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Management of the Throwing Shoulder: Cuff, Labrum and Internal Impingement

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KEYWORDS

- Shoulder • Throwing-related injury
- Glenohumeral ligament • Cuff impingement
- Labrum impingement • Internal impingement

Repetitive throwing places the shoulder in extreme positions in combination with tremendous stresses. In fact, professional pitchers generate up to 92 N·m of humeral rotation torque, greater than the torsional failure limit in human cadaveric shoulders.¹ Throwers are therefore constantly at risk for injury.

Preventing injury begins with maintenance of the “kinetic chain” that coordinates transmission of force from the legs and trunk to the upper extremity. Studies show that muscle imbalances in the “kinetic chain” are common in shoulder impingement,^{2–4} rotator cuff tears,^{4,5} and instability.^{5,6} One study reported that throwers with labral tears commonly have back inflexibility, infraspinatus and teres minor weakness, and core weakness.⁷ Injuries to the foot and ankle, tightness of the muscles crossing the hip and knee, weakness of hip abductors and trunk stabilizers, and conditions altering spine alignment influence kinetic chain transmission.

Kinetic chain abnormalities can cause the shoulder to assume a hyperabducted, externally rotated position that moves the arm out of the “safe zone” of glenohumeral angulation described by Pink and Perry.⁸ Violent acceleration from hyperabduction increases compressive and shear forces on the glenoid, capsulolabral complex, and rotator cuff. This motion can injure the

posterior capsule, damage and peel the labrum off the glenoid, tear and delaminate the rotator cuff, and tear and stretch the anterior restraints.

The phases of the baseball pitch have been extensively studied (**Fig. 1**). During wind-up, hip stability allows proper balance in preparation for the early cocking, when the hips drive toward home plate. Early cocking ends as the lead foot lands and decelerates the driving lower extremity and trunk. Flaws during this stage include opening up, or abduction of the lead leg, causing poor pelvis rotation with consequent loss of velocity and increased anterior shoulder strain.^{9,10} Most injured pitchers experience pain during the late cocking phase, when the throwing humerus externally rotates from roughly 45° to 170°. During this time, the periscapular muscles, including the trapezius, rhomboids, levator scapula, and serratus anterior, stabilize the scapula, which functions as a fulcrum for energy transfer from the lower extremity and trunk to the humerus.

Periscapular muscle weakness also contributes to shoulder injury.¹¹ To compensate for diminished serratus anterior strength, the thrower may drop the elbow, thus decreasing the degree of scapular rotation and elevation needed. If the pathologic process continues, the player may attempt to compensate further by moving the humerus behind the scapular plane worsening

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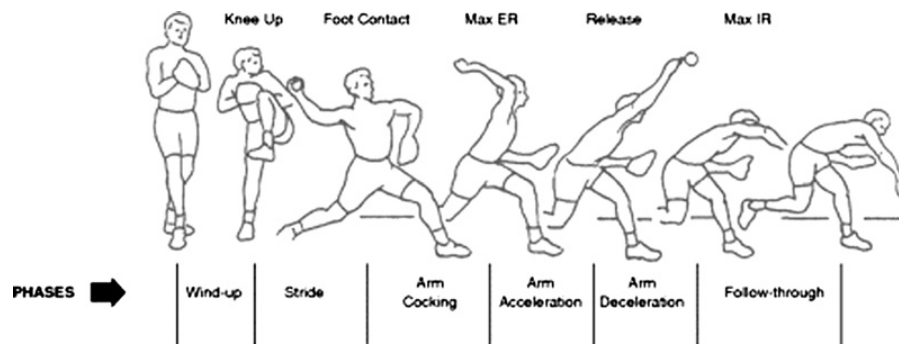


Fig. 1. The baseball pitch has been divided into six phases: wind-up, early cocking, late cocking, acceleration, deceleration, and follow-through. (From DiGiovine NM, Jobe FW, Pink M, et al. An electromyographic analysis of the upper extremity in pitching. *J Shoulder Elbow Surg* 1992;1(1):16; with permission.)

hyperabduction. Eccentric contraction of the subscapularis muscle then decelerates the externally rotating humerus, preparing it for acceleration.

In acceleration, the humerus reaches maximal external rotation and the lower extremity and trunk energy is transferred through the shoulder to the elbow and wrist as the body falls forward. Just before ball release, the arm internally rotates 80°, reaching peak angular velocities near 7000° per second. Within 0.05 seconds, the ball is released with speeds exceeding 90 mph.¹² If the thrower opens up too quickly, positioning the elbow behind the plane of the scapula, the glenohumeral joint hyperangulates, resulting in more pronounced internal impingement.

In deceleration and follow-through in a right-hander, the ball is released and the right hip rises up and over the left leg. During this phase, the teres minor, infraspinatus, and scapular rotator muscles eccentrically contract, dissipating unused kinetic energy. The glenohumeral distraction force absorbed by the capsule and posterior rotator cuff reaches 1 to 1.5 times the thrower's body weight.¹³ Eccentric contraction by the scapular rotators continue to decelerate the arm, and the posterior capsule experiences tension as the arm adducts.

