the power source to elevate the involved extremity. Patients are instructed to perform each exercise two to three times daily, with five repetitions. The arm is held in the maximally stretched position for a count of five during each repetition to provide a sustained stretch. Phase II of the rehabilitation program is continued until a normal or functional passive range of motion is attained. The time for this phase varies between four and eight weeks.

Phase III: Strengthening Exercises
Phase III consists of a series of exercises designed to strengthen the remaining muscles of the rotator cuff, deltoid, and scapular stabilizers (see Appendix). Stretching exercises are continued along with the strengthening routine. Once again, the patient must not overstrain the shoulder. The exercises should never cause the patient acute pain.

Rotator Cuff and Deltoid Strengthening
The program utilizes Therabands (Hygenics) of progressively increasing thickness and stiffness. There are six color-coded (yellow, red, green, blue, black, and gray) bands of increasing resistance, ranging from 1 to 6 lb (0.5 to 2.7 kg) in 1-lb (0.45-kg) increments. The elastic bands are made in 5- to 152-cm) lengths that are 3 in. (7.6 cm) wide. The ends of the band are tied to form a loop that is placed around a fixed object such as a doorknob. This type of strengthening regimen is based upon the principle of progressive resistance that is foundational to many rehabilitation programs for both the upper and lower extremities.

The exercises are begun with the elbow flexed 90° and the shoulder in the neutral position of 0° of forward flexion, abduction, and external rotation. The exercises are then performed through an arc of 45° in each of the five planes of motion (abduction, external rotation, extension, internal rotation, and flexion). The exercises are individualized so that if a patient is unable to perform one specific exercise comfortably, the exercise range is decreased to accommodate for this difficulty. If one specific exercise is too painful even after modification, it can be eliminated entirely until it becomes less painful.

These specific Theraband exercises are designed to slowly and gradually strengthen the remaining muscles of the rotator cuff and the three parts of the deltoid in both concentric and eccentric modes. As with the stretching exercises, patients are instructed to perform the strengthening exercises for a specific number of repetitions and the information is so marked in their rehabilitation manual. Usually, each exercise is done five times and is held for a count of five, two or three times daily. The usual interval before progression to the next level is two to three weeks, although patients are instructed not to progress to the next Theraband if there is any discomfort at the present level.

Because of its added importance, the anterior deltoid may require an additional exercise. Any patient with excessively poor anterior deltoid strength is placed on a specific program of strengthening exercises performed in the supine position with use of handheld weights. This allows the patient to strengthen the anterior deltoid while decreasing the effects of gravity. Exercises are initiated without any weight, which is then gradually added in 1-lb (0.45-kg) increments.

Scapular Muscle Strengthening
Full-thickness rotator cuff tears, especially if they are large, may result in dysfunctional scapular motion and shrugging of the entire shoulder complex, without shoulder elevation. Strengthening of the scapular stabilizers may improve scapular rotation and, in conjunction with strengthening of the remaining rotator cuff muscles, contribute to a functional—albeit proximally displaced—humeral fulcrum. Although any muscle that attaches the scapula to the thorax can be a scapular stabilizer, the most important ones are the rhomboids, levator scapulae, trapezius, and serratus anterior. To strengthen the serratus, rhomboids, and levator, the patients are started on wall-type push-ups as illustrated in the Appendix. Depending on their age and condition, older patients may be instructed in progressing to a knee push-up but rarely on to a standard military-type push-up. Shoul-
Phase IV: Maintenance Program

The final phase of the program, maintenance, is the continuation of all previously performed exercises once daily, at least two to three times weekly. Stretching is performed with use of the 3-ft (91-cm) stick or the pulley, and strengthening is performed with use of one of the stronger blue, black, or gray bands. Patients are monitored closely during this time and are encouraged to remain on a maintenance program with sedentary activity demands and a chronic rotator cuff tear should be managed with a home-based rehabilitation program before surgical repair is recommended.

