Arthroscopic Partial Repair of the Rotator Cuff

Patrick J. Denard and Stephen S. Burkhart

INDICATIONS/CONTRAINDICATIONS

With adherence to mechanical principles and proper tear pattern recognition, the vast majority of rotator cuff tears, including massive rotator cuff tears, can be completely repaired arthroscopically. However, there exists a subset of patients whose rotator cuff tears are considered “irreparable.” Historically, such patients were treated nonoperatively or with acromioplasty and débridement alone. While these methods frequently result in temporary pain relief, functional improvement was unpredictable and results deteriorated with time (1,2).

The concept of partial rotator cuff repair evolved from the observation of patients who appeared to be “copers,” that is, had normal function despite large rotator cuff tears. Such tears, termed “functional rotator cuff tears,” have normal function by satisfying five biomechanical criteria (3):

1. Force couples must be balanced in the coronal and transverse planes (Fig. 4-1).
2. A stable fulcrum kinematic pattern must exist.
3. The shoulder’s “suspension bridge” must be intact (Fig. 4-2).
4. The tear must occur through a minimal surface area.
5. The tear must possess edge stability.

In a patient whose massive, dysfunctional rotator cuff tear is not completely repairable, the goals of partial rotator cuff repair are to effect enough of a repair to regain overhead function, to improve strength with the arm at the side, and to achieve pain relief. A biomechanical study quantified the increased force required for the subscapularis and infraspinatus and teres minor to maintain stable glenohumeral abduction as tear size increases (4). Subscapularis force requirements increased by 45% in a 7-cm tear and 86% in an 8-cm tear; similar measurements were reported for the posterior cuff. Viewed another way, a reduction in tear size by as little as 1 cm may result in a near 50% reduction in force requirements. Thus, restoring overhead function may be achieved by partial repair that balances the force couple between the anterior and posterior portions of the shoulder; typically, this requires an intact subscapularis tendon anteriorly and an intact inferior half of the infraspinatus tendon posteriorly. Anatomically, this corresponds to the anterior and posterior attachments of the rotator cable (Fig. 4-3). It is important to understand that while there has been much recent interest in biologic augmentation materials, simply “covering the hole” will not restore force couples. Moreover, partial rotator cuff repair is preferable to tendon transfer because the former respects and preserves the normal mechanics of the rotator cuff, whereas tendon transfers adversely affect shoulder mechanics (Fig. 4-4).

The indications for partial rotator cuff repair comprise persistent pain and dysfunction due to any rotator cuff tear that is not completely repairable. Obviously, a complete rotator cuff repair is the primary goal of surgery. However, this can only be determined intraoperatively, and thus the indications for partial rotator cuff repair are similar to those for any rotator cuff tear. Partial repairs are recommended whenever complete closure of the defect is not possible.

There are few contraindications for partial rotator cuff repair. In low-demand elderly patients with preoperative functional rotator cuff tears, who require pain relief only and who are unable to protect the repair postoperatively, or who do not wish to participate in a long rehabilitation program, the surgeon may consider a subacromial decompression, biceps tenodesis or tenotomy, and débridement alone. Advanced cuff tear
Balanced force couples are required to maintain the normal glenohumeral relationship. A: In the coronal plane, the combined inferior rotator cuff force (C) is balanced against the deltoid (D). B: In the transverse plane, the subscapularis (S) is balanced against the infraspinatus and teres minor (I). O, center of rotation; A, moment arm of the deltoid; a, moment arm of the inferior rotator cuff; r, moment arm of the subscapularis; R, moment arm of the infraspinatus and teres minor.

A rotator cuff tear (A) can be modeled after a suspension bridge. B: The free margin corresponds to the cable, and the anterior and posterior attachments of the tear correspond to the supports at each end of the cable’s span.

Superior (A) and posterior (B) projections of the rotator cable and crescent. The rotator cable extends from the biceps to the inferior margin of infraspinatus, spanning the supraspinatus and infraspinatus insertions.

C, width of the rotator cable; B, mediolateral diameter of the rotator crescent; S, supraspinatus; I, infraspinatus; TM, teres minor; BT, biceps tendon.
arthropathy is a relative contraindication to arthroscopic partial rotator cuff repair, and these patients are often more likely to benefit from arthroplasty. In addition, arthroscopic partial rotator cuff repair is contraindicated in patients with significant permanent neurologic deficits or medical conditions precluding surgery.

PREOPERATIVE PLANNING

The clinical presentation of patients with rotator cuff tears that are only partially repairable is similar to those for whom complete rotator cuff repair is possible. However, patients are often older with a prolonged history of pain in the anterolateral aspect of the shoulder. Pain is typically aggravated by repetitive use of the arm overhead, and in chronic cases, pain can be constant with a significant component of night pain. In patients whose tears are only partially repairable, symptoms are usually prolonged, severe, and functionally disabling.

Physical examination in these massive tears demonstrates atrophy of the supraspinatus and infraspinatus muscles, tenderness over the anterolateral humerus, and palpable subacromial crepitus. Although passive range of motion is generally at or near normal, active range of motion is typically significantly limited, with many patients demonstrating only a shoulder “shrug.” Strength is limited. An external rotation lag sign indicates involvement of the infraspinatus tendon, while a horn-blower’s sign may be used to detect teres minor involvement (5,6). Subscapularis tear size may be estimated by the bear-hug and belly-press tests that may be positive in tears of the upper 30% and the liftoff that does not become positive until tears greater than 75% of the subscapularis (7).