ASYMPTOMATIC THROWING SHOULDER ADAPTATION

Overall Motion

The dominant shoulder of a thrower exhibits increased external rotation and diminished internal rotation compared with the contralateral arm.^{14–21} In asymptomatic throwers, the total arc of shoulder motion is maintained but shifted by 10° into external rotation.^{22–24}

Adaptations in bone and soft tissue are responsible for increased external rotation. Crockett and colleagues²⁵ showed that professional pitchers show 17° greater humeral retroversion in their throwing shoulder compared with their

nondominant shoulder. During development, humeral retroversion decreases from 78° to 30°, and repetitive throwing during growth is hypothesized to restrict this physiologic derotation.^{26–29} Soft tissue adaptations also occur. The anterior capsule and glenohumeral ligaments become lax, whereas the posterior capsule and glenohumeral ligaments stiffen. Repetitive microtrauma to the anterior capsule, particularly during the cocking phase of throwing, leads to anterior laxity and more external rotation.^{16–18}

Injury Patterns

The typical motions and forces around the glenohumeral joint during throwing lead to predictable injury patterns. Superior labral tears are frequent and commonly extend into the posterosuperior labrum. The posterior supraspinatus and anterior infraspinatus are usually partially torn with occasional intratendinous delamination. Andrews and colleagues³⁰ noted that labral tears were present in 100% of 36 competitive athletes with articular-sided partial-thickness rotator cuff tears, of whom 64% were baseball pitchers. In addition, the anterior capsule may become pathologically lax and the posterior capsule pathologically contracted.

Although the injury patterns are consistent, the exact mechanism is debated. Andrews and colleagues³⁰ originally theorized that articular-sided tears resulted from repetitive large eccentric forces to the supraspinatus and infraspinatus tendons during the deceleration phase of throwing. Davidson and colleagues³¹ hypothesized that repetitive contact between the articular side of the rotator cuff and the posterosuperior glenoid in late cocking caused tears. This pathology is aggravated by anterior subluxation and instability, particularly when dynamic stabilizers fatigue. Burkhart and colleagues³² proposed that the primary cause of rotator cuff and labral lesions was posterior capsular contracture,

leading to posterosuperior migration of the humeral head. This article describes the leading theories.

Internal impingement theory

Walch and colleagues³³ initially described internal impingement as occurring in the 90° abducted and 90° externally rotated position. In this position, the posterosuperior rotator cuff contacts the posterosuperior glenoid labrum and can be pinched between the labrum and greater tuberosity (Fig. 2). Although physiologic in a static position, forceful and repeated contact of the undersurface of the rotator cuff and the superior labrum during overhead activity can explain the development of partial-thickness rotator cuff tears and superior labrum anterior posterior (SLAP) lesions,^{17,31,33–35} which commonly coexist in throwers. In addition, kinetic chain abnormalities previously described can exacerbate this process when throwers compensate for poor mechanics through “opening up” or hyperangulating the arm.

Posterior capsular contracture theory

Burkhart and colleagues³⁶ proposed posterior capsular contracture as a consequence of throwing. They reasoned that the posterior capsule must withstand tensile forces of up to 750 N during the deceleration and follow-through phases of throwing. These posterior tensile forces are resisted by both the eccentric contraction of the rotator cuff, primarily the infraspinatus, and the posteroinferior capsule (posterior band of the inferior glenohumeral ligament [IGHL]). With repetitive infraspinatus eccentric contraction, the muscle and the posteroinferior capsule become

hypertrophied and stiff. The posterior contracture shifts the center of rotation of the shoulder to a more posterosuperior location, creating posterosuperior instability with shoulder in abduction and external rotation, which has been supported by biomechanical cadaver research.³⁷ The humeral head can consequently externally hyperrotate, producing increased shear in the rotator cuff tendon and more pronounced internal impingement. In addition, a peel-back phenomenon occurring during late cocking, consisting of a torsional force applied to the biceps anchor, contributes to SLAP lesion development.³⁸

Scapulothoracic function

The scapula plays a critical role in energy transfer from the trunk to the humerus. In the asymptomatic thrower, adaptive scapulothoracic changes leading to scapular asymmetry have been described.^{21,39–42} Altered static and dynamic scapular mechanics arise from overuse and weakness of scapular stabilizers and posterior rotator cuff muscles.¹³ With the arm hanging at the side, the throwing shoulder's scapula has increased upward rotation (abduction), internal rotation (protraction), antetilt in the sagittal plane and inferior translation. During cocking, when the humerus is terminally externally rotated and abducted, upward scapular rotation helps maintain glenohumeral articular congruency.⁴² Weakness, inflexibility, or imbalance of the periscapular and posterior rotator cuff muscles disturb the normal anatomic static and dynamic relationships of the scapula. Aberrant scapulothoracic motion has been called *scapular dyskinesis*.^{39,43} The abnormally positioned thrower's scapula has been labeled SICK (scapular malposition, inferior medial border prominence, coracoid pain, and dyskinesia of scapular movement) scapula by Burkhart and colleagues.⁴⁴

The SICK scapula predisposes the shoulder to labral and rotator cuff tears because the scapula sits in a protracted and upwardly tilted position, causing the glenoid to face anterior and superior. This position leads to three developments: anterior tension, posterior compression, and increased glenohumeral angulation. First, with glenoid protraction, the anterior band of the IGHL tightens, limiting anterior translation of the humeral head and, over time, becoming susceptible to chronic strain.⁶ Second, simultaneously, the posterior edge of the glenoid is brought toward the humerus, placing the posterosuperior labrum and rotator cuff at risk for injury. Finally, excessive protraction increases glenohumeral angulation. The thrower with increased glenohumeral angulation will find that the “arm lags behind the body.” Excessive

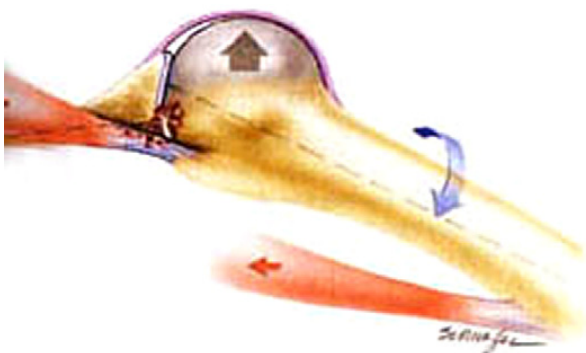


Fig. 2. Internal impingement results in the 90° abducted, 90° externally rotated position when the posterosuperior rotator cuff presses against the posterosuperior glenoid labrum. (From Jobe CM, Pink M, Jobe FW, et al. Anterior shoulder instability, impingement, and rotator cuff tear. In: Jobe FW, Pink MM, Glousman RE, et al, editors. Operative techniques in upper extremity sports injuries. St Louis (MO): Mosby; 1996. p. 170 with permission.)