Results

This system of “orthotherapy” was investigated by Rockwood in a study of fifty shoulders in forty-three patients who were more than sixty years old and had a documented, full-thickness rotator cuff tear. The subjective and objective findings on both the initial and follow-up visits were scored in accordance with the American Shoulder and Elbow Surgeons (ASES) evaluation form and the University of California at Los Angeles (UCLA) end-results scoring criteria. For this study, a score of 34 or 35 points on the UCLA scoring system indicated an excellent result; 28 to 33 points, a good result; 21 to 27 points, a fair result; and <21 points, a poor result.

All patients showed improvement in the UCLA score on paired t tests after the therapy program. The mean score improved from 12.5 points before treatment to 28.9 points after rehabilitation and treatment, with an average improvement of 16.4 points. At the time of the initial examination, one shoulder was rated as fair (21 points) while the remaining shoulders were rated as poor (<21 points). After treatment, thirty-four shoulders (68%) were graded as having an excellent (two shoulders) or good (thirty-two) result; fourteen (28%) were graded as having a fair result, and two (4%) were graded as having a poor result. All patients showed an improvement of at least three standard deviations above the pretreatment scores. Overall, on the basis of the UCLA scores, thirty-four (68%) of the fifty shoulders were graded as “satisfactory” (a good or excellent result) after treatment. Forty-one (95%) of the forty-three patients were satisfied with the rehabilitation program.

Since asymptomatic rotator cuff tears are common with increasing age and reruptures occur with increasing tear size and age, older patients (those who are more than sixty years of age) with sedentary activity demands and a chronic rotator cuff tear should be managed with a home-based rehabilitation program before surgical repair is recommended.

The Case for Rotator Cuff Repair

Clearly, many patients with a full-thickness rotator cuff tear are asymptomatic or respond symptomatically to nonoperative treatment. However, it is likely that the degree of symptoms as well as the long-term response to nonoperative management is not uniform across all age-groups and activity levels. Moreover, recent data with regard to the natural history of untreated rotator cuff tears have indicated that, in some patients, unrepaird rotator cuff tears may progress and become irreparable. Therefore, a review of the published scientific data before making a decision for nonoperative treatment is justified.

Anatomic studies evaluating the prevalence of rotator cuff tears in cadavers have described rates ranging from 17% to 72%. The majority of studies have described rates between 30% and 50%. Furthermore, there are age-dependent curves for the prevalence of tears, with higher tear rates occurring as age increases. More recent studies on the natural history of rotator cuff disorders have focused on magnetic resonance imaging or ultrasound evaluation of asymptomatic patients. Sher et al., in 1995, evaluated ninety-six asymptomatic patients with magnetic resonance imaging. They found that the prevalence of partial and complete tears was 34% overall, 28% for patients between forty and sixty years old, and 54% for those who were more than sixty years old. Tempelhof et al., in a study of 411 asymptomatic patients who were evaluated with ultrasound, found a 23.4% rate of tears overall and a rate of 38% for those who were more than seventh years old. Interestingly, they found a decrease in motion and strength in the patients with large or massive tears. These numbers correlate well with the aforementioned cadaver studies.

Fortunately, a rather high percentage of patients can live asymptatically with a rotator cuff tear. Patients without pain or limitation of activities of daily living certainly should not be counseled to undergo rotator cuff repair. Indeed, most of these people will not be presenting to an orthopaedic surgeon for...
treatment. However, two important concepts to remember are that an asymptomatic rotator cuff tear can convert to a symptomatic one and rotator cuff tears do progress in size. In a recent study, Yamaguchi et al. assessed forty-five patients with a bilateral rotator cuff tear that had been documented by ultrasound examination\(^7\). On presentation, all patients were symptomatic on only one side. Follow-up examinations revealed that 51% became symptomatic on the contralateral side. The ASES scores were 64.4 points for the symptomatic side compared with 89.9 points for the asymptomatic side. Additionally, twenty-three of the patients had a follow-up ultrasound study. Nine of the twenty-three patients had tear progression, and seven of the nine had become asymptomatic.