We routinely obtain five views of the shoulder (anteroposterior [AP] views in internal and external rotation, axillary view, outlet view, 30-degree caudal-tilt view) preoperatively in all shoulder patients. The AP view commonly shows sclerosis of the undersurface of the acromion and sclerosis and cystic changes in the region of the greater tuberosity. Acromioclavicular joint arthritis may be variably present. In massive tears, patients may demonstrate proximal migration of the humerus. We do not consider proximal migration alone a contraindication for partial rotator cuff repair. In some cases, the proximal migration may actually be reversed following repair. In most cases, the absence of adaptive changes of the greater tuberosity, the “rounding off” of the tuberosity occurring from acromial articulation, is a good prognostic sign for obtaining a successful repair.

An MRI can provide information on tear size, tear configuration, and tendon involvement, as well as findings to suggest whether a massive rotator cuff tear is potentially repairable (8). Combined tear length greater than 2 cm on coronal images and width greater than 2 cm on the sagittal images suggests that interval slides or partial repair will be necessary in over 75% of cases (Fig. 4-5). Combined length and width greater than 3 cm predicts the need for interval slides or partial repair in all cases. Careful evaluation of the axial views also is necessary to identify subscapularis tendon involvement, which significantly increases the complexity of repair (Fig. 4-5C). Although nonretracted tears of the subscapularis tendon are harder to appreciate, medial biceps subluxation virtually always indicates a tear of the upper tendon border. An MRI may also demonstrate a spinoglenoid ganglion cyst, which can cause symptoms that mimic a rotator cuff tear.

Some authors have advised against repairing tears with Goutallier grade III (50% fatty infiltration) or higher (2,9). We do not feel that fatty degeneration is a contraindication to surgical repair (Fig. 4-5B).
The senior author has demonstrated that individuals with 50% to 75% fatty degeneration can reliably obtain improvement in function and that even individuals with greater than 75% fatty degeneration can sometimes functionally improve with repair (10). Additionally, while we agree with the current trend toward repairing symptomatic rotator cuff tears as soon as possible, in our experience, patients have shown marked improvement even when undergoing repair of chronic tears more than 10 years after initial injury (11).

**SURGERY**

The principles and techniques used for arthroscopic partial rotator cuff repair are the same as those used when the rotator cuff tear is completely repairable. Although massive tears are technically demanding and may require advanced techniques, the essential elements of any arthroscopic rotator cuff repair are the following:

1. Visualization
2. Angle of approach
3. Creating a stable construct
4. Tear pattern recognition
Visualization

During arthroscopic shoulder surgery, nothing is more frustrating than poor visualization. Particularly in the subacromial space, bleeding can obscure visualization and frustrate attempts to obtain an effective rotator cuff repair. To maximize visualization, we use several techniques. First, the patient’s systolic blood pressure is maintained below 100 mm Hg (preferably less than 90 mm Hg) if not medically contraindicated. Second, we routinely maintain the subacromial pressure at 60 mm Hg using an arthroscopic pump. If bleeding occurs, the pressure may be temporarily increased up to 90 mm Hg to tamponade bleeding or to enhance visualization until bleeding is controlled. However, the duration of high subacromial pump pressures is restricted to minimize subcutaneous swelling. Electrocautery may be used to cauterize bleeding, although this can sometimes be difficult and time-consuming. Most important, careful attention must be paid to fluid leakage from noncannulated portals. Fluid flow from these portals creates a suction effect by virtue of the Bernoulli principle and draws blood into the subacromial space. Simply blocking these portals using digital pressure will facilitate a clear view by controlling turbulence within this closed system. In general, outflow cannulas are not used because they increase turbulence and exaggerate the Bernoulli effect.

Angle of Approach

The proper angle of approach is essential in repairing any rotator cuff tears. One of the great advantages of arthroscopy compared to open shoulder surgery is the ability to reach all areas of the shoulder with different arthroscopic angles and portals. Although most surgeons primarily rely on the 30-degree arthroscope, we frequently use a 70-degree arthroscope. The acute angle of the 70-degree arthroscope is particularly valuable in performing advanced techniques such as subscapularis repair, subcoracoid decompression, and interval slides.

Portal placement is critical to the angle of approach, and for that reason, with the exception of the initial posterior portal, we use an 18-gauge spinal needle to precisely establish all portals in an outside-in fashion. The three standard portals that are used during arthroscopic rotator cuff repair are posterior, anterior, and lateral subacromial. An anterosuperolateral portal is also required for subscapularis tendon repair. In addition to the most commonly used portals for arthroscopic repair, one should not hesitate to establish accessory portals for anchor placement or suture passage if the standard portals (combined with manipulation of the arm) do not afford a proper angle of approach. We commonly place anchors for instance through small percutaneous incisions to achieve the proper “deadman” angle (12).

Posterior Portal  Many surgeons create a posterior portal 1 to 2 cm inferior and 1 to 2 cm medial to the posterolateral corner of the acromion. We feel this location is too lateral and superior. During longer cases such as massive rotator cuff repairs, subcutaneous swelling will cause the skin incision to shift superiorly and laterally.

We establish a posterior portal by palpating the soft spot of the glenohumeral joint and enter the joint at or just below the equator of the humeral head. The exact position varies from patient to patient but is approximately 4 cm inferior and 4 cm medial to the posterolateral corner of the acromion. This portal is used for initial glenohumeral arthroscopy, and the same skin puncture is used for viewing and working in the subacromial space.

Anterior Portal  This is established using an outside-in technique just superior to the lateral half of the subscapularis tendon for diagnostic glenohumeral arthroscopy. This same skin puncture can be used as an anterior working portal and inflow subacromial portal and can be used during distal clavicle resection if indicated.

