With recent advances in shoulder arthroscopy, techniques for performing a successful rotator cuff repair have evolved from full open procedures to arthroscopically assisted mini-open techniques and, more recently, to all-arthroscopic techniques. Advantages of all-arthroscopic techniques include preservation of the deltoid attachment, less postoperative pain, and decreased postoperative morbidity, with earlier return of motion. However, arthroscopic repair is a technically demanding procedure that requires special instrumentation and techniques to achieve successful outcomes.

CLASSIFICATION

With the advancement of arthroscopic techniques for rotator cuff repair has come a better understanding of tear patterns, because of the ability to visualize the tear from a number of different directions and angles. This improved visualization has led to improved classification of tear patterns (Fig. 16-1). Recognition of tear patterns is an important first step to achieving an anatomic tension-free repair. Rotator cuff tears can be classified by tear pattern, tear size, and tear location. Lo and Burkhart have described four main types of tears.

Crescent-Shaped Tears. These tears are the simplest to repair and recognize. Tears can be large but demonstrate minimal medial retraction. Therefore, the tears can be easily mobilized laterally and secured to the greater tuberosity without excessive tension.

U-Shaped Tears. These tears resemble crescent-shaped tears but with significant medial retraction, often to the level of the glenoid rim. Therefore, the tendon cannot be simply pulled laterally to the greater tuberosity because it will place a significant amount of tension on the repair. Special techniques such as margin convergence can be used to help mobilize these tears before repair.

L-Shaped and Reverse L-Shaped Tears. These tears initially resemble U-shaped tears. We think that U-shaped tears are L-shaped until proved otherwise. The tears involve a tendon tear from bone, with an additional longitudinal split posteriorly or, more commonly, anteriorly, resulting in the posterior leaflet retracting posteriorly and medially. Care must be taken to reduce the corners of these tears anatomically.

Massive, Contracted, and Immobile Tears. This pattern is more commonly seen in older patients and is exceedingly rare in young athletes. It occurs when the tendon retracts significantly. Its mobilization is impossible without performing soft tissue releases anteriorly or posteriorly, or both.

Millstein and Snyder have introduced the SCOI (Southern California Orthopaedic Institute) rotator cuff classification. It is a descriptive classification that uses letters and numbers to describe the pathologic condition of the cuff tendon. This type of classification may be more useful for athletes because it takes into account partial tears. The location of the tear is termed A for articular-sided tears, B for bursal-sided tears, and C for complete tears. For partial-thickness tears, the degree of tendon damage is given a grade between 0 and 4. Grade 0 refers to a normal cuff, with smooth covering of the synovium and bursa. Grade 1 refers to a small tear (smaller than 1 cm), with superficial bursal or synovial irritation. Grade 2 is usually smaller than 2 cm and involves actual fraying and failure of some rotator cuff fibers. Grade 3 is smaller than 3 cm, including fraying and fragmentation of tendon fibers. Grade 4 is the most severe partial cuff tear and includes a flap tear, which encompasses more than one tendon.

Complete, or C, tears are full-thickness tears and are also classified into four categories. Grade C1 is a small complete tear, such as a puncture tear. Grade C2 is a complete tear smaller than 2 cm and involving one tendon with no retraction. Grade C3 is a large complete tear involving the entire tendon and measuring 3 to 4 cm. Minimal retraction may be seen. Grade C4 is a massive rotator cuff tear, which can involve more than one tendon and is usually retracted.

Although no single classification system is universally adopted, we use a simple classification based on tendon involvement and the amount of retraction. Type I is a single-tendon tear, type II is a two-tendon tear, and type III is a three-tendon tear. Type A is a minimally displaced tendon tear. Type B is a tendon tear retracted to the humerus. Type C is a tear retracted to the glenoid. In addition, it is important to inspect the magnetic resonance imaging (MRI) scan closely to determine the degree of muscle wasting and fatty infiltration. These factors play a paramount role in predicting the outcome of a cuff repair.
Figure 16-1. Tear classification and repair strategies. These include the crescent-shaped tear (A), U-shaped tear (B), and L-shaped tear (C).
BIOMECHANICS

Several factors play a role in the success or failure of an arthroscopic rotator cuff repair. These factors include the tear pattern and size, anchor placement, suture used, and knots placed to secure the repair.

Tear Pattern and Size

The larger the tear, and the more retracted it is, the less likely full function will be restored to the patient. Simple crescent and minimally retracted U-shaped tears have more successful results than larger L-shaped and massively retracted tears. We believe strongly that correct pattern identification and anatomic repair are critical to minimize stress on the repair and maximize the chance of tendon healing and functional outcome.