As the average age of the population increases, we will be confronted with this disorder with increasing frequency. Advances in medicine have provided a means for the aging population to remain more active. A study by Man cusco et al. polled people undergoing shoulder surgery for a variety of reasons to gain an understanding of their expectations\(^5\). The average age of those undergoing rotator cuff surgery was sixty-two years. Fifty percent of those patients expected to return to sports. As expectations increase, do the demands on the treating surgeon to provide the patient with the intervention most likely to maximize his or her functional needs.

Rotator cuff tears can have a profound effect on a person’s activity level. A recent study evaluated more than 300 individuals to ascertain some of the characteristics of those with a rotator cuff tear\(^9\). The patients with a tear could perform an average of 4.4 of the twelve functions on the Simple Shoulder Test, whereas the controls were able to perform all twelve functions\(^9\). The greatest functional deficits in the patients with a tear were the inability to throw overhead, to lift 8 lb (3.6 kg) to shoulder level, and to sleep comfortably. Furthermore, patients with a tear of the infraspinatus and the supraspinatus were older than those with only a supraspinatus tear—an observation that supports the concept of tear progression over time.

The function and appearance of a torn rotator cuff has been shown to deteriorate with time. A recent animal study showed that a detached cuff had substantial decreases in muscle twitch strength as well as the appearance of fatty infiltration of the muscle\(^6\). This was evident at six weeks and increased at three months. A correlate to these data was demonstrated in a recently presented sheep study\(^4\). A cuff tear was created in two experimental groups, and subsequent repair was done at six and eighteen weeks, respectively. A substantial increase in the time for recovery of contraction was noted in the eighteen-week group. The six-week group had a partial reversal of the fatty infiltration seen before the repair, but this reversal was not observed in the eighteen-week group.

Clinical data from studies by Goutallier et al. also support the concept that the longer a patient has symptoms of a rotator cuff tear, the more extensive the fatty degeneration of the torn rotator cuff muscle\(^2,6,7\). The authors also reported that surgical intervention when there is minimal fatty degeneration of muscle reduces the rate of retears. Similar trends were found with infraspinatus degeneration. Interestingly, after a repair, supraspinatus degeneration was reversed in 21% of the patients, whereas the infraspinatus demonstrated only a 3% reversal.

Another study illustrated that, in tears of the supraspinatus, recovery of strength and mobility were correlated to improvements in the appearance of the muscle belly on magnetic resonance imaging\(^4\). These data suggest that early operative intervention, when most tears are smaller and less degeneration of the cuff muscle has occurred, would facilitate improved outcomes for patients. Additional support for this statement can be found in a study by Harryman et al., who reported on the functional outcomes of 105 cuff repairs in eighty-nine patients relative to the integrity of the cuff as judged with ultrasound examination\(^1\). They found that 80% of the repaired isolated supraspinatus tears and 57% of the supraspinatus and infraspinatus repairs were intact. Patients with an intact repair after a large tear had outcomes that were equal to those for patients with small tears. Furthermore, as the size of recurrent defects increased, the strength, motion, and function decreased. Eighty-five percent of the shoulders without a recurrence of a full-thickness defect were pain-free, whereas only 70% of those with a full-thickness defect were pain-free.

The concept that a chronic massive rotator cuff tear contributes to the development of severe degenerative glenohumeral arthritis, or so-called cuff tear arthropathy, was first described by Neer et al.\(^6\). Melillio et al. demonstrated that nine (39%) of twenty-three patients with massive two-tendon tears had signs of cuff tear arthropathy after acromioplasty and debridement alone\(^6\), and all nine required subsequent hemiarthroplasty. These findings were not observed in any patient who underwent repair of the cuff defect. A similar study revealed a 26% rate of arthropathy and superior migration of the head with decompression alone\(^6\).

