

MASSIVE ROTATOR CUFF TEARS:
Complex Repairs and Salvage Procedures

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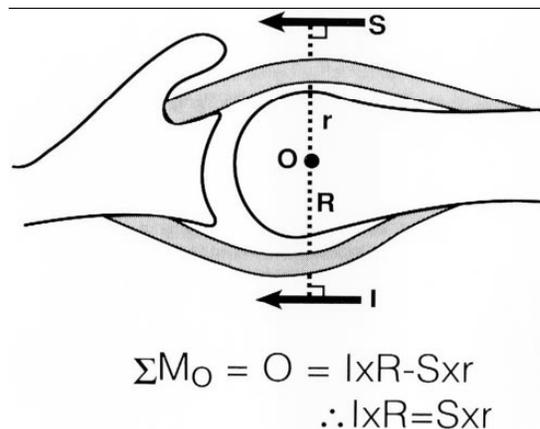
Pathoanatomy and Pathomechanics:

By definition, involve cuff tears of more than 5 cm and (almost by definition) involve more than one tendon. The cuff is comprised of four muscles whose tendons form a histologically confluent sleeve of tissue around the humeral head. Most massive tears involve the supraspinatus tendon and at least one other tendon. Massive isolated subscapularis tears can occur. Infrapinatus tears occur, without exception, in combination with supraspinatus tears.

The cuff acts as a dynamic stabilizer, resisting upward motion of the humeral head during contraction of the deltoid muscle. In some massive tears, this 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.

The supraspinatus is important in the *initiation* of abduction. In cadaveric studies performed by Thompson et al, loss of supraspinatus function doubled the force on the middle deltoid needed to initiate glenohumeral motion at low abduction levels. Loss of supraspinatus function did not significantly alter motion when the arm was abducted more than 60 degrees. The supraspinatus makes only a small (14%) contribution to the overall moment arm for abduction of the shoulder. The infrapinatus and teres minor contribute 32% while the subscapularis contributes 52%.

When the supraspinatus is not functioning, glenohumeral motion is still possible if the remaining rotator cuff is strong enough to compress the humeral head into the socket, thereby providing a stable fulcrum for elevation. Current thought is that this tends to be possible when there are balanced “transverse” force couples between the subscapularis anteriorly and the infrapinatus and teres minor posteriorly. If tears of the subscapularis or infrapinatus do not extend below the equator of the humeral head, a stable fulcrum may be maintained. When tears extend below the equator, biomechanical decompensation is likely to ensue.



Hansen et al have recently shown a substantial increase in subscapularis and posterior cuff forces with arm elevation in cadavera with simulated cuff tears. This force is applied through the smaller cross-sectional area of the remaining tendons and may predispose to further tearing. When the balance between these anterior and posterior forces is lost, patients lose motion.

Clinical Evaluation of a Patient with a Massive Cuff Tear

Variable manifestations: No symptoms or mild symptoms, or they may be completely disabled and in severe pain. Unpredictable deficits in both active and passive range of motion, ranging from little or no deficit to a complete loss of active motion. (See mechanics above.)

Inconsistent levels of disability.

Physical Examination:

Atrophy of the supraspinatus and infraspinatus in patients who have had longstanding lesions.

Passive and active ROM discrepancy. Weakness in abduction or rotation. Weakness of greater than 50% relative to the contralateral side is indicative of a large or massive rotator cuff tear. Patients with complete loss of rotator cuff function may only be able to shrug the shoulder.

Two distinct anatomic patterns.

Posteriosuperior (more common):

Complete tears of the supraspinatus, infraspinatus, and teres minor
Often have decreased abduction, forward flexion, and active ER

Two classic physical findings:

External rotation lag sign: Arm is placed in maximal ER. Pts with massive RTC tear will be unable to maintain the arm in the position and the arm will swing toward neutral rotation

Hornblower's sign: Unable to ER the arm to 90 degrees with arm in abduction. The hornblower's sign indicates a massive tear of infraspinatus and teres minor and a re-rupture rate of >50% after surgical repair.



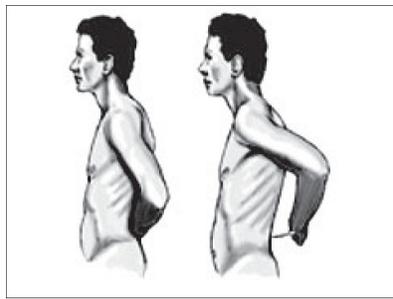
Anterosuperior:

Complete tears of the supraspinatus and subscapularis tendons, sometimes with damage or disruption of the long head of the biceps tendon. Often have decreased abduction and forward flexion and increased passive external rotation.

Loss of the coracoacromial arch combined with anterosuperior instability may lead to escape of the humeral head, a potentially devastating clinical situation.

Subscapularis is tested with lift-off test and abdominal compression test.

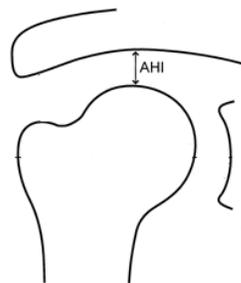
The lift-off test (Gerber and Krushell): The patient places the dorsum of the hand against the lumbar spine. If he or she can lift the hand off the back, the subscapularis is functioning.



Belly press test: 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.

X-Ray: Superior migration of humeral head indicates chronic long-standing, massive tear and is associated with failures of direct repair.