Anchor Placement

Suture anchors are the primary choice of fixation in arthroscopic repairs. When compared with bone tunnels, suture anchors behave favorably in rotator cuff repairs. Under cyclic loading, transosseous tunnels fail at low cycles by cutting of the suture through bone. In contrast, suture anchors fail by cutting of sutures through the tendon. These failures occur at higher cycles than transosseous tunnels. To maximize pull-out strength, the suture anchors should be placed at a 45-degree angle to the bone, also known as dead man’s angle (Fig. 16-2).

Suture Type

Nonabsorbable sutures are currently used for the arthroscopic treatment of rotator cuff tears. Sutures made with no. 2 Ethibond (Ethicon, Johnson & Johnson, Norwood, Mass) are strong enough for maximum physiologic loading conditions. Recently, stronger suture material such as FiberWire (Arthrex, Naples, Fla) has been introduced and incorporated into suture anchors. These no. 2 sutures are equivalent in strength to no. 5 Ethibond sutures and result in easier knot tying with less chance of suture breakage.

A number of stitch configurations have been described in arthroscopic repair techniques. Most commonly, simple or mattress sutures are used. In a biomechanical comparison, Burkhart and colleagues have concluded that simple sutures have a 39.7% greater ultimate load compared with mattress sutures.

Recently, there has been increased interest in a double-row repair technique to improve healing rates associated with rotator cuff repair. Studies have demonstrated that double-row fixation results in an increased area of contact between the repair footprint and the greater tuberosity. Furthermore, biomechanical data in a cadaveric model have demonstrated that double-row fixation results in increased ultimate failure strength and decreased gap formation with cyclic loading. However, limited clinical data are available. Although increased fixation strength would seem likely to improve healing rates, it does not change the biologic issues related to poor vascularity and tissue quality. Therefore, further clinical studies are necessary to justify the increased complexity and cost associated with double-row repairs.

Knot Placement

Arthroscopic knot placement has been the subject of debate for years. There are two general types of knots, sliding and nonsliding. Sliding knots such as the Duncan loop, Tennessee slider, and Revo knot require the suture to slide through the soft tissue and the anchor itself. Alternatively, nonsliding knots or half-hitch knots do not require the suture to move through the tissue or the anchor.

Two factors play a role in the placement of a knot: loop security and knot security. Loop security is the ability to keep a suture loop tight while the knot is tied. Knot security refers to the effectiveness of the knot in resisting slippage when a load is applied. In a biomechanical study aimed at comparing the different sliding and nonsliding knots, Lo and associates have concluded that a static nonsliding knot provides the best balance of loop security and knot security. This knot is performed by placing two half-hitches in the same direction on the same post followed by three alternating half-hitches on alternating posts. If a sliding knot is chosen, it is recommended that three alternating half-hitches be placed behind it to
improve its knot security. Moreover, the knots placed with a no. 2 FiberWire have a better knot security compared with the same knot placed with a no. 2 Ethibond suture. Therefore, for most of our applications, we use a nonsliding knot using no. 2 FiberWire.

**SURGICAL INDICATIONS AND CONTRAINDICATIONS**

The indications for arthroscopic rotator cuff repair are similar to those established for open and mini-open repairs. The primary indications for a repair are pain followed by weakness and poor function, with a failure of conservative management. However, in young patients and athletes with symptomatic full-thickness tears, we do not believe that there is a significant role for nonoperative management. In these cases, we believe that re-establishing tendon continuity is paramount for maximizing strength and function. Furthermore, as tears become more chronic, associated muscle changes such as atrophy and fatty infiltration, as well as tear progression, may occur and lead to compromised outcomes, with subsequent surgery.

Absolute contraindications include acute or chronic infections and significant medical illnesses precluding anesthesia. Relative contraindications include advanced glenohumeral arthritis or significant retraction and fatty infiltration of the tendon, along with a fixed superior migration of the humeral head.

**PREOPERATIVE CONSIDERATIONS**

A combination of interscalene block and general anesthesia is ideal for most patients. Advantages of regional anesthesia include decreased perioperative pain and nausea. Successful results with regional anesthesia alone have been reported, although our preference is to combine it with a general anesthetic.

Maintenance of a mean arterial pressure of 70 to 90 mm Hg or a systolic pressure near 100 mm Hg allows maximal visualization and minimizes bleeding in the subacromial space. We have also used epinephrine in the arthroscopic solution to help control bleeding and maximize visualization.