Lateral Subacromial Portal  This portal is approximately 4 cm lateral to the lateral aspect of the acromion, in line with the posterior border of the clavicle. One must ensure that the portal is parallel to the undersurface of the acromion. This portal serves as a viewing and working portal in the subacromial space.

Anterosuperolateral Portal  This portal is created in the presence of a subscapularis tear. It is established through the rotator interval just anterior to the supraspinatus tendon and directly above the long head of the biceps. The point of entry is approximately 1 to 2 cm lateral to the anterolateral corner of the acromion. The placement should allow a 5- to 10-degree angle of approach to the lesser tuberosity and should be parallel to the subscapularis tendon. This angle of approach is perfect for performing arthroscopic coracoplasty.

Creating a Stable Construct

Advances in technology have allowed us to transfer the weak link in rotator cuff repair from implants to the rotator cuff tissue itself. Several principles under the surgeon’s control are important to consider to optimize biomechanical stability including anchor properties, suture properties, knot tying, and margin convergence.

Traditional open repair relied on transosseous tunnels for fixation of the rotator cuff to bone. However, transosseous fixation is susceptible to failure under cyclic load through cutting of suture through metaphyseal bone. In contrast, under cyclic loading, suture anchors fail by cutting of suture through the tendon. Minimizing suture cutout can best be achieved by increasing the number of fixation points (Fig. 4-6). This is particularly relevant in massive rotator cuff repairs where tissue quality is often less than ideal. Anchor pullout strength is optimized when the angle of insertion (deadman’s angle) and tension reduction angle are both less than or equal to 45 degrees.
The final anchor factor to consider is suture abrasion that occurs through the anchor eyelet or against the anchor surface itself. Abrasion is minimized by using biodegradable anchors (compared to metal anchors) with a flexible suture loop eyelet. Our current workhorse anchor of choice in rotator cuff repair is the BioComposite Corkscrew-FT (Arthrex Inc., Naples, FL), which is a fully threaded biocomposite anchor with a no. 5 polyester suture eyelet.

We use only permanent sutures in rotator cuff repair. The healing time of rotator cuff repairs is beyond the viability of resorbable sutures. We use no. 2 Fiberwire (Arthrex Inc.), which is a polyblend suture shown to have higher load to failure and less susceptibility to suture abrasion than no. 2 Ethibond (Ethicon, Somerville, NJ). Several other current generation polyethylene sutures are also commercially available.

Secure knot tying relies on achieving knot security and loop security. Knot security, which is the effectiveness of the knot at resisting slippage, depends on friction, internal interference, and slack between throws. Loop security is the ability to maintain a tight suture loop around tissue as the knot is tied. Sliding knots can potentially damage the tendon as they slide through the rotator cuff or abrade and weaken the suture as they slide against the eyelets of the anchors (especially metal anchors). We tie strictly an arthroscopic surgeon’s knot, which is a static (nonsliding) knot composed of a base of three half-hitches in the same direction, followed by three reversing half-hitches on alternating posts. This knot has demonstrated the highest combination of knot and loop security compared to commonly used sliding knots. We also use a double-diameter knot pusher (Surgeon’s Sixth Finger; Arthrex Inc.), which allows the tissue to be secured and manipulated into place. Most importantly, continuous tension can be maintained on the post limb as knots are tied to prevent loosening of the soft-tissue loop between throws (i.e., loop security) as successive half-hitches are thrown. Although the Surgeon’s Sixth Finger has an initial learning curve, once mastered, it is highly efficient and has demonstrated superior loop security compared to knots tied with a single-diameter knot pusher (13).

For knot tying, a translucent cannula is valuable. When there is significant deltoid or adventitial swelling, knots may be tied entirely within the cannula. Before tying, retrieve both limbs out a separate cannula and hold all other sutures in temporary holding portals. When pushing half-hitches down the inner metallic sleeve of the Sixth Finger knot pusher, unravel any twists in the suture by turning the outer plastic sleeve followed by past-pointing to tighten each throw. In this way, knot security is maximized by minimizing slack between throws. Switching posts can be easily performed without rethreading, by flipping the half-hitch through differential tensioning of the suture limbs. Since the post limb is always the limb under the most tension, the wrapping limb can be converted to the post limb by tensioning it to a greater degree than the original post limb, thereby “flipping” the post. This is not only easy but it also optimizes the strength of any knot. Tissue indentation by the suture is a final indicator of good loop security.

Despite technological advances, one of the simplest and most important biomechanical principles in massive rotator cuff repair is margin convergence by side-to-side suturing. The technique of “margin convergence” not only allows repair of seemingly irreparable tears but also minimizes strain at the repair site. This theoretically decreases the risk of rerupture and subsequent failure of the rotator cuff repair. In the case of a U-shaped tear (discussed below), margin convergence along two-thirds of its length reduces strain to one-sixth the original value (Fig. 4-7) (14).