Acromiohumeral interval: >7 mm: better outcome with repair
<5 mm: two-tendon tear.



MRI:

Cuff retraction, Superior Migration of Head

Fatty Infiltration/Muscle Atrophy:

Tears with an increased degree of fatty infiltration/muscle atrophy are at high risk for irreparability. Goutallier et al. used CT scans to evaluate fatty infiltration, but MRI T1-weighted images are thought to be more sensitive.

Goutallier Classification of Fatty Infiltration

Stage 0=completely normal muscle with no fat.

Stage 1=muscle contains some thin fatty streaks.

Stage 2=fatty infiltration is present, but there is more muscle than fat.

Stage 3=equal fat and muscle.

Stage 4=more fat than muscle is present.

Degeneration is graded at the tip of the coracoid process and at the inferior margin of the glenoid and the values are averaged to determine the stage.

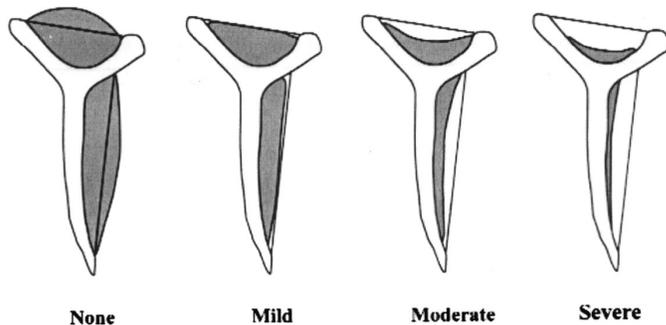
Fatty degeneration is an important negative prognostic factor in rotator cuff surgery and implies that an associated cuff tendon tear is chronic. Fatty atrophy grade 2 or higher is clinically relevant. The rate of re-rupture is 50% if degeneration in infraspinatus is stage-2 or more as opposed to 10% if it is stage-1 or less. Hornblower's sign had a sensitivity of 100% and a specificity of 93% for the presence of stage-3 or stage-4 fatty degeneration of teres minor on CT scan.

Muscular Atrophy (not equal to fatty infiltration):

Measured on oblique scapular MRI image where coracoid and scapular spine meet scapular body:

Grading scale (Warner et al):

- 1) No Atrophy: Muscle completely fills its fossa, outer contour is convex.
- 2) Minimal Atrophy: Outer contour is flat.
- 3) Moderate Atrophy: Outer contour is concave.
- 4) Severe Atrophy: Muscle is barely apparent.



Supraspinatus Atrophy: Strong predictive factor of postoperative re-tearing of rotator cuff repairs. (Thomazeau et al)

TREATMENT:

Non-Operative Management

Some massive tears can be treated without surgery.

Goal: create "biomechanically compensated" function by muscle substitution with use of the remaining rotator cuff, deltoid, and periscapular muscles.

Non-operative treatment includes non-steroidal anti-inflammatory medications, steroid injections, and local therapeutic modalities to relieve pain. Early restoration of 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.

Results of Non-operative Treatment

There have been few specific reports on the outcomes of conservative treatment of irreparable tears. In one study, on the non-operative management of 53 patients, Bokor et al. found that 39 patients had no to slight pain at the time of follow-up. Success rates correlated directly with the duration of symptoms prior to treatment. Patients with symptoms for less than 3 months did better than those who had had symptoms for longer than 6 months. The final result was usually evident after 6 months of non-operative management.

Zingg et al found that most patients had mild-to-moderate pain and maintained satisfactory shoulder function for at least 4 years when treated non-operatively. Active range of motion did not change over time. Patients with three-tendon tears showed more progression of arthritis than those with two-tendon tears. Four of the 8 rotator cuff tears that were graded as reparable at the time of the diagnosis became irreparable at the time of final follow-up.

Surgical Management

The surgical management of irreparable rotator cuff tears includes a number of procedures with varying degrees of complexity. These procedures include subacromial débridement and acromioplasty with or without partial repairs, open or arthroscopic repair, patches, 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.

Subacromial Débridement (Open and Arthroscopic) with limited acromioplasty, Partial Repair, Biceps Tenotomy/Tenodesis:

In some cases, subacromial decompression and rotator cuff débridement alone may relieve symptoms in patients with a massive tear of the rotator cuff. These procedures have been carried out both arthroscopically and through open techniques. An arthroscopic débridement has the advantage of not violating the deltoid insertion.

Subacromial débridement is indicated in lower-demand patients whose primary symptom is pain. The best results are in patients who have active elevation and control of descent of the shoulder as well as glenohumeral stability. Patients in whom a subacromial injection relieves symptoms and improves function may be reasonable candidates for this procedure.

Open

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, decompression, and rotator cuff débridement. Gartsman et al reported similarly favorable short-term results in another series after open debridement.

Arthroscopic

In a study by Ellman et al., arthroscopic débridement resulted in pain relief in 19 of 22 shoulders with an irreparable tear but there was no significant increase in strength or the range of motion.

Burkhart described good pain relief and function in 10 of 11 patients who had undergone arthroscopic débridement for treatment of a biomechanically stable irreparable rotator cuff tear. The goal was to obtain pain relief without loss of motion or strength. He postulated that normal function in the face of an unrepaired cuff tear can occur only if there is a balance of force couples, one in the coronal plane and the other in the transverse plane. He felt that this balance depended upon the functional integrity of the anterior cuff, the posterior cuff, and the deltoid. "In patients whose cuff tears satisfy these anatomic and biomechanical criteria, the achievement of pain relief through arthroscopic débridement and decompression seems to be all that is necessary for normal pain-free function."