Obesity is a factor in both placing the portals in the correct position and in controlling blood pressure. Most surgeons tend to place portals laterally in obese patients because it may be difficult to palpate the bony landmarks. In such cases, it is advisable to use an 18-gauge spinal needle to verify the accuracy of the portals before making incisions. Moreover, an obese patient placed in the beach chair position may run the risk of developing superior vena cava compression, leading to decreased venous return to the heart and uncontrollable hypotension. In these cases, we advise lowering the back of the table down or placing the patient in a lateral decubitus position.

**Patient Positioning and Draping**

**Beach Chair Position**

This is our preferred position for all arthroscopic procedures with primarily subacromial pathology (Fig. 16-3). The beach chair position has a number of advantages. The anatomy is in a familiar position and is easy to reference the instruments with respect to the body and floor. This position also allows easy conversion to an open procedure.

**Draping**

The patient is aligned on the edge of the table so that the affected shoulder and scapula are exposed. We place two folded towels on the medial edge of the scapula to retract it further laterally. The back of the table is elevated completely to position the acromion parallel to the floor. The head is secured to the operating table with tape or an optional head rest may be used if the table allows it. Care should be taken to prevent excessive flexion or extension in the neck.

**Examination Under Anesthesia**

Examination under anesthesia should be performed in all cases and is of particular importance in the athlete in whom coexisting conditions such as instability may be present. The shoulder is checked to verify normal range of motion and exclude significant stiffness or internal rotation deficit. Stability testing should be performed in anterior, posterior, and inferior directions.

**Portal Placement**

Consistent portal placement can help surgeons achieve reproducible results (Fig. 16-4). We begin every case by outlining the bony landmarks on the skin with a marking figure 16-3. Patient positioning. The patient is placed in a beach chair position for arthroscopic rotator cuff repair.
pen. Some bony landmarks should be palpable in most patients. The posterior and anterior corners of the acromion, as well as the soft spot between the posterior clavicle and anterior scapular spine, should be marked first. A line is drawn between the two corners of the acromion. The anterior and posterior edges of the clavicle are marked next, along with the scapular spine. The acromioclavicular (AC) joint is palpated and marked. Finally, a circle is drawn over the prominence of the coracoid.

Posterior Portal
This is the first portal to be created in most arthroscopic cases. Although precise measurements have been described to locate the posterior portal, we recommend relying on palpation of the landmarks instead. Using the Romeo three-finger shuck, the index finger of the same hand as the shoulder being operated on is placed in the soft spot between the clavicle and scapular spine. The middle finger is placed on the coracoid, and the thumb feels the interval between the infraspinatus and teres minor. This helps the surgeon find the best and softest location of the posterior portal. If the posterior portal is to be used primarily as a viewing portal, using direct suture-passing methods from the lateral portal, the surgeon may choose to place this portal superiorly and laterally to allow improved visualization during cuff repair.

Anterior Portal
The anterior portal is generally placed in the triangular space in the rotator interval formed by the humeral head, subscapularis muscle, and intra-articular portion of the long head of the biceps. Although this portal can be easily established with an outside-in technique using a spinal needle, we prefer to establish it through an inside-out technique. This involves driving the arthroscope anteriorly toward the triangle and gently pushing against the anterior capsule. The arthroscope is removed and a Wissinger rod is pushed through the scope cannula to create a puncture hole in the rotator interval. The skin is tented anteriorly and a no. 11 knife blade is used to create the skin incision. Ideally, the location of the portal is just lateral to the tip of the coracoid. The rod is pushed through the skin incision and a clear cannula is placed over the rod into the joint. The Wissinger rod is withdrawn and the arthroscope is reintroduced.

Lateral Portal
This is the viewing portal for arthroscopic cuff repairs and for the second stage of a subacromial decompression. It is only used for subacromial work. The ideal location of this portal is in the midaspect of the acromion. This portal is established by palpating the soft interval between the posterior edge of the clavicle and anterior edge of the scapular spine. A line is drawn from this point laterally past the acromial edge by 2 to 3 cm. A spinal needle is used to verify the appropriateness of the portal before making a skin incision.

Accessory Superolateral Portal
This portal is used for placement of suture anchors and for tying knots and suture shuttling. It is placed just lateral to the anterior corner of the acromial edge. A spinal needle is used to localize the portal (Fig. 16-5). It is important that this portal allow for the appropriate dead man’s angle for suture anchor placement within the greater tuberosity.
SURGICAL TECHNIQUES

Diagnostic Arthroscopy
In all cases, diagnostic glenohumeral arthroscopy is initially performed, and any intra-articular pathology is addressed. The rotator cuff can then be visualized to confirm the presence of a full-thickness tear and to provide an initial estimation of the size and configuration of the tear.