**Tear Pattern Recognition**

Arthroscopy has vastly improved the surgeon’s ability to evaluate rotator cuff tears from several different perspectives. Unlike traditional open surgery, which exposes the rotator cuff through an anterolateral incision, arthroscopy is not restricted by spatial constraints. Rotator cuff tears may now be approached and assessed from several different angles with minimal disruption to the overlying deltoid. Four basic patterns of rotator cuff tears exist (15):

1. Crescent-shaped tears
2. U-shaped tears
3. L-shaped tears and reverse L-shaped tears
4. Massive contracted tears
Crescent-shaped tears demonstrate excellent mobility from a medial-to-lateral direction and may be repaired directly to bone with minimal tension. U-shaped rotator cuff tears extend much farther medially than crescent-shaped tears, with the apex of the tear at or medial to the glenoid rim. In these seemingly irreparable tears, it is important to recognize that the apex of the tear is not purely the result of medial retraction, and attempts to repair the apex to the lateral bone bed will result in extreme tension on the rotator and result in failure. Rather, repair of these tears requires margin convergence followed by repair to the lateral bone bed in a tension-free manner. L-shaped tears and reverse L-shaped tears are similar to U-shaped tears, but either the posterior or anterior leaf, respectively, is more mobile. Repair requires identifying the apex, side-to-side suture of the longitudinal split, and repair of the converged margin to bone. These first three patterns represent greater than 90% of posterosuperior rotator cuff tears. Massive contracted tears demonstrate limited mobility from medial to lateral and from anterior to posterior. These tears cannot be repaired to bone without advanced mobilization techniques. In many cases, the “tongue” of the supraspinatus tendon at the anterior margin of the tears is useful for repair after mobilization with interval slides (Fig. 4-8). On other occasions, the supraspinatus tendon will

**FIGURE 4-7**
Free body diagram showing the mechanical condition before (A) and after (B) margin convergence with side-to-side repair. The length \( L \) has been reduced and the cross-sectional area \( A \) of the cuff at the apex of the tear is increased. \( F \), rotator cuff force.

**FIGURE 4-8**
Massive contracted tear amenable to repair to bone after interval slides. A: Superior view. B: Anterior slide in continuity is performed (not visualized) followed by a posterior interval slide. C: Margin convergence sutures are then placed. D: A tension-free repair to bone is achieved.
not reach the bone bed after interval slides and only a partial repair may be performed. In this scenario, a partial repair may be performed by suturing the leading edge of the supraspinatus side to side to the infraspinatus after the infraspinatus tendon has been advanced anteriorly (Fig. 4-9).

Setup
Following induction of general anesthesia, the patient is placed in the lateral decubitus position. The trunk is secured using a beanbag; anteriorly, it is important to keep the edge of the beanbag clear from the operative site, particularly for repairing the subscapularis. An axillary roll under the nonoperative arm protects the brachial plexus. The legs are flexed and padded with pillows between and beneath the patient’s legs. The thorax and legs are additionally secured to the operating room table using a tape. A warming blanket helps maintain core body temperature, particularly for longer, more complex procedures. Following an exam under anesthesia, the operative site is prepped and draped in the standard fashion. Ensure there is adequate exposure of the entire shoulder, particularly anteriorly and posteriorly. The arm is suspended with a Star Sleeve Traction system (Arthrex, Inc.) and balanced suspension of 5 to 10 lb to maintain the arm in 30-degree abduction and 20-degree forward flexion. By varying the amount of abduction and rotation, an assistant opposite to the surgeon can maximize exposure and visualization.

Diagnostic Glenohumeral Arthroscopy
Diagnostic arthroscopy is performed through a posterior viewing portal with an arthroscopic pump maintaining pressure at 60 mm Hg. In massive rotator cuff tears, the medial cuff edge is retracted to the glenoid rim and the subacromial space will be visible through the defect (Fig. 4-10). The biceps tendon is frequently subluxed, partially torn, or completely torn and retracted. In many cases, a subscapularis tear is also present. Visualization of the subscapularis footprint requires a 70-degree arthroscope and can also be improved with internal rotation of the humerus as well as a posterior lever push by an assistant. In the case of a retracted tear, the upper border of the subscapularis can be located by the “comma sign,” which is composed of portions of the superior glenohumeral ligament and the medial head of the coracohumeral ligament (Fig. 4-11).

Subscapularis Tendon Repair
If a subscapularis tear is present, we repair this as the first step in the overall process because swelling hinders visualization in the tight subcoracoid space. In all cases of subscapularis repairs performed in conjunction
with a massive anterosuperior cuff tear, a biceps tenodesis or tenotomy is performed. Tenotomy is limited to
individuals over the age of seventy or those with multiple medical comorbidities. The technique for arthroscopic
tenodesis is thoroughly described elsewhere (16). Briefly, an anterosuperolateral portal is established and an
8.25-mm threaded clear cannula is placed. Two half-racking no. 2 Fiberwire sutures are placed as traction
sutures in the biceps tendon and then a tenotomy is performed. The biceps is next exteriorized, secured with a
whipstitch, sized, and left for later tenodesis. This sequence of biceps preparation allows the biceps to retract
out of the way and allows greater access to the subscapularis insertion for subsequent repair, where attention
is now turned.