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.

Biceps Tenotomy with Arthroscopic Debridement

Klinger et al compared the results of arthroscopic débridement in massive, irreparable rotator cuff tears with and without tenotomy of the long head of the biceps (LHB). No statistical significance ($p > .05$) was found between the two groups. Patients with additional LHB tenotomy had a longer duration of postoperative pain relief but the final pain score difference was not statistically significant. Additional LHB tenotomy did not significantly influence the postoperative results at the latest follow-up.

In contrast, Boileau et al. reported relief of pain in seventy-four of eighty-seven patients who had undergone a tenotomy of the LHB for the treatment of an irreparable rotator cuff tear. There was no effect on the range of motion or strength. One-third of these patients also had an arthroscopic acromioplasty, which clouds the true results of the tenotomy. They concluded that arthroscopic biceps tenotomy can effectively treat severe pain or dysfunction caused by an irreparable rotator cuff tear associated with a biceps lesion. The

procedure was not recommended if the teres minor is atrophic or absent or if there is “pseudoparalysis” of the shoulder and/or severe rotator cuff arthropathy.

Anterosuperior Escape after Debridement

Wiley described 4 cases of superior migration of the humeral head following a debridement and bursal decompression. This serious complication may follow debridement and release of the subacromial space. Loss of the coracoacromial arch is associated with severe, often untreatable disability; therefore, decompression should include flattening and shaping of the acromion as opposed to a true release of the coracoacromial ligament in this patient population

Summary of Debridement for Massive Cuff Tears:

Débridement is best carried out in elderly low-demand patients with tears for which other muscles have compensated. Arthroscopic techniques are less invasive and do not violate the deltoid insertion. Débridement does not consistently improve function in patients with pain and poor function. Other surgical reconstructive options should be considered in younger, more active patients.

In carefully selected patients, cuff debridement and limited acromioplasty can lead to a significant decrease in pain and increase in ROM. If an acromioplasty is indicated, then attempt to leave the CA ligament intact and the acromioplasty should be conservative. An intact ligament helps prevent superior migration of humeral head.

The results of debridement may worsen over time and progression of arthritis and to irreparability may ensue.

SURGICAL REPAIR

Simply closing extensive tear will not suffice if atrophied muscles are not contracting adequately and if excessive tension is placed on the repaired cuff.

- repair of good quality rotator cuff tissue is especially important in achieving an optimal result.
- repairing attenuated, scarred, frayed, or fibrillated cuff tissue contributes to risk of failure, no matter how well tear closure is performed.

Excessive mobilization could stretch innervating nerves beyond their capacities, resulting in denervation of muscle and thereby defeating the purpose of the mobilization.

Poor prognostic indicators for open repair:

Factors related to irreparability include large tear size, poor quality tissue, profound ER weakness, superior displacement of the humeral head, and MRI evidence of fatty infiltration and muscle atrophy.

Vad et al found that negative prognostic factors for open repair include the presence of glenohumeral arthritis, decreased passive range of motion, superior migration of the humeral head, presence of atrophy, and external rotation/abduction strength less than 3.

The presence of 3 or more of these negative prognostic factors is correlated with poor outcomes in the treatment of massive rotator cuff tears.

As mentioned above, Goutallier et al reported a rate of re-rupture is 50% if degeneration in infraspinatus was stage-2 or more as opposed to 10% if it was stage-1 or less.

Flatow and associates found that there was a strong negative correlation between increasing muscle degeneration and poorer functional outcomes and strength. Muscle atrophy and fatty infiltration were actually better predictors of outcome than tear size or repair integrity.

OPEN REPAIR:

Techniques of Mobilization and Repair:

Capsular releases: Supraspinatus tendon is closely blended w/ underlying capsule and synovial tissue of the shoulder.

- this connection can be divided before the muscle can be advanced.

“Interval slides”:

- coracohumeral ligament may be scarred down to the base of the coracoid which keeps the supraspinatus in a retracted position;
- by releasing the rotator interval and the coracohumeral ligament from the base of the coracoid may allow up to 1.5 cm of increase tendon excursion;

Open Repair of Massive Cuff Tears: Results

In most studies, smaller tears have had better outcomes and lower re-tear rates than larger tears.

Rokito et al reported on 30 patients with massive cuff tears treated with open repair. All patients were satisfied with the result and had increased strength compared with preoperatively. There was a significant decrease in pain ($p < 0.01$) and significant improvements in function ($p < 0.01$) and range of motion ($p < 0.01$). The mean UCLA shoulder score increased significantly from 12.3 points preoperatively to 31.0 points at the most recent follow-up ($p < 0.01$). Mean peak torque in flexion, abduction, and external rotation increased significantly to 80 percent ($p < 0.01$), 73 percent ($p < 0.01$), and 91 percent ($p < 0.01$), respectively, of that of the uninvolved shoulder by the time of the most recent follow-up examination.