Despite the evidence in the aforementioned data, Rockwood et al. previously reported on the efficacy of acromioplasty and subacromial debridement alone for massive, irreparable rotator cuff tears\(^6\). Using a modified UCLA score, they found satisfactory results in forty-four (83%) of fifty-three shoulders. Improvements in pain, range of motion, strength, and function were noted, but the significance of the findings was not addressed. These results were not reproduced in studies by several other authors\(^57\). In a study with similar demographics, Gartsman demonstrated improvements in pain but substantial decreases in strength, and he noted that only 27% (nine) of thirty-three patients had a satisfactory rating overall according to the UCLA scoring system\(^6\). He also stated that the results of decompression alone were shown to be clearly inferior to those of a rotator cuff repair in the peer-reviewed literature. Similarly,
Ellman et al. reported satisfactory results after decompression alone for four of eight shoulders with 2 to 4-cm tears and for nine (41%) of twenty-two with tears that were >4 cm. The tears in those studies, unlike those in the study by Rockwood et al., were reparable.

Studies in which decompression alone was compared side-by-side with decompression and repair, in reparable defects, have also shown superior results after rotator cuff repair. Ogilvie-Harris and Demaziere showed an 87% rate of satisfactory outcomes in twenty-three shoulders after repair and decompression compared with a 59% rate of satisfactory outcomes in twenty-two shoulders after decompression alone. Additionally, they noted that grade-5 of 5 muscle strength was attained by only 9% of the shoulders in the decompression group in contrast to 48% of those in the repair group. Melillo et al. demonstrated an even more striking difference in outcomes, as the rate of satisfactory results was 87% after repair compared with 8% after decompression alone.

Finally, Zvijac et al., in a study of twenty-five patients, demonstrated that the results with decompression alone deteriorate over time. They noted that there was a decrease in satisfactory outcomes from 84% initially to 68% at an average follow-up of 3.8 years. They also showed a decline in function and worsening pain scores.

There is a large amount of data that supports the practice of rotator cuff repair. A review of the literature concerning the results of open repair showed that satisfactory outcomes have ranged from 70% to 95%, with an average of 85%. Even in a study involving large and massive tears, Bigliani et al. showed satisfactory outcomes in 85% of the shoulders. More recently, Watson and Sonnabend reported on 667 patients with open repair of a cuff tear. The results of a follow-up questionnaire completed by the patients demonstrated that 87% had a satisfactory result, indicated by an affirmative response to a question about whether they were pleased that they had had the surgery.

Mini-open repair has had similar success, with satisfactory outcomes ranging from 80% to 96%, with an average of 87%. Park et al. reported satisfactory results in 96% of 110 patients after a mini-open repair with use of a portal-extension technique, and recently Shinners et al. described a satisfactory outcome in 93% of forty-one patients managed with a mini-open technique. An intra-institutional comparison of the mini-open procedure and all-arthroscopic repair was recently published. It showed satisfactory outcomes in 93% of the twenty-nine shoulders managed with the mini-open repair compared with 91% of the thirty-five shoulders in the all-arthroscopic group. The final UCLA and ASES scores were not found to be significantly different. The postoperative range of motion at six and twelve weeks was considerably greater in the arthroscopic group, but there was no difference between the groups at the time of the final follow-up.

Arthroscopic repair of the rotator cuff has gained more attention in the last five to seven years. Several series have had satisfactory results ranging from 84% to 95%. In 1998, Gartsman et al. reported on seventy-three patients with full-thickness cuff tears that were repaired arthroscopically. At an average follow-up period of 2.5 years, 84% had satisfactory results. It should be noted that 77% of those tears were small or medium in size. Burkhart et al., in a study of sixty-two patients who had an arthroscopic cuff repair, reported that 95% had a satisfactory outcome. The average follow-up was 3.5 years, and 42% of the tears were large or massive. In that series, no difference in outcome was found when shoulders with small or medium tears were compared with shoulders with large or massive tears. Wilson et al. recently reported on sixty-five patients undergoing arthroscopic repair with an average four-year duration of follow-up. The average UCLA score was 32.5 points, with 91% satisfactory results. Therefore, the technique of rotator cuff repair continues to evolve into less invasive procedures with similar results.