Subacromial Inspection and Decompression
Once the glenohumeral inspection is complete, the arthroscope is placed in the subacromial space. This is achieved by angling the trocar superiorly until it passes just under the posterior acromion. The trocar is then angled anteriorly and laterally to enter the subacromial bursa. The arthroscope is reintroduced to verify the location of the trocar. A “room with a view” is achieved when the arthroscope is inside the bursal sac. If the view is not seen, the arthroscope may be too anterior or medial, and this procedure should be repeated if necessary.

Working from the lateral portal, a thorough débridement of bursal tissue is performed using a standard 5.0-mm shaver to allow visualization of the tear. Care must be taken to débride all bursal tissue thoroughly anteriorly, posteriorly, and within the lateral gutter, because soft tissue remnants may swell during the remainder of the procedure and can impede visualization.

Once débridement is completed from the lateral portal, we prefer to switch the arthroscope to the lateral portal. Next, working from the posterior portal using the shaver, care is taken to remove any remaining posterior bursa to allow adequate visualization of the posterior tear margins. At this point, a standard arthroscopic acromioplasty is completed using the cutting block technique.

Preparation of Tuberosity Insertion Site
To enhance healing of the torn tendon to the bone insertion site, the bone should be prepared with gentle débridement to achieve a bleeding bony surface (Fig. 16-6). This can be accomplished while viewing through the posterior portal, using a burr or bone-resecting shaver through the lateral portal. Bone preparation should begin just off the articular margin and proceed laterally to re-create the normal 10- to 15-mm footprint for rotator cuff insertion. Care must be taken to avoid decortication because this could compromise fixation strength of the suture anchors.

Determination of Tear Configuration and Repair
At this point, the arthroscope is placed into the lateral portal to allow direct visualization of the tear and determine tear configuration. Accurate identification of tear patterns is extremely important to achieve anatomic repair of the rotator cuff. Anatomic repair minimizes stress on the repair during the postoperative period and maximizes the chance of tendon healing. Finally, the technique used to repair each type of tear varies slightly, and accurate tear pattern recognition is imperative so that the most appropriate repair configuration can be selected.

Crescentic Tears
For small single-tendon tears, the crescentic pattern is most commonly encountered. This pattern represents detachment of the cuff from the tuberosity with minimal

![Figure 16-6. Bone preparation. A, A high-speed burr or bone-cutting shaver is used to decorticate the tuberosity repair site lightly to create bleeding bone for tendon healing. Care must be taken to avoid significant bone resection, which could compromise anchor fixation. B, Completed bone bed can be checked for adequate bleeding by decreasing the pump pressure and visualizing an adequate bleeding bony surface.](https://example.com/figure16-6)
retraction (Fig. 16-7A). The tear is easily reduced to the greater tuberosity with little tension and can be directly repaired to bone.

Repair of crescentic tears begins with appropriate placement of the accessory anterolateral portal using spinal needle localization, as described earlier. Next, the first suture anchor is placed at the most posterior aspect of the tear. Suture anchor placement may be facilitated by humeral rotation and abduction. Anchors should be placed 5 to 10 mm lateral to the articular surface and should be separated by 5 to 8 mm. Anchors are sequentially placed in a posterior to anterior direction.

Once the anchor has been placed, a penetrator is placed through the posterior portal (Fig. 16-8). The device is used to penetrate the cuff tissue a minimum of 5 mm medially to the tear edge. The penetrator is then used to grasp one limb of the posterior suture and pass it through the torn cuff and out of the posterior portal. This step is repeated for one limb of the second suture. The free ends of the sutures are then retrieved out through the posterior portal using a crochet hook. At this point, sutures can be stored on a hemostat and tied after all anchors are placed, or they can be tied immediately. The advantage of delaying suture tying until all sutures are passed is that the tendon remains mobile, which allows easier passage of subsequent sutures. However, multiple sutures in the space can cause confusion and difficulties with suture tangling.