Gerber et al described the results of 29 massive rotator cuff tears. Constant scores improved from an average of 49 pre-operatively to an average of 85. Pain-free flexion improved from 92 degrees to 142 degrees, and abduction improved from 82 degrees to 137 degrees. Pain decreased and performance of activities of daily living improved significantly ($p < 0.05$). Re-tears occurred more often in patients who had had a shorter interval between the onset of the symptoms and the operation ($p < 0.05$). Patients who had a re-tear had improvement of the shoulder compared with the pre-operative state, but

they had less improvement than did those who had a successful repair. All 17 patients who had a structurally successful repair had an excellent clinical outcome.

Failed open repairs:

Jost et al showed that, even when MRI shows a re-tear, an attempt at rotator cuff repair significantly decreases pain ($p = 0.0026$) and significantly improves function ($p = 0.0005$) and strength ($p = 0.0137$). Out of 20 patients with a re-tear on MRI, 11 were very satisfied with the result, six were satisfied, two were disappointed, and one was dissatisfied. These findings suggest that re-rupture should not be considered a formal failure after cuff repair if optimal functional recovery is the goal of treatment. However, fatty degeneration of the supraspinatus and infraspinatus muscles, atrophy of the supraspinatus muscle, and glenohumeral osteoarthritis progressed significantly from the pre-operative state ($p < 0.05$).

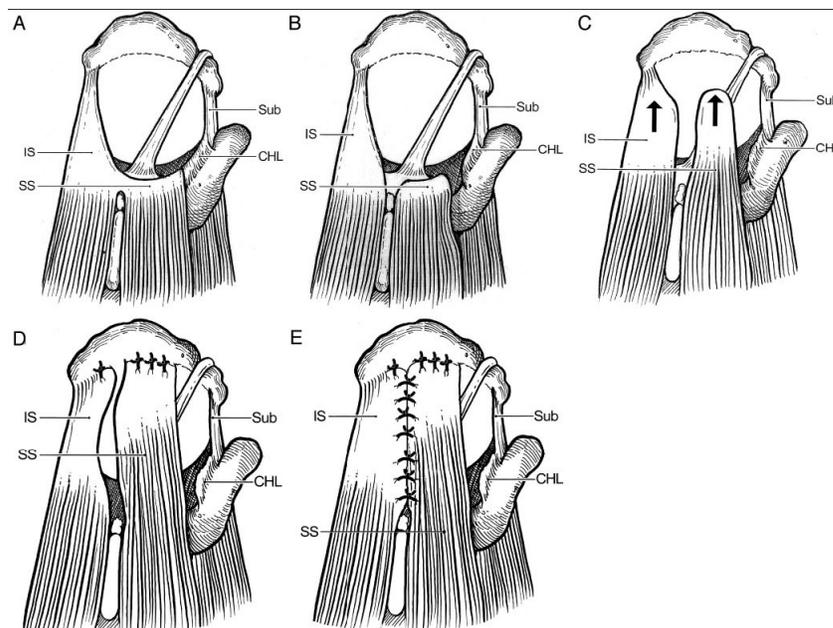
Flatow and associates found that patients with re-tears of an open repair had slightly lower post-operative scores but that the difference was not significantly different from those in whom the repair was intact. In a later study, they indicated that fatty infiltration and muscle atrophy were better predictors of outcome than the integrity of the repair.

ARTHROSCOPIC REPAIR

Techniques of Mobilization and Repair:

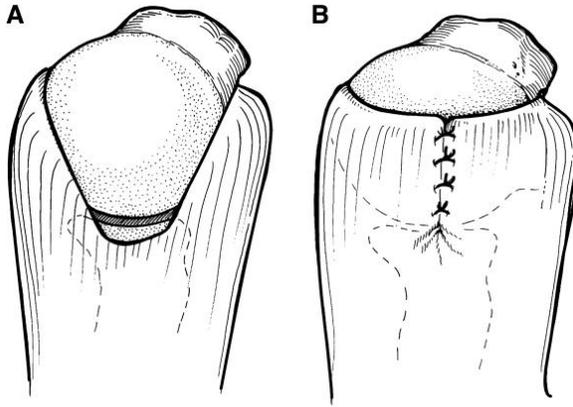
Single and Double Interval Slides

Arthroscopic modifications of the open interval slide.



Margin Convergence

Allows for the partial closure of the rotator cuff defect along with the proximal advancement of the posterior cuff.



Results of Arthroscopic Repairs of Massive Tears

In contrast to the reports for open repair, Burkhart et al reported that large and massive tears did as well as small and medium-sized tears. Results were independent of tear size ($p > .05$). Results of tears repaired by margin convergence were not significantly different statistically from those repaired by direct tendon-to-bone repair ($p > .05$).

In a subsequent paper, Burkhart et al reiterated that arthroscopic rotator cuff repair in patients with grade 3 or 4 fatty degeneration ($\geq 50\%$) can provide significant functional improvement. Those with 50% to 75% fatty degeneration showed a much greater degree of improvement (with all 17 cases exhibiting postoperative increases in their UCLA scores ranging from 12 to 26 points) than those with $>75\%$ fatty degeneration (with only 2 of 5 cases showing an increase of 10 or more points in their UCLA scores). Clinical improvement was observed in 86% of cases that would have been classified as likely to fail by the Goutallier criteria.