As our knowledge base concerning rotator cuff disorders increases, so too does our ability to choose the proper interventions for our patients. A synthesis of the aggregate data available tells us several things. Rotator cuff tears increase with age, but they are not always symptomatic. In asymptomatic individuals or those with extremely low functional demands, nonoperative management is indicated, although recent information tells us that at least 50% of asymptomatic patients with tears will become symptomatic. The longer a tear is left untreated, the more extensive fatty infiltration becomes, and tear progression is likely. Decompression and acromioplasty alone, in comparison with repair in reparable defects, gives suboptimal results that deteriorate over time. Repair undertaken earlier for isolated tears has shown decreased rerupture rates and improvements in the functional anatomy of the cuff, which has implications on overall function.

The decision to repair a symptomatic, full-thickness rotator cuff tear in a young, active patient is a wise one that is justified by the preponderance of the literature. However, the results of various repair techniques should be reported with anatomic data so that strategies for increasing healing rates can be developed.

Irreparable Rotator Cuff Tears

Indications

Irreparable rotator cuff tears have been treated with muscle transfer or debridement. It is not a question of which option is better, but, rather, when each option is best indicated in a specific patient. We know of no study that has investigated these two options in a clinical trial with use of the same indications for surgery. The indications for each of these options are distinct from one another and should be carefully determined preoperatively. Patients who are ideally suited for limited-goals surgery and debridement generally have lower functional demands for overhead lifting and have their greatest functional limitation secondary to shoulder pain. These patients are able to hold the arm at shoulder level when it is placed there and can control the descent of the arm from a
fully elevated position. If pain inhibits active elevation above shoulder height, then relief of the pain with a subacromial injection of a local anesthetic will often allow full active elevation.

The ideal patient for débridement should demonstrate good deltoid function and a functionally intact coracoacromial arch with the humeral head contained in this arch. Patients ideally suited for muscle transfer have shoulder weakness as the primary indication for surgery, and they have physical demands that require shoulder strength that exceeds that which is present after local anesthetic injection that temporarily relieves the pain. The ideal patient for a transfer has loss of active elevation, good deltoid function, an intact coracoacromial arch, and a contained humeral head with a functionally intact rotator cuff contralateral to the side of the cuff that is being reconstructed.

Débridement
Débridement of the shoulder for an irreparable rotator cuff tear should minimize surgical trauma to the rotator cuff and, in most patients, should be done by arthroscopic means. A limited acromioplasty or smoothing of the undersurface of the acromion is performed so that the coracoacromial arch is not functionally disrupted, which means that the antero-posterior dimension of the acromion should not be shortened beyond its normal dimension and the coracoacromial ligament should not be resected. All degenerative nonfunctional soft-tissue and osteophytes on the tuberosity should be removed and the bone made smooth to form a congruent arc of curvature with the articular surface of the humeral head. All inflamed bursal tissue and synovium is removed. Degenerative remnants of the cuff that impinge between the humeral head and the coracoacromial arch are trimmed to a stable base, but the surgeon should avoid removing any cuff tissue that is stable and confluent with tendon tissue still attached to the tuberosities, since the potential remains for loading to occur through radial fibers between the torn tendon and the intact tendon (Figs. 1-A and 1-B). Postoperative immobilization is limited to twenty-four hours, and the patient should begin active-assisted range-of-motion exercises on the first postoperative day, isometrics for the deltoid in the first week, and progressive resistive exercises within the first two weeks after surgery.

The results of débridement for large and massive, irreparable rotator cuff tears were reported in a study by Rockwood et al. The degenerative long head of the biceps (LHB) was released from its origin, and the edges of the rotator cuff were trimmed to a stable base, leaving the intact posterior portion of the cuff (IST) and anterior cuff (SubS). HH = humeral head. Fig. 1-A A bursectomy and tuberoplasty of the greater tuberosity (GT) was performed.