external rotation in this setting has two harmful consequences. One, it exacerbates the aforementioned biceps peel back effect.⁴⁴ Two, with preexisting scapular protraction, external rotation and abduction produce posterosuperior glenoid impingement.^{39,40}

A cascade of pathologic entities explain injuries associated with the SICK scapula: coracoid pain from pectoralis minor contracture and tendinopathy, superior medial angle scapular pain from levator scapula insertional tendinopathy, subacromial origin pain from acromial malposition and decreased subacromial space from upward tilting, acromioclavicular joint pain caused by anterior joint incongruity, sternoclavicular pain, thoracic outlet syndrome radicular pain, and subclavian vascular problems such as arterial pseudoaneurysm or venous thrombosis.¹³

In summary, anterior instability, posterior capsular contracture, and internal impingement in throwers are influenced by alterations in the kinetic chain and scapulothoracic thoracic function. Shoulder pathology should be viewed as a syndrome because the injury cascade is a continuum of interrelated pathomechanics. Although when viewed independently some of the current popular theories on the cause of specific throwing-related shoulder injuries may conflict, they complement each other when they are considered elements of a pathologic continuum.

EVALUATION OF THE OVERHEAD ATHLETE

History

A wide variety of disorders may present in the thrower, including those that affect the kinetic chain such as the hip, core, and low back. The goal should be to accurately diagnose and efficiently direct treatment. Initial symptoms may be vague, such as loss of control, velocity, or difficulty warming up. Typical shoulder-related symptoms include anterosuperior or posterosuperior shoulder pain in the late cocking phase. Popping, locking, and snapping may occur with unstable labral tears. Instability symptoms may be related to rotator cuff dysfunction and excessive anterior capsular laxity.

Physical Examination

A systematic physical examination should be performed to assess the knee, hip, and low back. Functional movement may be assessed with single leg squats for hip and trunk control, muscle imbalance, and inflexibilities.

Muscular atrophy and scapular winging should be noted. Tenderness should be assessed at

glenohumeral joint lines, the acromioclavicular joint, the long head of the biceps tendon, and the coracoid process. Tenderness over the long head of the biceps tendon suggests tendonitis or a SLAP tear. Coracoid process tenderness suggests pectoralis minor tendonitis or tightness, which has been correlated with scapular protraction and dyskinesis.⁴⁴

Active and passive range of motion of the glenohumeral and scapulothoracic joints are measured. Forward elevation in the plane of the scapula, external rotation, and internal rotation (in 0° of abduction, this is the highest spinal level the patient can reach with thumb behind the back) in both 0° and 90° of abduction should be documented. Kibler³⁹ measured scapular asymmetry through comparing the distance from the inferior angle of the scapula to the spinous process of the thoracic vertebra in the same horizontal plane (the reference vertebra) in three test positions. In position one, the arm is at the side. In position two, the humerus is internally rotated and abducted 45°, as the hands are placed on the hips. In position three, the shoulder is abducted further to 90°. An asymmetrical difference of greater than 1.5 cm determines a positive lateral scapular slide test (LSST).³⁹

With the scapular assistance test, scapular upward rotation is assisted through manually stabilizing the upper medial scapular border and rotating the inferomedial border as the arm is abducted. A positive test will relieve symptoms of impingement, clicking, or rotator cuff weakness present without the manual assistance. The scapular retraction test is performed through manually stabilizing the medial border of the scapula. When manual stabilization increases strength in patients with apparent rotator cuff weakness and a protracted scapula, scapular dyskinesis is present.

Manual muscle strength testing should aim to isolate the muscle being tested and compare the injured with the contralateral, uninjured side. The supraspinatus can be isolated in the “empty can” position. The subscapularis is best assessed using the “lift off” test,⁴⁵ or the internal rotation lag sign, which is more sensitive.⁴⁶

A proper examination assesses range of motion of both shoulders in both adduction and 90° of abduction. An overhead athlete will typically have reduced internal rotation and increased external rotation. The Jobe's relocation test is also a provocative maneuver that reproduces the symptoms of internal impingement. In this test, the patient is supine and the arm is placed into 90° of abduction and 10° of forward flexion, and the shoulder is forced anteriorly. Pain represents

a positive test. Pain subsequently subsides with a posteriorly directed force.¹⁷

Many tests have been described to assist in diagnosing SLAP lesions. The active compression test has good sensitivity and specificity for type II SLAP lesions.⁴⁷ The arm is positioned in 15° of adduction and 90° of forward elevation. The examiner applies downward force on the forearm while the hand is both pronated and supinated, and compares the resulting pain and weakness. A positive test occurs when the patient reports pain that is worse in the pronated position. The compression–rotation test is similar to McMurray's test of the knee.⁴⁸ It is performed through compressing the glenohumeral joint and then rotating the humerus in an attempt to trap the labrum in the joint. This test should be performed in the supine position, so that the patient is more relaxed.

Speed's biceps tension test is also sensitive for SLAP lesions.^{49,50} This test is performed through having the patient resist downward pressure with the arm in 90° of forward elevation, with the elbow extended and the forearm supinated. Although this test is more suggestive of biceps tendon damage, an unstable biceps anchor will cause the test to elicit pain. A positive apprehension relocation sign for posterior shoulder pain may suggest a SLAP lesion in the posterior labrum as part of a spectrum of internal impingement.

Many other tests have been described, but the authors have found them to be less useful.^{51–53} Finally, external impingement should be assessed with impingement tests such as the Neer and Hawkins tests.