Following identification of the upper subscapularis border, a window is made in the rotator interval and the
subcoracoid space is assessed. For complete tears, a traction suture is placed at the junction of the “comma
sign” with the upper subscapularis using a Viper or Scorpion (Arthrex, Inc.) antegrade suture passer. The
coracoid tip, which is usually located just anterior to the upper border of the subscapularis tendon, is identi-
fied. All work is performed through the anterosuperolateral working portal while continuing to view from the
posterior portal. A 30-degree arthroscope is used to initially locate the coracoid tip. This helps to maintain
proper orientation so as to avoid inadvertent inferior dissection; keeping this landmark in view ensures safety
of approach as all important neurovascular structures are greater than 2.5 cm from the tip of the coracoid. In
the case of a retracted subscapularis tendon, a window is created in the rotator interval while pulling on the
traction suture, taking care to preserve the comma tissue. Once the coracoid tip is identified, the posterolateral
aspect of the coracoid is skeletonized from its tip to its base while viewing with a 70-degree arthroscope. This
step constitutes the anterior release as the first portion of a three-sided release of the subscapularis, which is
performed in retracted tears. The conjoined tendon insertion is easily identified and is preserved. The width of
the coracohumeral interval is estimated by comparing to the known width of a 5-mm shaver. An interval of less
than 6 mm is considered stenotic and is an indication for coracoplasty. If necessary, a high-speed burr is used
to create a 7- to 10-mm space between the coracoid tip and the subscapularis. For retracted tears, a superior
release of the subscapularis is performed by clearing the neck and base of the coracoid of soft tissue and then
using a 30-degree elevator to break adhesions between the coracoid neck and the superior tendon border; it is
important to keep the instruments on bone during this step. It is not necessary to release any further medially
than the midportion of the coracoid neck. A posterior release of the subscapularis tendon is performed with a
15-degree elevator between the posterior subscapularis and anterior glenoid neck.

A combination of electrocautery, ring curettes, shaver, and burr is used to prepare the lesser tuberosity bone
ded to a bleeding base. If there is insufficient lateral excursion of the subscapularis tendon, the footprint can
be medialized 5 to 7 mm. An anterior portal is established. This portal begins somewhat more medial than
the typical anterior portal and is created to enter the glenohumeral joint just lateral to the coracoid tip and
approach the lesser tuberosity at a 30- to 45-degree angle. Due to retroversion of the proximal humerus, the
angle of approach results in the surgeon’s hand being near the patient’s jaw during punch preparation and

FIGURE 4-10
Intra-articular view of a right shoulder through a posterior viewing portal showing a massive contracted rotator cuff tear. The subacro-
mial space is visible superior and the supraspinatus is retracted to the glenoid rim.

FIGURE 4-11
Retracted subscapularis tear in a right shoulder, as seen through a posterior viewing portal. The comma tissue (asterisks) marks the
leading edge of the subscapularis tendon (dotted lines). G, glenoid; H, humerus.
anchor insertion. One anchor is used for every linear centimeter of tear; because the subscapularis footprint is 2.5 cm, one anchor is used for upper tears and two anchors are used for complete retracted tears. The inferior anchor is placed first and sutures are passed retrograde in a mattress configuration with a Penetrator (Arthrex, Inc.) before placing the superior anchor. Sutures are then tied sequentially from inferior to superior following the placement of the second anchor. The biceps tenodesis is then completed if planned.

In addition to force-coupling benefits of restoring the subscapularis tendon, repair provides important contributions to treatment of massive contracted tears. Making the window in the rotator interval and performing an anterior release of the subscapularis tendon down to the coracoid base constitute an anterior interval slide in continuity because the medial attachment of the coracohumeral ligament is removed, while the comma tissue is preserved (Fig. 4-12). We prefer an anterior interval slide in continuity to a complete anterior interval slide, as the former improves mobility of both the subscapularis and supraspinatus without disrupting the comma tissue. Preserving the comma tissue facilitates repair of the posterosuperior cuff, maintains a rotator cable attachment anteriorly, and avoids creating “floppy” tissue that can be difficult to work with (Fig. 4-13).

![Figure 4-12](image)

**FIGURE 4-12**
Anterior interval slide in continuity. **A:** An anterosuperior rotator cuff tear involving 50% of the subscapularis tendon and a massive tear of the supraspinatus and infraspinatus tendons. **B:** A coracoplasty is performed. The **dotted box** outlines the proposed area for resection of a portion of the rotator interval for the interval slide in continuity. **C:** An interval slide in continuity is performed by first exposing the posterolateral aspect of the coracoid all the way to the coracoid neck, releasing any adhesions between the subscapularis tendon and the inferolateral coracoid. Then, the medial rotator interval tissue is excised, creating a “window” through the rotator interval, partially releasing and excising the coracohumeral ligament. Care is taken to ensure that the lateral margin of the rotator interval remains intact, maintaining the continuity between the subscapularis and the supraspinatus tendons. Then, soft tissues are débrided and released from the posterolateral base of the coracoid while viewing through the “window” with a 70-degree arthroscope. This completes the release of the coracohumeral ligament without creating separate tissue flaps. **D:** Following an interval slide in continuity, mobility of the subscapularis tendon is improved. The subscapularis tear can now be repaired to bone, leaving a U-shaped posterosuperior rotator cuff tear to be repaired.
FIGURE 4-12 (Continued)

E: The residual U-shaped posterosuperior rotator cuff tear is repaired with side-to-side sutures using the principle of margin convergence. F: The converged margin is then repaired to bone in a tension-free manner. CHL, coracohumeral ligament.

FIGURE 4-13

Importance of the comma tissue in facilitating repair of the supraspinatus. A: A massive rotator cuff tear involving the subscapularis and supraspinatus. B: Following an anterior interval slide in continuity, the subscapularis tendon is repaired to bone. Note that maintenance of the comma tissue and restoration of the subscapularis footprint improve reduction of the supraspinatus tear. C: The supraspinatus tendon can then be repaired directly to bone in a tension-free manner.
Subacromial Bursoscopy and Posterosuperior Tear Evaluation

After subscapularis repair, the arthroscope is placed in the subacromial space through the posterior portal. A lateral subacromial working and viewing portal is established. All bursal tissue and fibrofatty tissue are débrided from the rotator cuff. With the arthroscope posterior and a shaver lateral, the margins of the tear are débrided and the lateral gutter is exposed. The arthroscope is then moved to the lateral portal and the posterior gutter is cleared followed by dissection of the scapular spine. The scapular spine appears like the keel of a boat and identification is required for a posterior interval slide (Fig. 4-14). A complete débridement of the subacromial bursa and fibrofatty tissue is essential since adventitial swelling during arthroscopic repair can obscure visualization. The true margin of the tear may be obscured by a synovialized “leader” of thickened bursal tissue. Such tissue margins should be followed laterally, and if they are found to insert into deltoid fascia rather than bone, they are not tendons and must be débrided until the posterior tendon insertion into bone is clearly visualized.