Muscle Transfers
Irreparable rotator cuff tears that have been successfully treated with muscle transfers can be classified as either anterosuperior tears involving the subscapularis and supraspinatus or posterosuperior tears involving the infraspinatus and supraspinatus. The muscles that have been transferred with satisfactory clinical results are the pectoralis major for the anterosuperior defect and the latissimus dorsi and/or teres major for the posterosuperior cuff tear.

Anterosuperior Tears
Resch et al. described the technique and results of transfer of the pectoralis major muscle for isolated subscapularis tendon tears that were irreparable and without coracoacromial arch deficiency. The results were described for twelve patients.
with irreparable isolated subscapularis tears, two of whom had prior surgery, four of whom had symptoms of instability, and all of whom had a positive abdominal compression test prior to the muscle transfer. Six of the twelve patients had a negative abdominal compression test postoperatively. The four patients with preoperative instability had resolution of the instability symptoms.

The technique described by Resch et al. involves transferring the insertion of the pectoralis major to the lesser tuberosity; the transferred muscle and tendon are passed under the conjoined tendon. Passing the tendon and muscle under the conjoined tendon is done to improve posterior and inferior vectors of the transferred muscle (Fig. 2). Passing the transferred muscle under the conjoined tendon presents an increased risk of injury to the musculocutaneous nerve, and care must be taken to isolate the nerve. The muscle is passed deep to the clavicular head, taking care not to injure its nerve supply. The sternocostal head is then passed deep to the clavicular head prior to passing it deep to the conjoined tendon. Transfer of the sternocostal portion of the pectoralis major is also indicated to treat a prosthetic shoulder with anterior soft-tissue deficiencies and instability. Any prosthetic malposition must also be corrected if a soft-tissue reconstruction is to be successful. The muscle transfer can be used in conjunction with an iliotibial band reconstruction of the anterior capsule in cases of anterior instability associated with both subscapularis and capsular deficiency (Fig. 3).

Coracoacromial arch deficiency with anterosuperior cuff tears is a very challenging problem for reconstruction and remains an unsolved problem (Fig. 4). In a brief report by Flatow et al., the use of semi-tendinosis graft to reconstruct the coracoacromial arch with cuff reconstruction and muscle transfer demonstrated only fair and poor results. Wiley reported on the use of a structural coracoacromial bone graft to create an osseous buttress between the acromion and the coracoid process, with less than satisfactory results. Coracoacromial arch reconstruction combined with transfer of the pectoralis major muscle was recently described by Galatz et al. They reported substantial relief of pain and modest improvement of function. In shoulders with massive cuff deficiency, preservation of the coracoacromial arch is the best method to prevent this complication.

Fig. 2
The sternocostal portion of the pectoralis major is transferred under the conjoined tendon, to achieve a more favorable inferior resultant vector.

Fig. 3
Posterosuperior Tears

The indications for transfer of the latissimus dorsi and/or teres major muscle for an irreparable posterosuperior cuff tear are weakness of external rotation and loss of active elevation in a physiologically young patient. The best results occur in patients with a functionally intact subscapularis and good deltoid function. An intact coracoacromial arch is also associated with the best results.

Latissimus dorsi transfer for an irreparable rotator cuff tear was first reported, as far as we know, in 1988 by Gerber et al.16 Several other authors have also reported the results of latissimus transfer20,97,102,104. The latissimus dorsi is normally an internal rotator of the shoulder. In its transferred position, it is expected to be a humeral head depressor and an external rotator of the shoulder. In this procedure, the latissimus dorsi insertion is detached from the proximal portion of the humerus and is then mobilized toward its origin. The neurovascular pedicle is dissected several centimeters from its entry into the muscle. The posterior superficial fascial layers must be dissected to mobilize the muscle and provide sufficient length to allow the tendon to be transferred deep to the deltoid, through the subacromial space, and over the top of the humeral head or to the lateral aspect of the greater tuberosity (Figs. 5-A, 5-B, and 5-C).