Imaging

Radiographic evaluation includes the standard three views of the shoulder (anteroposterior, axillary, and outlet views) to help exclude other bony abnormalities. MRI-enhanced arthrography outperforms plain MRI when diagnosing SLAP lesions with sensitivity of 89%, a specificity of 91%, and an accuracy of 90%.⁵⁴ The diagnostic feature of the MR arthrogram is contrast between the superior labrum and the glenoid that extends around and under the biceps anchor on the coronal oblique view (**Fig. 3**). The axial views visualize possible extension into the anterior and or posterior labrum. Partial thickness rotator cuff tears will also be identified (see **Fig. 3**).

Some experts have recommended MRI with the shoulder in both the abducted and adducted and externally rotated position.⁵⁵ These views may further enhance visualization of the articular side of the rotator cuff and superior glenoid, and may



Fig. 3. Coronal oblique image of MRI arthrogram showing a superior labral tear (*white arrow*) with dye tracking into the space between glenoid and labrum, and a partial-thickness rotator cuff tear (*red arrow*). (Courtesy of Columbia University, Department of Orthopaedic Surgery, New York, NY; with permission.)

be helpful in diagnosing delaminating tears of the rotator cuff.⁵⁶ Up to 40% of professional pitchers have completely asymptomatic partial articular-sided supraspinatus tendon avulsion (PASTA) lesions.⁵⁷

MANAGEMENT OF SPECIFIC SHOULDER CONDITIONS IN ATHLETES

Nonoperative Treatment

Nonoperative treatment is directed at all observed pathology, such as correcting lower extremity, hip, core, and low back disorders, in addition to scapular function, restoring shoulder range of motion, strength, and flexibility. Several phases of rehabilitation can be used, progressing from inflammation reduction, to range of motion restoration, muscle strengthening, and soft tissue flexibility, and finishing with proprioception and neuromuscular control and a comprehensive return to throwing program. Although nonoperative treatment strategies have been presented comprehensively in other sources,^{21,58} the following discussion focuses on several important pathologic features.

Correction of pathologic posterior capsular contracture is critical. Nonoperative management has proved successful in the management of glenohumeral internal rotation deficit, reported as greater than 20°. ⁵⁹ Some authors have detailed a series of exercises that, theoretically, improve posterior capsular contracture and fairly reliably decrease glenohumeral internal rotation

deficit.^{21,60} These exercises include “sleeper stretches,” which require athletes to lie on their side with the shoulder in 90° of flexion, in neutral rotation, with the elbow also in 90° of flexion. The shoulder is then passively internally rotated by pushing the forearm toward the table around the fixed point of the elbow.⁴⁴ In the horizontal adduction stretch, the arm is horizontally adducted while the scapula is stabilized. The pectoralis minor should also be stretched, which can be performed by placing a rolled towel between the shoulder blades while the patient is supine, and steadily pushing posteriorly on the shoulders.

Treatment for SICK scapula consists of scapular stabilizer muscular strengthening, and re-education.^{13,44,61–63} The involved side is addressed first, using closed chain exercises followed by open chain exercises. The kinetic chain is incorporated into the rehabilitation. Scapular rehabilitation has been successful in returning patients with SICK scapula to their previous level of competitive play.

For patients with an acute injury, such as a development of a SLAP and or partial thickness rotator cuff tear, initial treatment is directed at eliminating pain, restoring motion, correcting strength deficits, and restoring normal synchronous muscle activity. Initial treatment involves rest from provocative activities, anti-inflammatory medication, and therapeutic modalities. Strengthening is initiated once pain is resolved. For throwing athletes, a gradual return to throwing may begin as muscular balance and range of motion are restored. Failure of a nonoperative program, early suspicion of significant mechanical dysfunction, or seasonal timing may direct treatment toward surgical intervention.

Classic subacromial bursitis symptoms and external impingement may also be present and can be treated with nonsteroidal anti-inflammatory drugs or subacromial corticosteroid injection. Rotator cuff strengthening may proceed only after proper capsular elasticity and scapular dynamics have been restored.

Examination Under Anesthesia and Arthroscopic Evaluation

When the decision is made for surgery, the shoulder should be tested for translation and range of motion under anesthesia because it provides useful laxity measurements. Often, the office examination may be clouded by patient apprehension, muscle tightness, or pain. Examination under anesthesia provides an unobstructed examination and can provide useful preoperative information.

The shoulder should be tested for translation in multiple planes. The arm should be positioned in 90° of abduction and 30° of forward flexion. An axial load should be applied along the humeral shaft, and the humerus is translated in all planes. Translation is graded based on the amount of humeral head translation relative to the glenoid. Grade 1 represents mild translation, grade 2 translates to the glenoid rim, grade 3 translation produces a dislocation that spontaneously reduces, and grade 4 represents translation that results in a fixed dislocation. Range of motion should also be evaluated in all planes, and comparison is ideally made to the contralateral limb.

The diagnosis of SLAP lesions ultimately relies on arthroscopic evaluation.⁶⁴ Types I, III, and IV lesions are obvious when fraying or splitting of the labrum is noted. Viewing the joint from both the anterior and posterior portals is mandatory to entirely assess the degree of involvement. Diagnosis of type II lesions is more difficult. The normal superior labrum often has a small cleft between it and the glenoid, especially in the setting of a meniscoid labrum. The stability of the biceps anchor is determined through probing and attempting to elevate the labrum and biceps. The glenoid articular cartilage usually extends medially over the superior corner of the glenoid. Absence of cartilage in this region indicates labral detachment. Traction on the biceps tendon will show any loss of integrity at the superior labral attachment.

Burkhart and Morgan³⁸ described the arthroscopic examination for peel-back. The arm is placed in a throwing position and, with humeral external rotation, the labrum peels away from the posterosuperior glenoid.