For massive rotator cuff tears, we do not perform a formal arthroscopic acromioplasty, but rather perform a subacromial “smoothing.” The undersurface of the acromion is cleared and osseous irregularities are gently beveled and smoothed with a burr. The coracoacromial ligament is preserved because it is an essential restraint to anterosuperior migration of the humeral head if the rotator cuff repair fails or is nonfunctional.

In patients who have previously undergone surgery, adhesions between the rotator cuff and deltoid and between the rotator cuff and acromion may occur and must be lysed or excised for sufficient cuff mobility. To locate the proper plane of dissection, begin the dissection medially at the apex of the tear, beneath the medial acromion, and locate the fibrofatty layer above the rotator cuff (Fig. 4-15A). Follow this layer posteriorly and dissect the posterior leaf of the rotator cuff tear off the deltoid using a shaver (Fig. 4-15B). Even in chronic adhesed tears, this fibrofatty layer separates the deltoid from the rotator cuff and thus may be used as a guide to separate the peripheral tear margins from the deltoid. Continue to excise these adhesions between the deltoid and rotator cuff using a shaver or electrocautery until the tear is fully defined.

The tear pattern is then assessed by determining the mobility of the tear margins. For medial-to-lateral mobility, a tendon grasper is introduced through the lateral portal while viewing posteriorly (Fig. 4-16). If the tear can be easily brought to the bone bed with minimal tension, the tear may be directly repaired to bone with suture anchors. If the tear cannot be brought easily to the lateral bone bed, the surgeon must determine if the tear is a mobile U-shaped tear and therefore amenable to repair by margin convergence. Place the arthroscope in the lateral portal and assess the anterior-to-posterior mobility of the tear. With the tendon grasper in the anterior portal, pull the posterior margin of the cuff anteriorly and then grasp the anterior tendon margin from the posterior portal and test posterior mobility (Fig. 4-17). If sufficient mobility is present to allow contact of the anterior and posterior leaves to each other, then the tear is a U-shaped tear and may be initially sutured with side-to-side sutures using the principle of margin convergence. Those tears without significant mobility represent massive, fixed, severely contracted rotator cuff tears and require interval slides for mobilization (17,18).

Bone Bed Preparation

Soft tissue is cleared from the greater tuberosity bone bed with an electrocautery (Fig. 4-18A). The charcoaled surface is removed with a burr, lightly “dusting” without decortication (Fig. 4-18B). This maximizes the bone’s resistance to suture anchor pullout. Furthermore, in vivo animal studies have demonstrated that tendon healing...
Arthroscopic Partial Repair of the Rotator Cuff

FIGURE 4-15
Arthroscopic views of a right shoulder through a lateral portal during rotator cuff mobilization in adhesed rotator cuff tears. A: The rotator cuff is initially dissected beneath the medial acromion and the fibrofatty layer is identified above the rotator cuff. B: The same layer is then followed posteriorly to identify the posterior margin of the tear. AC, acromion; G, glenoid; RC, rotator cuff; H, humeral head, B bursal “leader.”

to a bleeding surface of cortical bone is as strong as tendon healing to cancellous bone. A curette is used to create a sharp margin next to the articular surface (Fig. 4-18C). The bone bed may be medialized by up to 5 mm, if necessary, to maximize tendon-to-bone contact and to minimize resting muscle tension, but we do not recommend medializing any more than 5 mm.

Margin Convergence (Side-to-side) Suturing
For large U-shaped, L-shaped, and reverse L-shaped tears, margin convergence is performed prior to securing the cuff margin to the lateral bone bed. The arthroscope is placed in the lateral portal. Depending on the angle of approach, passage of side-to-side sutures from the anterior-to-posterior rotator cuff leaves is accomplished with a combination of antegrade and retrograde techniques. In the case of a U-shaped tear for example, a Viper or Scorpion (Arthrex, Inc.) antegrade suture passer is used to place a suture in the anterior leaf (Fig. 4-19A). A Penetrator is placed through the posterior portal, passed through the posterior leaf, and used to retrieve the suture limb on the undersurface of the anterior leaf (Fig. 4-19B). Withdrawing the

FIGURE 4-16
Assessing medial-to-lateral mobility in a right shoulder. With the arthroscope in the posterior portal, a tendon grasper is introduced through the lateral portal grasping the margins of the rotator cuff tear. This tear demonstrates very limited medial to lateral mobility.
FIGURE 4-17
Assessing anterior-to-posterior mobility in a right shoulder viewed from a lateral portal. A: Massive rotator cuff tear. B: The anterior mobility of the posterior leaf is assessed by introducing a grasper through the anterior portal and pulling the posterior leaf anteriorly. C: The posterior mobility of the anterior leaf is assessed by introducing a grasper through the posterior portal and pulling the anterior leaf posteriorly.