At this point, additional anchors are placed anteriorly as needed, and sutures are passed using a similar technique. However, the most anterior portion of the tear is usually not reachable using a penetrator from the posterior portal. In this case, a curved spectrum from the posterior portal or a straight spectrum from the anterior portal can be used (Fig. 16-9). When shuttling sutures using a spectrum-type device, three of the four sutures from the anchor are brought out through the anterior or posterior portal, whichever one is not being used for the spectrum. Only one suture now

Figure 16-7. Arthroscopic views from the lateral portal. A, Crescentic-type tear. B, U-shaped tear. C, L-shaped rotator cuff tear.
remains in the accessory anterolateral portal. A curved spectrum through the posterior portal or straight spectrum through the anterior portal is then used to pierce the anterior portion of the torn cuff. A monofilament suture is then passed and retrieved out through the anterolateral portal. The monofilament suture is tied around the anchor suture and then used to shuttle the anchor suture through the torn cuff. This process is repeated for the second anchor suture.

At this point, all sutures are tied, working from a posterior to anterior direction. The tear is then inspected and the arm taken through internal and external rotation to ensure a complete repair that is stable throughout the normal range of motion (Fig. 16-10).

An alternate technique for suture passage involves direct suture-passing devices, such as the EXPRESSEW (DePuy Mitek, Raynham, Mass) or Scorpion (Arthrex, Naples, Fla). When using these devices, the scope is placed in the posterior or an accessory posterolateral portal for viewing because the lateral portal is required for suture management. A 6- or 8.25-mm cannula is placed in the direct lateral portal and suture anchors are placed percutaneously through an accessory superolateral portal. Using this technique, anchors are placed from anterior to posterior. After anchors are placed, the most medial and anterior limb of the first suture is brought out through the lateral portal and loaded into the suture passer. The tissue is then grasped and the suture directly passed using the device (Fig. 16-11). The suture is then brought out through the anterior portal using a grasper and the process is repeated for the second suture. Finally, the free limbs of the suture are transferred from the anterolateral portal to the anterior portal, where all four strands of suture from a single anchor are placed on a hemostat. When using this technique, suture tying must be delayed until all sutures are passed because tying sutures early impedes the ability to pass the device under the torn edge of the rotator cuff to pass subsequent sutures. Multiple anchors can be placed by repeating the same technique. Finally, sutures are tied in a posterior to anterior direction through the lateral portal to minimize suture tangling.

U-Shaped Tears
U-shaped tears occur as tears become larger and retract further medially (see Fig. 16-7B). The hallmark of a U-shaped tear is the inability to reduce these tears to
the tuberosity without undue tension on the repair. Anterior to posterior mobility in these tears is commonly maintained. These tears are initially managed with a margin convergence technique using side-to-side sutures (Fig. 16-12). Placement of these sutures causes the free margin of the torn cuff to converge laterally toward the tuberosity insertion site, allowing eventual repair of the tendon to bone while minimizing tension on the repair site (Fig. 16-13).

Side-to-side sutures can be placed using direct antegrade passing or a hand-off technique. In direct antegrade passing, a penetrator device is loaded with a suitable nonabsorbable suture. While viewing from the lateral portal, the penetrator is placed through the posterior portal and penetrates the posterior leaf of the tear, followed by the anterior leaf of the tear. A suture retriever is then used through the accessory anterolateral portal to retrieve the suture from the anterior leaf. The penetrator is removed and the suture retriever is again used from the anterolateral portal to retrieve the suture from the posterior leaf. The suture can then be tied from the anterolateral portal, reducing the anterior and posterior leaves of the tear. Additional sutures can be placed laterally as needed.

Using the hand-off technique, the scope is again placed in the direct lateral portal. A penetrator is loaded with suture and placed through the posterior portal and then through the posterior leaf of the tear. A second free penetrator is then placed through the anterior portal and pierces the anterior leaf of the tear. The suture is handed off from the posterior to the anterior penetrator and brought out through the anterior portal. A suture retriever is used to retrieve the posterior and anterior ends of the suture out through the anterolateral portal, where it can be tied.

Once all side-to-side sutures have been placed, the tear can be repaired primarily using the technique described for crescentic tears. It may be helpful to place the sutures from the anchors medially to the side-to-side

Figure 16-11. Direct suture-passing device used to pass a loop of suture in an antegrade fashion from the direct lateral portal. A grasper seen in the background is then used to retrieve the loop through the anterior portal.