A comprehensive and methodical diagnostic arthroscopy is performed visualizing the entirety of the joint with the assistance of a probe. Typically, two portals are used for the diagnostic arthroscopy: a posterior portal and a rotator interval portal. When planning a SLAP repair, both portals should be made relatively laterally to allow access to the glenoid rim.

Depending on the nature of the expected pathology, the patient is placed into the beach chair position for rotator cuff and external impingement, or the lateral decubitus position for labral tears and capsular laxity. First, the glenoid and humeral head are evaluated for any chondral wear. Next, the biceps is evaluated at its superior attachment and throughout its course in the rotator interval. The probe is used to pull the tendon into the joint and evaluate for synovitis or fraying. Next, the superior and anterior labrum is evaluated from 12 o'clock to 6 o'clock. The

arthroscope is then placed in the axillary pouch and the recess evaluated for hemosiderin deposits, synovitis, or excessive volume. At this time, the posterior labrum can be visualized and probed.

Visualization through the anterior portal improves visualization of the posterior labrum and posterior IGHL, and should be performed when any posterior labral pathology is suspected. The arm may be brought into 90° of abduction and maximal external rotation, with the camera in the posterior viewing portal, and abnormal impingement of the rotator cuff and posterosuperior labrum visualized. Evidence of peel-back may also be seen. Finally, the capsule and anterior glenohumeral ligaments can be fully assessed, and the degree of capsular laxity or tears determined. Finally, the subscapularis tendon is evaluated for its integrity in internal and external rotation.

The rotator cuff should be carefully evaluated. In the thrower, special attention should be given to the undersurface of the rotator cuff at the junction between the supraspinatus and infraspinatus tendons. Tears of the rotator cuff at this location are common and care should be taken to evaluate for intratendinous delamination.

The subacromial space should be entered and examined carefully for bursitis and evidence of external impingement, such as fraying or ossification of the coracromial ligament or inflammation of the bursa. Once a careful examination under anesthesia and an arthroscopic evaluation is performed, the surgeon may proceed with operative fixation of the pathology at hand.

OPERATIVE TREATMENT

Anterior Capsular Laxity with Instability

Nonoperative treatment is usually successful for isolated anterior instability. Surgical intervention is commonly considered after no improvement occurs with nonoperative treatment after 3 months, or the patient fails to return to sport by 6 months. Open capsular procedures have been described that have had reasonable results in throwers but are associated with risk for morbidity to the subscapularis.

Thermal-assisted capsular shrinkage is advocated by some authors for treating arthroscopic microinstability in throwers.^{65,66} However, several studies have reported unpredictable outcomes and this technique is associated with the potential for serious complications, so the authors do not recommend this treatment currently. They prefer to perform arthroscopic capsulorrhaphy. A rasp is used to abrade the capsule to stimulate healing. A curved suture passer is used to penetrate

capsule laterally and then advance the capsule onto the labrum. A nonabsorbable suture is passed and tied with the suture knot away from the glenoid. The plication sutures are repeated as necessary. Care must be taken to avoid over-tightening the capsule. Range of motion should be assessed at the end of the procedure.

Posterior Capsular Contracture

Operative management should only be offered to those for whom aggressive rehabilitation fails to provide relief. For the rare patients for whom nonoperative treatment fails, arthroscopic posteroinferior quadrant capsulotomy is recommended, from 6 o'clock to 3 or 9 o'clock. The capsule should be incised until the muscle belly of the external rotators can be visualized.

Morgan¹³ found an average 62° (55°–68°) increase in internal rotation after the capsulotomy. Yoneda and colleagues⁶⁷ performed posterior capsular releases on 16 patients and reported that 11, including all 4 who had no other concomitant lesions, returned to their preinjury level of performance.

Superior Labrum Anterior Posterior Lesions

Appreciating the normal anatomic variants of the superior labrum and biceps insertion is critical to recognizing abnormal pathology. First, although the labrum located inferior to the glenoid equator is a constant fibrous structure continuous with the articular cartilage, the anterior superior labrum has a high degree of normal variation. Typically, it is either rounded or meniscoid, with the meniscal component overlying but not attached to the glenoid articular surface. Soft tissue variants exist and include a cord-like middle glenohumeral ligament. The Buford complex is a normal variant consisting of a cord-like middle glenohumeral ligament that originates directly from the superior labrum at the base of the biceps tendon. As a result, there is an absence of anterosuperior labral tissue. Inappropriate surgical attachment of the cord-like middle glenohumeral ligament on the anterosuperior glenoid results in painful restriction of external rotation and elevation.

Snyder and colleagues⁶⁸ originally described four types of SLAP lesions. Type I lesions consist of fraying and degeneration of the superior labrum without instability of the long head of biceps attachment. Type II lesions consist of detachment of the biceps tendon anchor from the superior glenoid tubercle. Type III lesions consist of a bucket-handle tear of a meniscoid superior labrum with an intact biceps tendon anchor. Type IV lesions consist of a superior labral tear that extends into

the biceps tendon. Different SLAP types may coexist. Typically, type III or IV lesions will present in conjunction with a significantly detached biceps anchor (type II lesions). If this scenario presents, the lesions are classified as complex SLAP type II and III or type II and IV.

Maffet and colleagues⁶⁹ expanded this classification to include (1) anteroinferior Bankart-type labral lesions in continuity with SLAP lesions, (2) biceps tendon separation with an unstable flap tear of the labrum, and (3) extension of the superior labrum–biceps tendon separation to just beneath the insertion of the middle glenohumeral ligament.

Type I SLAP lesions are treated with debridement alone. Type II SLAP lesions are repaired back to the glenoid rim using suture anchors. In the case of type III SLAP lesions, if the unstable bucket-handle fragment is small, simple resection suffices. If the unstable fragment is large, it should be repaired. Type IV SLAP lesions are treated similarly to type III lesions, and the tendon split is managed with tenotomy, tenodesis, or repair. Biceps tendon management depends on the age and activity level of the patient and the condition of the tendon.