FIGURE 4-18
Bone bed preparation in a left shoulder viewed from a posterior portal. A: Electrocautery is used to remove soft tissue. B: A burr removes cautery remnants and achieves a bleeding base.
Penetrator suture passer passes the suture limb through the posterior leaf, completing a side-to-side suture placement. Continue placing side-to-side sutures in a similar fashion progressing from medial to lateral (Fig. 4-20A). Space the sutures at 5- to 10-mm intervals alternating the color of suture to facilitate suture management. Ordinarily, four to five side-to-side sutures are required for massive U-shaped tears, with the most lateral suture abutting against the medial portion of the bone bed. Gentle traction on the extremity can facilitate suture passage, as can “stabilizing” the opposite leaf with grasper or cannula as the penetrator passes the suture. Place all side-to-side sutures before knot tying to allow unobscured suture passage through the rotator cuff. As the sutures are tied in a sequential fashion from medial to lateral, the free margin of the rotator cuff will converge laterally toward the bone bed (Fig. 4-20B and C). If the rotator cuff converges completely over the lateral bone bed (Fig. 4-20D), a complete rotator cuff repair will be achievable with lateral anchors.

If an antegrade technique cannot be used, a handoff technique can be performed with two retrograde instruments. A Penetrator is “loaded” in the middle of a no. 2 Fiberwire suture and inserted through the posterior portal. The instrument is passed through the posterior leaf near the apex of the tear medially (Fig. 4-21A). Next,
FIGURE 4-20
Margin convergence in a right shoulder viewed from a posterior portal. **A:** Margin convergence sutures in place. **B:** The double-diameter knot pusher (Surgeon’s Sixth Finger, Arthrex Inc., Naples, FL) is introduced. **C:** With the Surgeon’s Sixth Finger, reduction of the two leaves of the tear is obtained and can be maintained while subsequent throws are completed. **D:** Appearance of the same tear following the placement of side-to-side sutures.

a second empty suture passer is introduced through the anterior portal and passed through the anterior leaf. A “handoff” is performed, from the posterior to the anterior suture passer (Fig. 4-21B), followed by withdrawal of the anterior instrument. This draws the suture through the anterior leaf and out the anterior portal, effectively creating a side-to-side suture.

**Fixation of the Posterosuperior Tear to Bone**

After effecting as much of a margin convergence as possible, each leaf of the rotator cuff must be fixed securely to the lateral bone bed. Although we prefer double-row repairs, for partial rotator cuff repairs, this is not possible, and we usually use one suture anchor for each leaf. While viewing through a posterior portal, the suture anchors are inserted through 3-mm percutaneous skin punctures immediately adjacent to the lateral acromion. A spinal needle locates the optimal position for each anchor and ensures the placement at a “deadman” angle of 45 degrees. Placing anchors at this angle increases the pullout strength of the anchor and minimizes tension in the suture, thus minimizing suture breakage. Anchors are generally placed 1 cm from the anterior and posterior leaves to shift the leaves to the anchors as the knots are tied. This maneuver maximizes the moment of
the posterior rotator cuff in the transverse and coronal planes to effectively balance the force couples. In most cases, tapping the bone socket is not necessary. Anchor fixation can be confirmed by pulling on the sutures. All anchors are placed before suture passage.

Following anchor placement, the sutures are passed through each leaf of the tear. We prefer simple sutures through the rotator cuff and use both antegrade and retrograde techniques. Antegrade suture passage is particularly useful for the supraspinatus and is typically accomplished with a Viper or Scorpion suture passer. With these instruments, the tissue may be grasped and pulled toward the bone bed before stitch delivery to ensure that the proposed suture location is satisfactory. The Viper allows the surgeon to grasp the tissue, deliver the suture, and retrieve the suture in a single step. The Scorpion is useful for situations requiring a larger bite or for passing suture through thick tissue. The Scorpion does require a second step with suture retrieval via another instrument. Our routine for antegrade suture passage is as follows: While viewing from the posterior portal, a suture limb is retrieved through an 8.25-mm threaded cannula placed in the lateral portal. The antegrade suture passer is loaded extracorporeally, slack is removed by pulling on the opposite suture limb as the instrument is inserted into the shoulder, and an antegrade pass is performed.

Retrograde passage is typically used to secure the infraspinatus to the posterior anchor. The arthroscope is placed in the lateral portal and a suture-passing instrument is introduced through the posterior portal. The Penetrator suture passer through the posterior working portal provides an excellent angle of approach for the posterior leaf. The arthroscope is withdrawn so that the suture passer and suture anchor are both within the view. We use a “lineup the putt” approach and pass the Penetrator suture passer through the posterior leaf toward the suture anchor, grasp one suture limb from the anchor, and withdraw it through the posterior leaf.

Following passage of all sutures, simple sutures are tied in a sequential fashion. By passing all sutures before tying, it is easier to manipulate the suture retriever under the rotator cuff margin, because the cuff is not bound down by sutures that have already been tied. Arthroscopic knot tying for fixation of tendon to bone is usually performed through a lateral portal with all other sutures retrieved through a holding portal(s). Knots are tied over the rotator cuff rather than the bone. This completes the repair (Fig. 4-22).