Figure 16-12. Diagrammatic representation of techniques used to place margin convergence sutures during repair of U-shaped tears.
sutures. This results in a Mac stitch configuration, which has been shown to improve strength at the suture-tissue interface.\textsuperscript{7}

L-Shaped Tears

L-shaped tears occur when the rotator cuff tears off the tuberosity with extension of the tear along the anterior rotator interval (see Fig. 16-7C). Less commonly, the tear may have an extension posteriorly in the interval between the supraspinatus and infraspinatus. Tears with anterior extension result in retraction of the torn tendon in a posterior and medial direction. The important step in repairing these tears is to reduce the corner of the tear initially, bringing it anteriorly and laterally so that the anterior and posterior leaves of the tear are aligned. Once this has been completed, the intertendinous split can be repaired in a side-to-side fashion, converting the tear into a crescentic pattern, which can be repaired to the tuberosity as described earlier. As these tears become chronic, they assume a more U-shaped configuration. In these cases, it is important to identify the tears as an L-shaped pattern by identifying which leaf, anterior or posterior, is more mobile and easily reduced.

The first step in the repair of these tears is to reduce the more mobile leaf of the tear to the opposite side, thus reducing the tendon and creating a crescentic tear. This can be done by placing a suture anchor and reducing the corner of the tear, or by placing side-to-side sutures along the longitudinal split. Our preference is to place the initial anchor at the corner of the L portion of the tear to reduce the tendon anatomically. Once this anchor has been placed, we use penetrators through the anterior and posterior portals to place one limb of each suture through one leaf of the tear, and then the second limb through the opposite leaf of the tear. This creates a horizontal mattress to secure the tendon to bone and reduce the anterior and posterior leaves together. These sutures may be tied immediately, although this may complicate subsequent suture passage. If this is done, sutures or a stay stitch may be used for provisional reduction while the remaining sutures are passed to ensure that anchor sutures are passed through the appropriate location in the tendon.

Next, additional side-to-side sutures are placed along the longitudinal split as necessary to complete this portion of the repair. Once completed, the tear now assumes a crescentic pattern. Additional sutures anchors are then used in the greater tuberosity to complete the repair in standard fashion.

POSTOPERATIVE REHABILITATION

In general, rehabilitation after arthroscopic rotator cuff repair can be divided into three phases focusing on restoration of passive motion, restoration of active motion and, finally, strengthening of the shoulder (Appendix 16-1). However, the rehabilitation program for a rotator cuff tear should not be a standard protocol, but should be customized based on factors such as patient age, tear size, tissue quality, and security of repair. Any concomitant procedures performed may also need to be considered.

In the initial phase, restoration of passive motion and prevention of stiffness constitute the primary goals. Although it has been documented that early active range of motion will help restore normal shoulder kinematics, it is...
important to take the risk of compromising the surgical repair into consideration. The patient is maintained immobilized in a sling with a small abduction pillow for the initial 6 weeks. Passive motion is initiated after the first postoperative visit; this includes Codman's exercises, external rotation at the side, and forward elevation in the scapular plane. These exercises should be performed with the patient supine, the arm at the side, and the elbow bent. This reduces the forces across the shoulder and decreases the effect of gravity by shortening the lever arm of the upper extremity.

Pain is one of the key elements in deterring the restoration of motion. Therefore, it is important to provide pain relief during the rehabilitation phase of treatment. This can include rest, medications, avoidance of painful movements, cryotherapy, ultrasound, and galvanic stimulation. Once the pain and discomfort are controlled, motion exercises can be initiated.

At 6 weeks postoperatively, immobilization is discontinued and active range of motion is allowed. During this phase, the emphasis is on restoring symmetrical passive range of motion and progressing to normal active range of motion. Significant strengthening is avoided until 12 weeks postoperatively. Light rotator cuff, deltoid, and scapular isometrics can be initiated at 8 weeks postoperatively. Furthermore, it is important to initiate the strengthening of scapular stabilizers and other endurance exercises for the entire body early.

With progressive recovery, more aggressive measures can be taken for strengthening the injured shoulder. At 12 weeks after surgery, we initiate aggressive strengthening of the shoulder, beginning with isometrics and progressing to Thera-Bands (Hygenic Corporation, Akron, Ohio), and finally light weights. Strength training should be restricted to three times weekly to minimize pain and aggravation of the repair site. Internal and external rotation exercises should be performed in the scapular plane because they put minimal stress on the joint capsule.

The most functional open-chain exercises are plyometrics activities. They help the muscle recover its strength and power. The muscle is initially stretched eccentrically and then slowly loaded. Examples of plyometrics exercises include the use of Thera-Bands, medicine balls, and free weights.

Sports-related rehabilitation is initiated at 5 months postoperatively. Throwing is delayed until 6 months postoperatively, with throwing from a mound delayed until about 9 months. We allow a return to contact sports at 9 months. Patients should expect maximal improvement to occur at about 12 months postoperatively.