In contrast, Galatz reported clinical and ultrasound findings after arthroscopic repair of large and massive tears of the cuff. Recurrent tears were seen in 17 of the 18 patients. Despite the absence of healing at 12 months after surgery, 13 patients had an ASES score of ≥ 90 points. 16 of 18 patients had an improvement in the functional outcome score, which increased from an average of 48.3 to 84.6 points. 16 of 18 patients had a decrease in pain, and twelve had no pain. Although 8 patients had pre-operative forward elevation to $<95^\circ$, all 18 regained motion above shoulder level and had an average of 152° of elevation. At the second evaluation, a minimum of 24 months after surgery, the average ASES score had decreased to 79.9 points; only 9 patients had a score of ≥ 90 points, and 6 patients had a score of ≤ 79 points. The average forward elevation decreased to 142° .

Post-operative Rehabilitation after Cuff Repair

Many recommend an abduction splint for up to 6 weeks after repair. Abduction of 30 degrees has been shown to substantially reduce tension on a supraspinatus repair. (Zuckerman et al)

Basic concepts of Post-Op Rehabilitation (Kibler et al):

- 1 Muscle activation and motion follow a proximal to distal recruitment pattern.
- 2 Shoulder musculature functions in an integrated pattern and should be rehabilitated accordingly.
- 3 Rotator cuff activation and scapular control are essential to proper shoulder function.
- 4 The primary means of early shoulder rehabilitation is closed chain axial loading exercises.

Weeks 0-4:

Sling Immobilization

Passive forward flexion to tolerance.

(Goal: full passive forward flexion by 3-4 weeks)

Passive forward flexion with pulleys.

Pulleys for home use.

Gentle pendulums.

Scapular rehabilitation :

Stability exercises:

Isometrics

Scapular Pinch

Scapular Shrug

Weeks 4-8:

Gentle active and AAROM.

-emphasize forward flexion and abduction

-Do Not Force Rotation, but gently assist.

Active supine forward flexion (eliminates gravity).

Progress to standing active forward flexion.

Therabands: internal/external rotation cuff strengthening with arm at side.

Deltoid isometrics at low abduction levels.

NO EMPTY CAN EXERCISES!!!!!!

Scapular Closed-chain exercises: (Hand in contact with wall or ball)

Perform specific scapular maneuvers:

- Elevation, Depression, Retraction, Protraction

> 8 weeks:

When passive and active forward flexion are symmetrical with opposite side, begin to orient for home strengthening program.

Add dumbbell strengthening

Emphasize strengthening of the internal and external rotators.

ALL STRENGTHENING SHOULD BE DONE WITH THE ARM IN LOW LEVELS OF ABDUCTION.

Advise patient to avoid heavy lifting and overhead work.

Specific drills to restore neuromuscular control

Reciprocal isometric contractions for IR/ER muscles.

PNF patterns with rhythmic stabilization

FACILITATE AGONIST-ANTAGONIST CO-CONTRACTION TO RESTORE BALANCE TO FORCE COUPLES.

Fatty Infiltration and Muscle Atrophy after Cuff Repair

Gerber et al reported that muscle atrophy could not be reversed after cuff repair except in successfully repaired supraspinati. Fatty degeneration increased in all muscles.

Flatow and associates confirmed that a successful repair did not lead to improvement or reversal of muscle degeneration (although healed repairs showed minimal progression) and found that a failed repair resulted in significantly more progression. These findings suggest that repairs should be performed, if possible, before more significant deterioration in the cuff in order to optimize outcomes, and that understanding the degree of muscle atrophy and fatty infiltration before surgery can help guide patient expectations.

IRREPARABLE TEARS

An Italian group cautions against overzealous attempts to repair possibly irreparable cuff tears with open techniques. Twelve patients who had open surgery to attempt repair a tear which technically could not be repaired because the residual tendon tissue was of poor quality, insufficient, or both. Only one patient was satisfied with the result of surgery because of pain relief. Attempts at open repair of a possibly irreparable cuff tear should be avoided because functional results generally are poor. They cautioned that, when there is a risk that an irreparable tear will be found, open surgery should not be done or alternative procedures should be planned before surgery.

Arthroscopic Partial Repair

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 created a force to stabilize the humeral head against the glenoid, enabling the deltoid to raise the arm. 13 of 14 patients had pain relief and improvement of function after partial repair. The UCLA Shoulder score improved from 9.8 to 27.6 points. . The authors are of the opinion that this technique is preferable to other reconstructive techniques, such as tendon transposition, that emphasize coverage of the defect at the expense of destroying the normal mechanics of the shoulder.

Rotator crescent-cable complex (Burkhart):

Rotator crescent: thin, crescent-shaped sheet of rotator cuff comprising the distal portions of the supraspinatus and infraspinatus insertions. Crescent is bounded on its proximal margin by a thick bundle of fibers called the **rotator cable**. This cable-crescent configuration spans the insertions of supraspinatus and infraspinatus tendons.

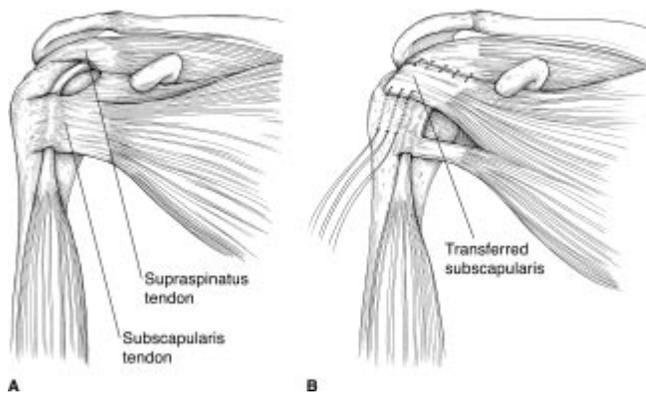
The rotator cable was found to be a very substantial structure, averaging 2.59 times the thickness of the rotator crescent that it surrounded. Supports the concepts of stress-shielding of the rotator crescent by the stout rotator cable and stress transfer by this loaded cable.