The intent of this transfer is to provide increased function by virtue of active use of the transferred muscle-tendon unit. It is not intended to provide coverage of the humeral head and close the cuff defect, although this is desirable if the muscle and tendon length is sufficient to achieve this goal. It remains to be determined whether this transfer is capable of active function during elevation or external rotation or whether its tenodesis effect is primarily responsible for its effect on shoulder function. Some studies have demonstrated active electromyographic activity with external rotation of the shoulder and have concluded that it is an active transfer15,23,101. Others have considered this transfer to provide a tenodesis effect as a humeral head depressor, thereby improving the ability of the deltoid to elevate the shoulder.

In an unpublished series, Hennigan et al. reviewed the clinical results and the electromyographic and magnetic resonance imaging findings of fourteen consecutive patients with posterosuperior cuff defects108. Postoperatively, nine of the fourteen patients had >120° of ac-
tive forward elevation and satisfactory clinical results with an improvement in the shoulder score from 44 to 78. All patients demonstrated active electromyographic activity within the transferred latissimus dorsi with adduction of the arm or with resisted isometric external rotation during simultaneous adduction of the shoulder, with the arm by the side. This demonstrated that all transferred muscles were normally innervated. Conversely, no patient had electromyographic activity of the transfer with active forward elevation. Two transfers had electrical activity with active external rotation with the arm by the side, and three others had activity with resisted external rotation in the abducted shoulder. All five patients with some electrical activity with external rotation had a satisfactory clinical result. No patient had electromyographic activity with active external rotation in more than one plane of motion. Twelve of the fourteen magnetic resonance imaging studies clearly demonstrated healing of the tendon transfer to the proximal aspect of the humerus. Patients with a satisfactory postoperative outcome averaged 129° of active forward flexion and 23° of external rotation before surgery. Patients with an unsatisfactory postoperative result had an average of only 63° of active forward flexion and 6° of active external rotation before surgery. These results demonstrate that the factors that were most predictive of a satisfactory postoperative clinical outcome and patient satisfaction were the preoperative shoulder score and the degree of active forward flexion and external rotation. The data support both a passive tenodesis effect and an inconsistent, but demonstrable, active functional role of the latissimus dorsi transfer.

Discussion
Rotator cuff tears are common and, in older people, are often asymptomatic. Furthermore, nonoperative rehabilitation is successful in a large number of older, sedentary patients. The clinical results of rotator cuff repair are good, despite a high prevalence of rerupture. Why, then, do we repair rotator cuff tears? First, not all patients respond to a nonoperative program, especially if they are young and active. Second, the reparability of the tear and the prognosis following rotator cuff repair vary and are dependent on, among other things, tear rotation before surgery. Patients with an unsatisfactory postoperative result had an average of only 63° of active forward flexion and 6° of active external rotation before surgery. These results demonstrate that the factors that were most predictive of a satisfactory postoperative clinical outcome and patient satisfaction were the preoperative shoulder score and the degree of active forward flexion and external rotation. The data support both a passive tenodesis effect and an inconsistent, but demonstrable, active functional role of the latissimus dorsi transfer.
size, retraction, and the extent of atrophy and fatty degeneration. Given the body of evidence that tear size, atrophy, and fatty infiltration all progress with time in a high percentage of shoulders, early repair is indicated in young (actual or physiologic) patients with full-thickness tears, especially if the tears are retracted. More emphasis should be placed on developing strategies to improve healing rates following repair. In the case of irreparable tears, the prognosis for any intervention is related to many factors, including deltoid and coracoacromial arch integrity. In more sedentary patients, without anterosuperior escape of the humeral head, subacromial decompression alone may relieve pain. In younger patients, particularly those whose primary symptoms are weakness and lack of function rather than pain, tendon transfers may be indicated. The best results, assuming all other factors are equal, occur with latissimus dorsi and/or teres major transfer for posterosuperior defects and pectoralis major transfer for anterosuperior defects.

Appendix

Figures illustrating the shoulder rehabilitation program outlined in this symposium are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on “Supplementary Material”) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM).

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