It is important to stress that the biology of repair of rotator cuff muscles is the same regardless of the method used (open versus arthroscopic). The most noticeable difference between open and arthroscopic repairs of the rotator cuff is the amount of discomfort experienced early by the arthroscopic patients. Less pain early enables patients to tolerate their range-of-motion exercises more readily. However, it is important not to accelerate the rehabilitation of arthroscopic patients because of their comfort levels. In all cases, the biology of repair has to be given time to work.

RESULTS AND OUTCOMES

When evaluating the results of arthroscopic rotator cuff repairs, important factors include pain relief and clinically based scoring scales, recovery of objective strength measures, and radiographic evaluation of tendon healing. Although many studies have reported excellent clinical results, there are only limited data on objective tendon healing, which we think is the most important factor in predicting strength recovery. Finally, most series involve primarily older patients. We are not aware of any specific studies on the outcome of rotator cuff repair in competitive athletes.

Several studies have reported favorable clinical results after arthroscopic rotator cuff repairs. Bennett has reported the results of arthroscopic repairs of 24 small to medium-sized tears. Overall, 100% of patients were satisfied with their outcome and all had significant improvements in terms of pain relief and function. Burkhart and associates have reported the results of 59 rotator cuff tears repaired arthroscopically. The patients had 95% good to excellent results, and results were independent of the size of the tear and whether margin convergence sutures were used. Moreover, the delay from injury to surgery did not adversely affect surgical outcome. A large retrospective study by Wolf and coworkers has reviewed the results of % rotator cuff arthroscopic repairs after 4 to 10 years. Of the patients available for re-evaluation, 94% had good to excellent results using the UCLA shoulder rating scale. Gartsman and colleagues have followed 73 patients for a minimum of 2 years who were treated arthroscopically for full-thickness rotator cuff tears. Of their patients, 84% rated their results as good or excellent. Significant improvement was seen in range of motion, strength, and in the results of the SF-36 short-form health survey.

These studies involved the general population. Because rotator cuff tears are rarely seen in younger athletes, few studies have focused on this population and the ability of those patients to return to their sporting activities. Sonnery-Cottet and colleagues followed 51 middle-aged tennis players with rotator cuff tears for 57 months, with the following results: 42 patients underwent open repair and 9 patients underwent arthroscopic débridement, and 80% of patients were able to return to playing tennis with no difference between the open and arthroscopic groups.
More recently, some studies have reported the extent of tendon healing after arthroscopic rotator cuff repairs. Boileau and associates\textsuperscript{14} followed 65 patients with full-thickness rotator cuff tears treated arthroscopically for an average of 29 months. Computed tomography (CT) arthrography and magnetic resonance imaging (MRI) were used to assess the extent of tendon healing. Of these patients, 71% completely healed radiographically and the remainder did not, but showed a smaller defect size. Overall, 93% of patients were satisfied with their surgery, regardless of their tendon healing. However, those patients who had radiographic evidence of healing had better forward elevation strength. Another unpublished study by Verma and coworkers used ultrasound to check the integrity of arthroscopic and mini-open rotator cuff repairs (personal communication). The patients were followed for a minimum of 2 years. Using ultrasound, the failure rate of the mini-open group was 24% and that of the arthroscopic group was 25%. Smaller tears had a lower rate of failure, 17% in the mini-open and 19% in the arthroscopic group. Wilson and associates\textsuperscript{15} used second-look arthroscopy to evaluate the healing of 33 patients with rotator cuff repairs. The rotator cuff healed completely in 67% of patients.

Future directions of arthroscopic rotator cuff repair are focused on improving the rates of tendon healing. Promising techniques include double-row fixation, which can increase the repair footprint and may improve the chances of healing.\textsuperscript{18} In most cases, however, failure of healing is likely the result of a biologic failure rather than failure of fixation. Therefore, the application of select biologic stimulators of soft tissue healing, such as growth factors, will likely play an important role in the future of rotator cuff repair surgery.

References
**APPENDIX 16-1 Rehabilitation After Arthroscopic Rotator Cuff Repair**

**Phase I (weeks 0-6)**

1. Restrictions
   a. No active or active-assisted range of motion
      i. Small tears (0-1 cm): No active forward flexion for 6 weeks
      ii. Medium tears (1-3 cm): No active range of motion for 6 weeks
      iii. Large tears (3-5 cm): No active range of motion for 8 weeks
      iv. Massive tears (>5 cm): No active range of motion for 12 weeks
   b. Passive range-of-motion exercises allowed
      i. 140 degrees of forward flexion
      ii. 40 degrees of external rotation
      iii. 60 degrees of abduction
   c. No strengthening until 12 weeks after surgery
      i. In young healthy patients with small acute tears, isometric exercises can be initiated at 8 weeks.