TENDON TRANSFERS

Tendon transfers from other periscapular muscle groups may be useful in young, active patients with a tear that is unlikely to be repairable and with profound functional loss and weakness as the primary symptoms. 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

Subscapularis Transfer

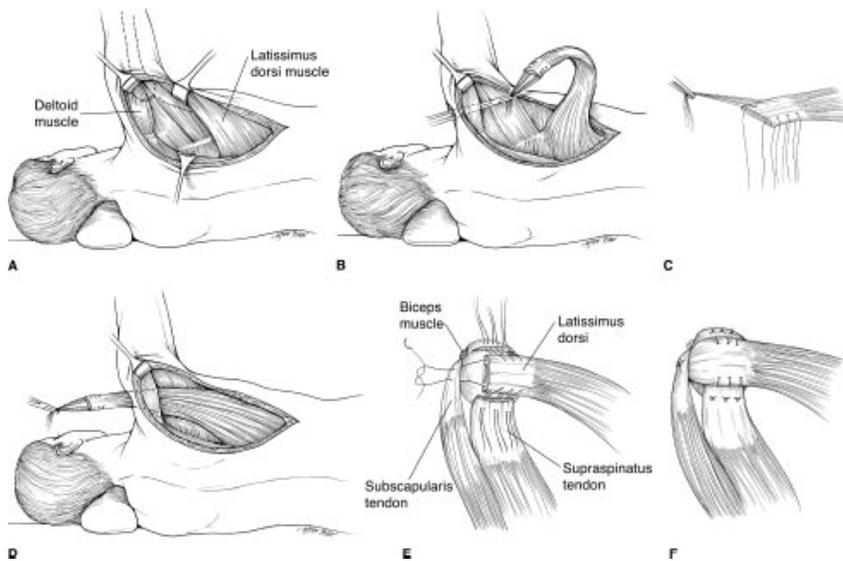
The upper third to half of the subscapularis tendon can be transferred to repair a residual anterosuperior defect in the rotator cuff. The subscapularis receives dual innervation from the upper and lower subscapular nerves. This neuroanatomy allows approximately 3 cm of mobilization of the upper part of the tendon without risking denervation.



In the series of Karas and Giachello, 17 of 20 patients with massive tears were satisfied with their outcome. However, a small subset of patients lost the ability to actively elevate the arm after the transfer and has rapid deterioration. Unfortunately, transfer of the subscapularis tendon also risks loss of an important component of the force couple necessary to maintain shoulder function in the face of a massive tear. For these reasons, the procedure is not commonly advocated at this time.

Latissimus dorsi transfer

Symptomatic irreparable rotator cuff tears sometimes involve near-complete loss of the substance of the supraspinatus and infraspinatus tendons. Loss of external rotation control and superior migration of the humeral head on attempted flexion or abduction are seen in these patients. Transfer of the latissimus dorsi tendon from the humeral shaft to the superolateral humeral head provides a large, vascularized tendon that can be used to close a massive cuff defect and that exerts an external rotation and head-depressing moment that allow more effective action of the deltoid muscle.



Gerber has reported the results of latissimus dorsi transfer for treatment of massive rotator cuff tears. 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. If the subscapularis was torn and could not be adequately repaired, latissimus dorsi transfer was of no value. In cases with good subscapularis function but irreparable defects in the external rotator tendons, restoration of approximately 80% of normal shoulder function was obtained. In a later report, Gerber noted that patients with a negative pre-operative lift-off test (subscapularis functioning), average ER improved by degrees, and average abduction and forward flexion improved by 20 degrees and abduction strength improved by 1 kg. In patients with a positive pre-operative lift-off test (non-functioning subscapularis), ER decreased by 7 degrees, flexion improved by 19 degrees, abduction by 14 degrees, and strength did not improve.

In this later report, Gerber also noted that fatty infiltration of the teres minor should be considered prior to surgery, as it is predictive of outcome. Fatty infiltration of the teres minor less than or equal to stage 2 was associated with a better postoperative Constant score, active external rotation (36 degrees vs 16 degrees, $p = .016$); and active elevation (143 degrees vs 115 degrees, $p = .012$) relative to patients with fatty infiltration greater than stage 2.

Miniaci and MacLeod 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 described improvements with regard to pain relief and function in nine of fourteen patients who had been treated with a latissimus dorsi transfer. Twelve of the fourteen patients had a clear demonstration of attachment of the tendon transfer on MRI. Nine patients were satisfied with the outcome, had significant clinical improvement, and

reported that they would have the operation again under similar circumstances. The other five patients were dissatisfied with the result and had significantly worse PENN scores, active elevation, and objective measures of strength. Patients with good clinical results had had significantly better pre-operative active range-of-motion and strength in both forward flexion and external rotation compared with the patients with poor results. Patients who had unsatisfactory results were significantly worse than they were prior to surgery.