Although labral repairs can be performed in the beach chair or the lateral decubitus position, the authors prefer the lateral decubitus position, with traction to improve visualization and access the posterior labrum. The patient is positioned in 20° of reverse Trendelenberg and tilted slightly posteriorly. Typically, 10 lb of traction are applied to the arm with a modular joint distractor or a hydraulic positioner. Traditionally, three portals are used for labral repair in the lateral decubitus position (Fig. 4). The anterior and posterior portals are made to create an appropriate angle to the face of the glenoid for anchor placement. The transrotator cuff portal is made at the junction between the middle and posterior one third of acromion just off the lateral edge. Diagnostic arthroscopy begins and the superior labrum is probed.

True avulsion of the superior labrum is indicated through fraying and irregularity of the labral undersurface and visible chondromalacia of the normally smooth hyaline cartilage of the underlying superior glenoid rim. Arthroscopic examination should include placing the shoulder in the late-cocking position of throwing and observing the posterosuperior labrum for peel-back. Hypermobility of the posterosuperior labrum and traction of the posterior capsule will cause the biceps labral complex to move medially and off the articular edge of the glenoid. The articular surface of the rotator cuff is also examined in this position for injury.

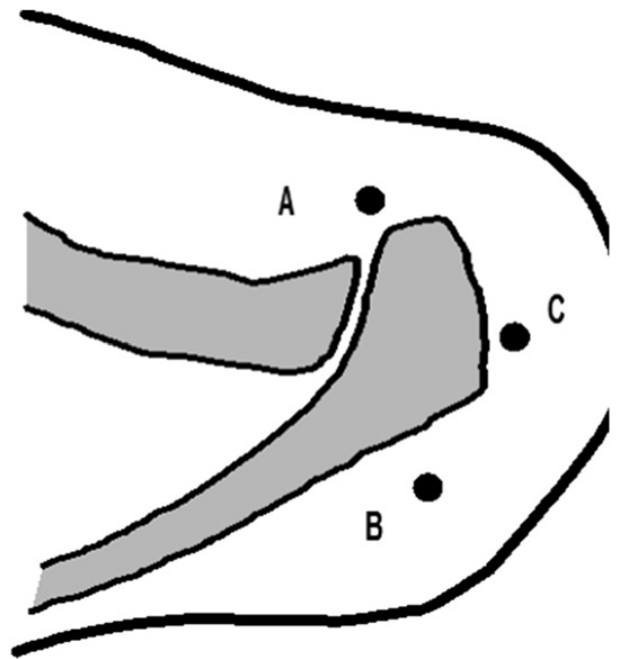


Fig. 4. Location of portals used for labral repair include the (A) anterior and (B) posterior, and (C) the portal of Wilmington. (Courtesy of Columbia University, Department of Orthopaedics, New York, NY; with permission.)

Degenerative tissue is debrided from the labrum, biceps, and articular surface of the rotator cuff. In cases requiring multiple sites of repair, the authors' preferred order of repair is as follows: (1) anterior inferior labrum proceeding superiorly along the anterior glenoid to the glenoid sulcus, (2) posterior inferior labrum proceeding from inferior to superior, (3) anterior superior labrum, and (4) rotator cuff. Care should be taken not to overtighten the joint or constrain the biceps. Significant decrease in rotation can result, precluding return to competitive throwing. Sutures should be placed, including in the labrum and only enough of the capsular reflection necessary for tissue integrity. Likewise, anchors and sutures should not be placed directly at the biceps–labral base so as to preserve maximal biceps excursion with external and internal rotation.

A type II SLAP repair is illustrated in Fig. 5. For a reparable lesion, a motorized shaver is introduced through the anterior working portal and used to prepare the superior neck of the glenoid beneath the detached labrum. The soft tissues are debrided and the bone abraded to enhance healing.

Because SLAP lesions often coexist with partial articular-sided supraspinatus tears and rotator cuff function is critical in throwers, the authors use a percutaneous technique that minimizes morbidity to the supraspinatus. A spinal needle is used to find a position at the desired angle on