**Advanced Techniques: Interval Slides and Reestablishing the Rotator Cable**

As noted above, we prefer an anterior slide in continuity that is performed when a massive tear includes the subscapularis tendon. A posterior interval slide is required when there is limited mobility in both medial-to-lateral and anterior-to-posterior directions. The posterior interval slide begins with the placement of two traction sutures, one near the posterior border of the supraspinatus tendon and one near the anterior border of the infraspinatus tendon. As noted previously, visualization of the scapular spine is critical to performing the posterior slide. While viewing from posteriorly, arthroscopic scissors are introduced through the lateral portal and the scapular spine is visualized. The posterior working portal is directed toward the scapular spine and a suture is passed through this portal and retrieved through the posterior leaf of the rotator cuff. The suture passer is then used to deliver the suture through the posterior leaf of the rotator cuff. Once the suture is delivered, the suture passer is retrieved through the posterior working portal and the suture is tied over the rotator cuff.
portal. The supraspinatus and infraspinatus are separated by incising toward the base of the scapular spine (Fig. 4-23A). The scissor blades are lifted upward while cutting to protect the suprascapular nerve. The incision is stopped when the tendon gives way to the perineural fat-pad (Fig. 4-23B). Maintaining lateral traction helps guide the incision and protects the suprascapular nerve. In most cases, 4 to 5 cm of increased lateral excursion is obtained with the posterior interval slide.

In over 90% of cases, the techniques described above will allow a complete repair. However, in some cases, the margin of the rotator cuff will not converge sufficiently to completely cover the articular surface. In these cases, only partial rotator cuff repair is possible, and a defect must be left in the superior portion of the rotator cuff. In these cases, side-to-side suturing is continued as far laterally as possible and then each leaf is repaired to bone with suture anchors. This effectively mobilizes and shifts the rotator cuff superiorly, restoring the posterior moment and balancing the transverse plane force couple.

**FIGURE 4-22**
Completed arthroscopic partial rotator cuff repair. Arthroscopic view through a lateral portal demonstrating a partial rotator cuff repair with a small residual defect in the superior portion of the rotator cuff with exposed humeral bone.

**FIGURE 4-23**
Posterior interval slide in a left shoulder viewed from a lateral portal. **A:** Traction sutures (not visible) are placed and the incision is directed toward the scapular spine. **B:** Completed posterior interval slide. SS, supraspinatus; IS, infraspinatus; SP, scapular spine.
If, despite interval slides, the supraspinatus does not have sufficient mobility to reach the greater tuberosity, then the supraspinatus is sutured side to side to the infraspinatus after the infraspinatus has been advanced and repaired to bone (Fig. 4-9). These efforts are made to reestablish the rotator cable and do as much possible to rebalance force couples. Clinically, we have not found it necessary to routinely perform suprascapular nerve decompression for massive retracted rotator cuff tears. There is evidence that recovery of suprascapular neuropathy occurs with partial or complete repair (19).

POSTOPERATIVE MANAGEMENT

All arthroscopic rotator cuff repairs are performed on an outpatient basis. The arm is placed in a sling with a small abduction pillow. The sling is worn continuously for 6 weeks except during bathing and exercises. Active elbow and hand motion are encouraged. Passive external rotation is allowed in the absence of subscapularis involvement; no external rotation past neutral is allowed if there is a tear of the subscapularis. For massive tears, overhead stretching is avoided until 6 weeks postoperatively to avoid stressing the repair. Codman exercises are not performed. At 6 weeks, the sling is discontinued and the patient begins overhead stretches with a rope and pulley. Internal rotation stretches are begun at 12 weeks. Although strengthening is allowed at 12 weeks for most rotator cuff tears, it is delayed until 16 weeks for tears greater than 5 cm in diameter or for tears that involve interval releases. Progressive activities are incorporated as strength allows and unrestricted activities are usually resumed from 6 to 12 months after surgery. We believe the practice of aggressive early passive range of motion is detrimental to healing. Primate studies of rotator cuff repair have shown that it takes at least 12 weeks for Sharpey fibers to return (20). We also feel that the notion of early passive range of motion to avoid stiffness is a misconception that is a carryover from the days when open rotator cuff repair created greater soft-tissue damage. The senior author has reported that using this protocol stiffness was observed in only 2% of massive rotator cuff tears (21).

RESULTS

Although the results of partial rotator cuff repair are not as good or as consistent as complete rotator cuff repair, they are superior to débridement and decompression alone. It is important to remember that these patients represent a small subgroup of patients with massive tears and are usually significantly disabled. In the senior author’s previous series of patients who underwent partial rotator cuff repair, strength improved an average of 2.3 grades, forward flexion improved from 60 to 150 degrees, and UCLA functional outcome scores improved from 9.8 to 27.6 (22). Duralde and Bain (23) reported similar results in a series of 24 patients with a 43-month average follow-up; forward flexion improved from 114 to 154 degrees, ASES scores improved from 41% to 80%, and 92% of patients were satisfied with the procedure. In a recent report, 42 patients with massive rotator cuff tears and 50% or greater fatty infiltration were randomized to débridement or partial repair (24). At 2-year follow-up, partial repair resulted in significantly greater improvement with an average age-adjusted Constant score of 73, compared to 50 in the débridement group.

COMPLICATIONS

The complication rate after shoulder arthroscopy is very low. In an unpublished report, members of the International Society of Arthroscopy, Knee Surgery, and Orthopedic Sports Medicine (ISAKOS) submitted cases to a registry. The ISAKOS complication registry recorded only 4 infections out of 60,000 shoulder arthroscopies that were registered (Burkhart, personal communication, 2000). We have not observed any major intraoperative complications from arthroscopic partial rotator cuff repairs. During prolonged procedures, however, the shoulder and particularly the deltoid can become quite swollen, thus impairing visualization and making repair more difficult. Although compartment syndrome of the deltoid has not been reported in the published literature, we are aware of one case of deltoid necrosis presumably secondary to extravasation of fluid into the deltoid during a prolonged arthroscopic procedure. For this reason, we recommend that if visualization is impaired or the surgeon cannot easily complete the entire case within 2 1/2 hours, conversion to an open repair should be strongly considered.

REFERENCES