Rehab after Latissimus Transfer:

Abduction splint with 30-45 degrees of abduction and 0-30 degrees of ER day and night x 4- 6 weeks. Consider change to sling after 4 weeks.

Passive ROM on 1st post-op day with arm in abduction and ER. IR and adduction are not allowed.

At 6-7 weeks, begin active motion and gentle strengthening low abduction levels.

Try to re-train latissimus as an external rotator: Have patient initiate external rotation while isometrically adducting the arm.

Patient is seated with shoulder abducted 30 degrees and elbow resting on pillow.
Adduct arm against pillow while actively externally rotating.

Biofeedback unit can provide audible feedback while patient tries to maintain contraction of latissimus during flexion and ER.

Progress strengthening exercises to isotonic forward elevation with hand-held weights. (Initially supine, then progress to seated.)

EMG After Latissimus Transfer

In the study of Iannotti above, all patients had active EMG 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 EMG activity of the transfer with active forward elevation, 6/20 had activity during ER with the arm at the side, and no patient had EMG activity with ER in 90 degrees of abduction. This study supports the concept of a tenodesis effect with some active functional role of the latissimus transfer. However, the lack of activity with abduction and external rotation indicate that function of the transferred tendon may be limited.

In contrast, Habermeyer et al reported positive EMG activity in all transferred latissimi with resisted ER with the arm at the side in their series.

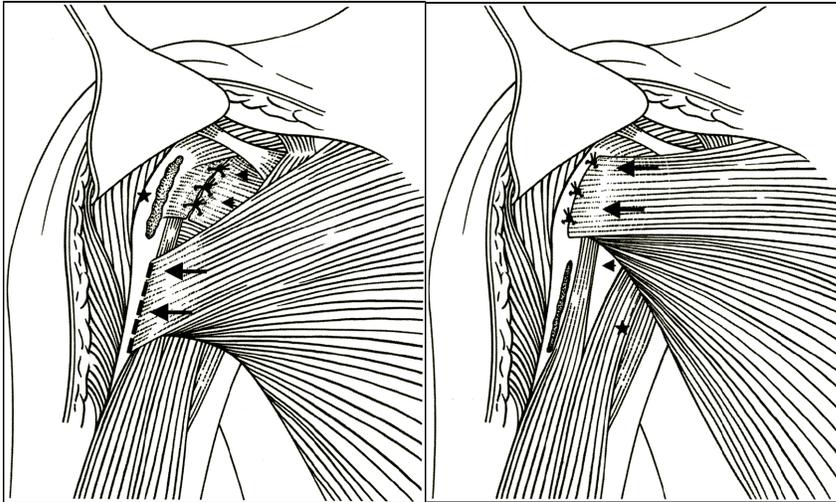
Summary of Latissimus Transfers:

If the subscapularis is intact and there is not significant fatty infiltration of the teres minor, latissimus dorsi transfer has the potential to substantially improve chronically painful, dysfunctional shoulders with irreparable rotator cuff tears. If subscapularis function is deficient or there is grade 3 or greater atrophy of the teres minor, the procedure is of questionable benefit and probably should not be used.

Patients with poor pre-operative motion and strength may be made significantly worse by the procedure.

Pectoralis Major Transfer

Subcoracoid pectoralis major transfer has been reported at a number of centers for irreparable anterosuperior tears. In each series, the upper portion of the pectoralis major was passed under the conjoined tendon and sutured to the lesser tuberosity. Resch et al. 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 reported satisfactory results in ten of thirteen patients who had undergone a pectoralis major transfer.

Jost et al have noted the results of pectoralis are better in patients with isolated irreparable tears of subscapularis when compared to those with tears of both the subscapularis and supraspinatus. Pectoralis transfer may not be warranted in these patients.

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. 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.

Rehab after Pectoralis Transfer:

Sling or abduction splint (massive tears) for 4-6 weeks.

Immediate post-op passive ROM in “safe zone” determined intra-operatively. (Forward flexion below horizontal with arm in neutral rotation; Limit ER to 10-30 degrees, full forward flexion with arm in IR.)

Active and AAROM at 4-6 weeks.

Rotator cuff strengthening at 12 weeks.

Combined Pectoralis Major and Latissimus Transfer

Aldridge et al. reported the use of combined pectoralis major and latissimus dorsi tendon transfer to treat massive cuff defects in eleven patients with both anterior and posterior deficiencies.. Each patient's chief complaint was diminished shoulder function and motion with little or no accompanying pain. The primary operative objective was to increase active shoulder motion. 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, and strength in external rotation from 2.1. to 2.7 lb. Four patients reported feeling no better, two had slight improvement, and five had substantial improvement.

Summary:

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 re-education 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/AUGMENTATION:

Tissue substitution with synthetic materials and with autogenous and allograft tissue implants has been attempted, but there are limited published data on such procedures.

Bulk Tissue Allografts

Neviaser et al. reported good-to-excellent results in fourteen of sixteen patients treated with a freeze-dried rotator cuff allograft for massive, but probably not irreparable, tears.

Unfortunately, these results have not been reproduced by others. In two other series, the authors reported poor results with the use of bulk allografts and recommended that they not be used.

Tissue Patches

Tissue 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.

Porcine small intestine submucosal patches (“Restore OrthoBiologic Implant”)

Xenografts have had historically poor results in orthopaedics, but some promising animal studies led to its use.