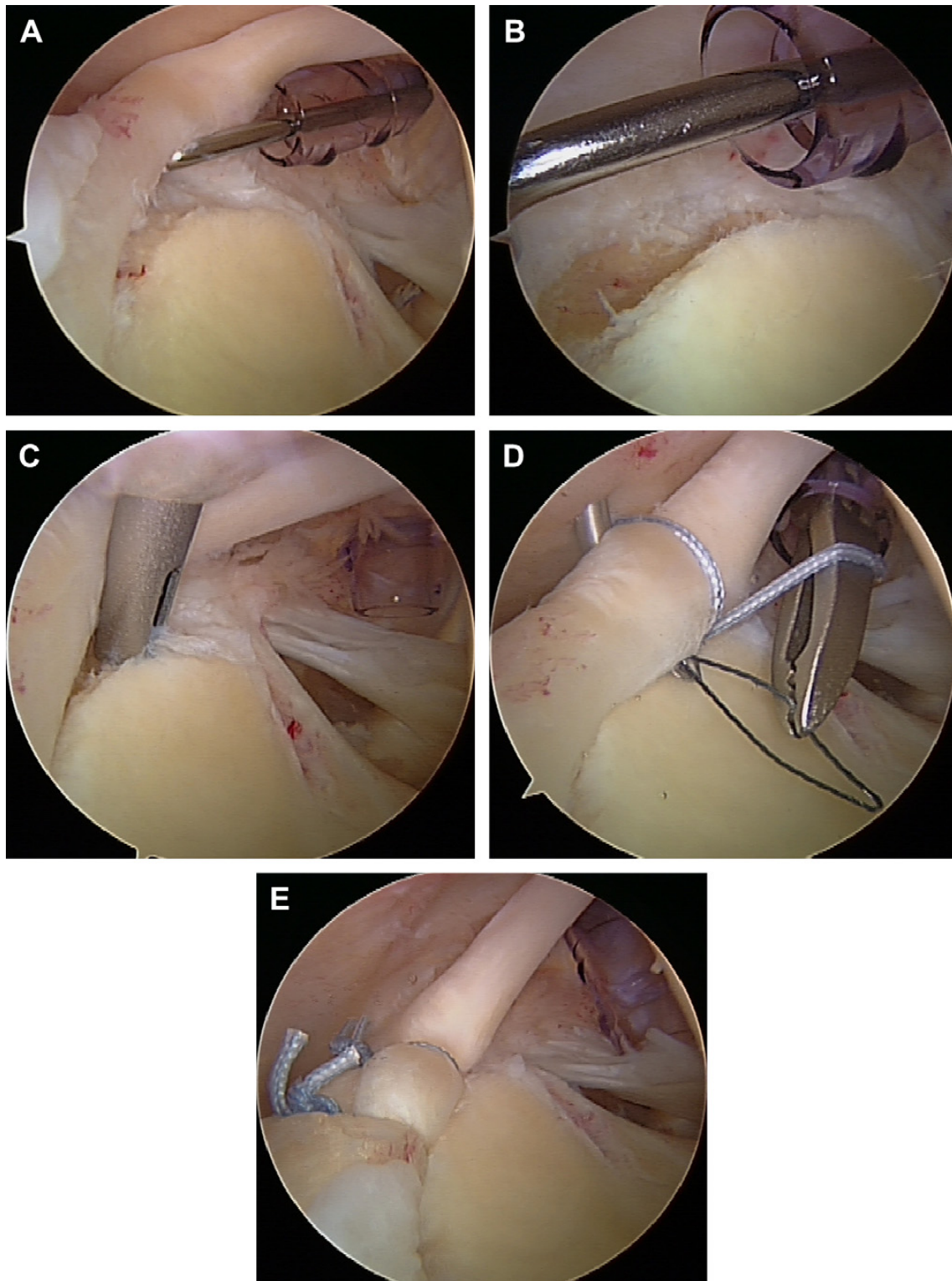


Fig. 5. Author's percutaneous superior labrum anterior posterior (SLAP) repair technique. Arthroscopic view of a right shoulder in the lateral decubitus position. (A) A motorized shaver is introduced through the anterior working portal and used to prepare the superior neck of the glenoid beneath the detached labrum of a type II SLAP tear. (B) The superior labrum is debrided and the bone is abraded to a cancellous surface. (C) Anchor guide in position on the superior aspect of the glenoid. (D) Percutaneous suture passage demonstrated using a suture shuttling device (E) Completed repair demonstrating anatomic restoration of the superior labrum. Note secure fixation with knots medial to the glenohumeral articulation. (Courtesy of Columbia University, Department of Orthopaedics, New York, NY; with permission.)

the glenoid at the location of the Wilmington portal, posterior to the biceps. A small stab incision allows introduction of the drill guide that penetrates the supraspinatus. The anchor is placed and the suture limb that will be passed through the labrum is retrieved through the anterior cannula. A 90° suture lasso (Arthrex, Inc, Naples FL, USA) is inserted percutaneously, through the supraspinatus, and then passed through the labrum. Both suture limbs are then retrieved out the anterior cannula, with the cannula placed posterior to the biceps to facilitate knot tying. In meniscoid-type labrums, sutures may be placed in a vertical fashion to achieve a more anatomic repair. Knot tying is performed with the goal of keeping the knots away from the glenohumeral articulation.

Rehabilitation

Postoperatively, the shoulder is protected in a sling for 3 weeks to avoid undue stress on the biceps tendon. The patient begins elbow, wrist, and hand exercises immediately, and gentle pendulum exercises in 1 week. Strengthening exercises for the rotator cuff, scapular stabilizers, and deltoid are initiated with the goal of restoring full range of motion at 6 weeks. Biceps strengthening is begun 8 weeks postoperatively. Strenuous lifting activities are implemented after 3 months. At 4 months, throwing athletes begin an interval throwing program on a level surface. They continue a stretching and strengthening program, with particular emphasis on posteroinferior capsular stretching. At 6 months, pitchers may begin throwing full-speed, and at 7 months pitchers are allowed to throw from the mound at maximal effort.

Outcomes

For unstable SLAP lesions, simple debridement has yielded poor results.⁷⁰ Surgical repair has achieved improved results as fixation techniques have evolved. Stapling⁷¹ and absorbable tack devices^{72–74} initially were superior to debridement alone, but concerns developed, including synovitis, foreign body reaction, adhesive capsulitis, and breakage of the tack devices.^{72,75,76}

Transglenoid sutures have also been used to repair SLAP lesions with good results but with substantial technical difficulty.⁴⁹ More recently, suture anchors have achieved more reliable results than previous devices.^{77–80} Kim and colleagues⁷⁸ reported 94% satisfactory results after repair with suture anchors in 34 patients with isolated SLAP lesions, with 91% regaining their preinjury level of shoulder function. Similarly, Morgan and colleagues⁷⁹ were able to return 87% of throwing

athletes in their study to preinjury levels of throwing after suture anchor repair.

Conway described results of SLAP repair in nine baseball players. At 1 year, eight were able to return to play at the same or a higher level.⁵⁶ A study by Ide and colleagues with 3-year follow-up showed a 90% return to sports competition after type II SLAP repair in 40 overhead athletes. Within a group of baseball players, 18 of 19 returned to play, but 5 could not return to their previous level of competition.⁸¹

Brockmeier and colleagues⁸² reported on 61 patients with isolated type II SLAP repairs. Of these, 12 of 16 baseball or softball players returned to their previous level of competition. Because of the professional requirements of pitchers, including velocity, control, and endurance, return to play can be challenging.