2. Immobilization
   a. Amount of abduction depends on tear and what is required to keep tension on repair at a minimum
      i. Sling only (if there is minimal tension on repair)
         1. Small tears: 1-3 weeks
         2. Medium tears: 3-6 weeks
         3. Large or massive tears: 6-8 weeks
      ii. Abduction pillow (tension minimized with arm at 20-40 degrees of abduction)
         1. Small tears: 6 weeks
         2. Medium tears: 6 weeks
         3. Large tears: 8 weeks

3. Pain control
   a. Medications
      i. Narcotics for 7-10 days after surgery
      ii. Nonsteroidal anti-inflammatory drugs (NSAIDs) for patients with discomfort beyond first 10 days
   b. Therapeutic modalities
      i. Moist heat before therapy, ice after therapy
      ii. Ultrasound
      iii. Galvanic stimulation

4. Motion—shoulder
   a. Passive only
      i. 140 degrees of forward flexion
      ii. 40 degrees of external rotation
      iii. 60 degrees of abduction
   b. Codman’s pendulum exercises to promote early motion

5. Motion—elbow
   a. Passive and active flexion and extension
   b. Passive and active supination and pronation

6. Muscle strengthening
   a. Grip strengthening only

7. Progress to phase II if:
   a. 6 weeks of recovery
   b. Painless passive range of motion to:
      i. 140 degrees of forward flexion
      ii. 40 degrees of external rotation
      iii. 60 degrees of abduction

**Phase II (weeks 6-12)**

1. Restrictions
   a. No strengthening or resisted range of motion until 12 weeks after surgery
   b. No active range of motion for massive tears

2. Immobilization
   a. Discontinue sling or abduction pillow
   b. Use for comfort only

3. Pain control
   a. NSAIDs
   b. Therapeutic modalities

4. Motion—shoulder
   a. Goals
      i. 140-160 degrees of forward flexion
      ii. 40-60 degrees of external rotation
      iii. 60-90 degrees of abduction
   b. Exercises
      i. Continue with passive range of motion
      ii. Begin active-assisted range of motion
      iii. Progress to active range of motion
      iv. Light passive stretching at the end ranges of motion

5. Muscle strengthening
   a. Only for small nondisplaced tears
      i. Can advance to light Thera-Band for internal and external rotation
      ii. Can begin scapular stabilizers
6. Progress to phase III if:
   a. Painless active range of motion
   b. No shoulder pain

**Phase III (months 3-6)**

1. Goals
   a. Improve shoulder strength, power, and endurance
   b. Improve shoulder proprioception
   c. Establish a home maintenance program performed three times/week
   d. Stretching exercises daily
2. Motion
   a. Achieve motion equal to contralateral side
   b. Passive capsular stretching at end ranges of motion, including cross-body adduction and internal rotation to stretch posterior capsule
3. Strengthening
   a. Begin with closed-chain isometric exercises
      i. Internal rotation
      ii. External rotation
      iii. Abduction
      iv. Forward flexion
      v. Extension
   b. Progress to open-chain exercises with Thera-Bands
      i. Exercises with elbow bent to 90 degrees
      ii. Start with shoulder at 0 degrees of forward flexion, abduction, and external rotation
      iii. Arc of 45 degrees in each of five planes of motion
   iv. Progress through six color-coded bands
   v. Progression to next level band occurs at 2- to 3-week intervals
   vi. Thera-Bands permit isotonic eccentric and concentric shoulder strengthening
   vii. Progress to isotonic dumbbell exercises in all five planes
   c. Strengthening of deltoid (especially anterior)
   d. Strengthening of scapular stabilizers
      i. Closed-chain
         1. Scapular retraction (rhomboids, middle trapezius)
         2. Scapular protraction (serratus anterior)
      3. Scapular depression (latissimus dorsi, trapezius, serratus)
      4. Shoulder shrugs (trapezius, levator scapulae)
      ii. Progress to open-chain
4. Functional strengthening
   a. Begin after 70% of strength recovered
   b. Plyometrics
5. Return to sport
   a. Sport-specific exercises (e.g., throwing, golfing, tennis)
6. Maximum improvement
   a. Small tears (4-6 months)
   b. Medium tears (6-8 months)
   c. Large tears (8-12 months)
   d. Patients will continue to show improvements in function for at least 1 year.