The device was “...intended to reinforce soft tissues...Not intended to replace normal body structure...provides a resorbable scaffold that is replaced by the patient’s own tissue.

In a randomized, controlled trial, Iannotti et al reported that augmentation of the surgical repair of large and massive chronic rotator cuff tears with porcine small intestine submucosa did not improve the rate of tendon-healing or the clinical outcome scores. On the basis of these data, they did not recommend using porcine small intestine submucosa to augment repairs of massive chronic rotator cuff.

Murrell and associates abandoned a randomized controlled trial with the Restore patch when several patients developed severe inflammatory reactions a few weeks after surgery. Two years after surgical repair of a large rotator cuff defect supplemented with a patch, patients had several persisting deficits and no recognizable benefit as compared with the results in a control group. In view of these findings, together with the unsatisfactorily high proportion of patients with a severe inflammatory reaction to the xenograft, they did not recommend use of the Restore Orthobiologic Implant in its present form.

Allograft human skin Patch (“GraftJacket”)

Cadaver skin processed to remove dermal and epidermal cells while retaining structural and “bioactive components” including collagen types I, III, IV, and VII, elastin, chondroitin sulfate, proteoglycans, hyaluronic acid, laminin, tenascin, and fibroblast growth factor.

Snyder and associates assessed the short-term results and describe the technique of arthroscopic repair of irreparable rotator cuff tears by use of a GraftJacket allograft. At a mean follow-up of 27 months, 15 of 16 patients were satisfied with the procedure. The mean UCLA score increased from 18.4 preoperatively to 30.4 postoperatively ($P = .0001$). The Constant score increased from 53.8 to 84.0 ($P = .0001$). Statistically significant improvements were seen in pain, forward flexion, and external rotation strength. 13 patients had full incorporation of the graft into the native tissue as documented on magnetic resonance imaging. There were no complications in this cohort of patients.

Hemiarthroplasty

Cuff tear arthropathy: A massive tear also allows the humeral head to be displaced upward, causing subacromial impingement that in time erodes the anterior portion of the acromion and the acromioclavicular joint. Eventually the soft, atrophic head collapses, producing the complete syndrome of cuff-tear arthropathy. The incongruous head may eventually erode the glenoid so deeply that the coracoid becomes eroded as well.

Hemiarthroplasty may be considered treatment for some patients with an irreparable rotator cuff tear and concomitant arthritis. Total shoulder replacement (with resurfacing of the glenoid) is not recommended in patients with rotator cuff deficiency since the humeral component tends to load the edge of the glenoid component. Glenoid component loosening then ensues.

Successful results have been reported following hemiarthroplasty with or without an extended-coverage humeral head component.

These patients can expect pain relief with some (minimal) return of function. In a long-term follow-up study of hemiarthroplasty in patients with rotator cuff deficiency, Bigliani and associates reported that patients who could actively elevate the arm to 90 degrees preoperatively had significantly better function (mean ASES function score, 31 compared with 23 points; $p = 0.05$), pain relief (mean ASES pain score, 48 compared with 30 points; $p = 0.002$), and higher total ASES scores (mean, 80 compared with 54 points; $p < 0.001$) than the patients who were unable to actively elevate the arm to 90 degrees. Twenty-six of thirty-four shoulders satisfied the limited goals criteria described by Neer et al.

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. 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.

Zuckerman et al reported that average active forward elevation increased from 69 degrees to 86 degrees, and average active external rotation increased from 15 degrees to 29 degrees after hemiarthroplasty for cuff tear arthropathy. (Note the minimal gains in range of motion.) Thirteen patients had an increase in their ability to perform activities of daily living, 1 patient was unchanged, and 1 patient had a decrease in ability to perform activities of daily living. Pain relief was significantly improved in all but 1 patient

Hemiarthroplasty should not be done in patients who have anterosuperior shoulder instability. Hemiarthroplasty requires a functionally intact coracoacromial arch and a functional deltoid. In a report from the Mayo Clinic, 7 of 33 shoulders that were treated with hemiarthroplasty for cuff tear arthropathy developed anterosuperior instability. Because of unpredictable results in such patients, **reverse total shoulder arthroplasty** is now increasingly used in place of hemiarthroplasty in patients with irreparable cuff tears. The reverse ball prosthesis seems to provide more predictable pain relief and return of function, at least in the short term. However, Bigliani et al recommend that hemiarthroplasty continue to be considered as a treatment option in patients with >90 degrees of pre-operative active elevation as it has a lower complication rate than reverse arthroplasty. In patients with <90 of active elevation, the functional benefits of reverse arthroplasty may outweigh the higher complication rate.

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.

Arthrodesis is generally reserved for patients who had both an irreparable rotator cuff tear and irreparable deficiencies of the deltoid muscle.

FUTURE DIRECTIONS

Rodeo et al recently reported on sheep that underwent detachment of the infraspinatus tendon followed by immediate repair to test the effects of growth factors on scar tissue formation in a gap between tendon and bone. The administration of osteoinductive growth factors resulted in greater formation of new bone, fibrocartilage, and soft tissue, with a concomitant increase in tendon attachment strength but less stiffness than repairs treated with a collagen sponge carrier alone. This is the first study to demonstrate the possibility of increasing tissue formation in a tendon-bone gap with use of a biologic agent.

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