Partial Articular-sided Supraspinatus Tendon Avulsion Lesion Management

Partial rotator cuff tears can be bursal-sided, intrasubstance, or articular-sided. In athletes, articular-sided tears predominate and have been referred to as PASTA lesions by Snyder.⁸³ Conway⁵⁶ further described (PAINT) in throwers, in whom the tear extends into the middle layers of the infraspinatus tendon. Surgical treatment is reserved for patients for whom nonsurgical management fails. Diagnostic arthroscopy often shows concomitant pathology that may be the primary cause of the patient's symptoms.

Many surgical options exist for managing PASTA lesions, including debridement of rotator cuff tear, subacromial decompression, arthroscopic in situ repair, or completion of the tear followed by open, mini-open, or all arthroscopic repair. Tears are classified according to percent of thickness of tear, number of tendons involved, and whether it involves the bursal or articular side. Weber found that tears greater than 50% of tendon insertion width in a medial to lateral direction did better with repair.⁸⁴ Mazzocca and colleagues⁸⁵ found in a cadaver model that articular-sided partial tears with 50% of depth or greater significantly increased strain in the remaining intact bursal tendon fibers.

Although a consensus has not been established for treatment, the authors' guidelines are consistent with those of others.⁸⁶ The normal footprint of the supraspinatus insertion ranges from approximately 12 to 21 mm in width. Therefore, the percentage that the partial-thickness tear involves can be calculated. If 25% of cuff is torn, rotator cuff debridement and subacromial debridement is performed. If 50% of the cuff is torn, an in situ

all-arthroscopic repair to the footprint is performed without completing the tear. If 75% or greater of cuff is torn, the tear is completed and an all-arthroscopic rotator cuff repair is performed. Bursal-sided tears have superior results when an acromioplasty is concurrently performed. For intratendinous laminar tears, intratendinous repair is performed. In younger throwing athletes, intratendinous repairs are preferable and acromioplasty should be avoided if no bursal-sided damage is present.

The normal bare area that exists between the articular margin and the posterior rotator cuff insertion is important to recognize. In throwing athletes, repairs must be avoided in this area because it makes normal contact with the posterosuperior glenoid. Occasionally, anterior rotator cuff detachments are repaired to bone in the most anterior aspect of the rotator cuff footprint because this area has less normal internal impingement contact in throwing athletes.

Rotator Cuff Repair

Managing rotator cuff tears that have failed nonoperative treatment is a challenge in overhead throwers. For many throwers, rotator cuff footprint contact on the glenoid from internal impingement is expected, and therefore repair into those insertional regions is subject to failure. The various tear types require different repair techniques.

Intratendinous Tears

Tears with intralaminar extension are commonly observed and repair can prevent propagation. An intratendinous repair technique is illustrated in **Fig. 6**. Glenohumeral arthroscopy shows what is typically a frayed and degenerated undersurface of the supraspinatus and infraspinatus. The magnitude and mobility of the lamination is appreciated using a grasper. The inside of the lamination is abraded with a shaver or rasp to enhance healing. If the tear is retracted posteriorly but reduces anatomically when pulled anterior, the sutures are passed first through the posterior aspect and then through the anterior aspect of the lamina.

Before repairing the tear, the subacromial space is inspected and a complete bursectomy is performed to enhance visualization. Mattress sutures are then placed from outside (bursal surface) to inside using a spinal needle and #2 nonabsorbable sutures. The spinal needle is introduced percutaneously just lateral to the acromion to penetrate the intact bursal lamina. The needle is maneuvered to penetrate the articular lamina at the desired location. A monofilament suture is passed through the needle and retrieved out the anterior cannula.

A needle meniscal repair device with a wire shuttle is used to retrieve the suture. Alternatively, another monofilament suture is passed and retrieved out the anterior cannulae and tied to the first. A #2 nonabsorbable suture is then shuttled through the rotator cuff to create a mattress suture. These steps are repeated to create the necessary number of mattress sutures. The camera is then placed in the subacromial space and the sutures tied through a standard lateral working portal. The camera is then placed back in the glenohumeral joint and the repair is evaluated.

Outcomes

Ide and colleagues⁸⁷ presented a transtendinous suture anchor technique in a series of 17 patients, including 6 participating in overhead-throwing sports. They noted excellent outcomes in 16 patients, but only 2 of the 6 overhead-throwing athletes were able to resume sports at their previous level of competition. Conway⁵⁶ used a suture shuttling technique and found that of 14 baseball players (average age, 16 years) treated with repair of intratendinous rotator cuff tears and concurrent pathology (labral tears, SLAP tears), 89% percent were able to return at the same or higher level at 16-month follow-up.

Complete Tears

Near complete tears are treated with tear completion and arthroscopic repair. Complete tears are also treated with repair. The authors prefer double-row transosseous-equivalent repair techniques to create tissue compression against the tuberosity to enhance healing.⁸⁸ These new techniques have also been referred to as suture bridge techniques.

Research studies have shown that transosseous equivalent repair techniques provide improved footprint coverage,⁸⁹ pressurized contact area at the footprint,⁹⁰ and reduced motion at the footprint tendon–bone interface compared with standard double-row fixation.⁹¹ Experts believe that improved contact characteristics will help maximize healing potential between repaired tendons and the greater tuberosity.

Outcomes

Full-thickness tears have a poor prognosis in elite throwers. Mazoué and Andrews⁹² reported the results after a mini-open repair of a full-thickness rotator cuff tear in 16 professional baseball players. Among these patients, 12 were pitchers with injury to their dominant shoulders, 4s were position players, 2 had injuries involving their dominant shoulders, and 2 had injuries to their nondominant shoulders. Only 1 player (8%) with

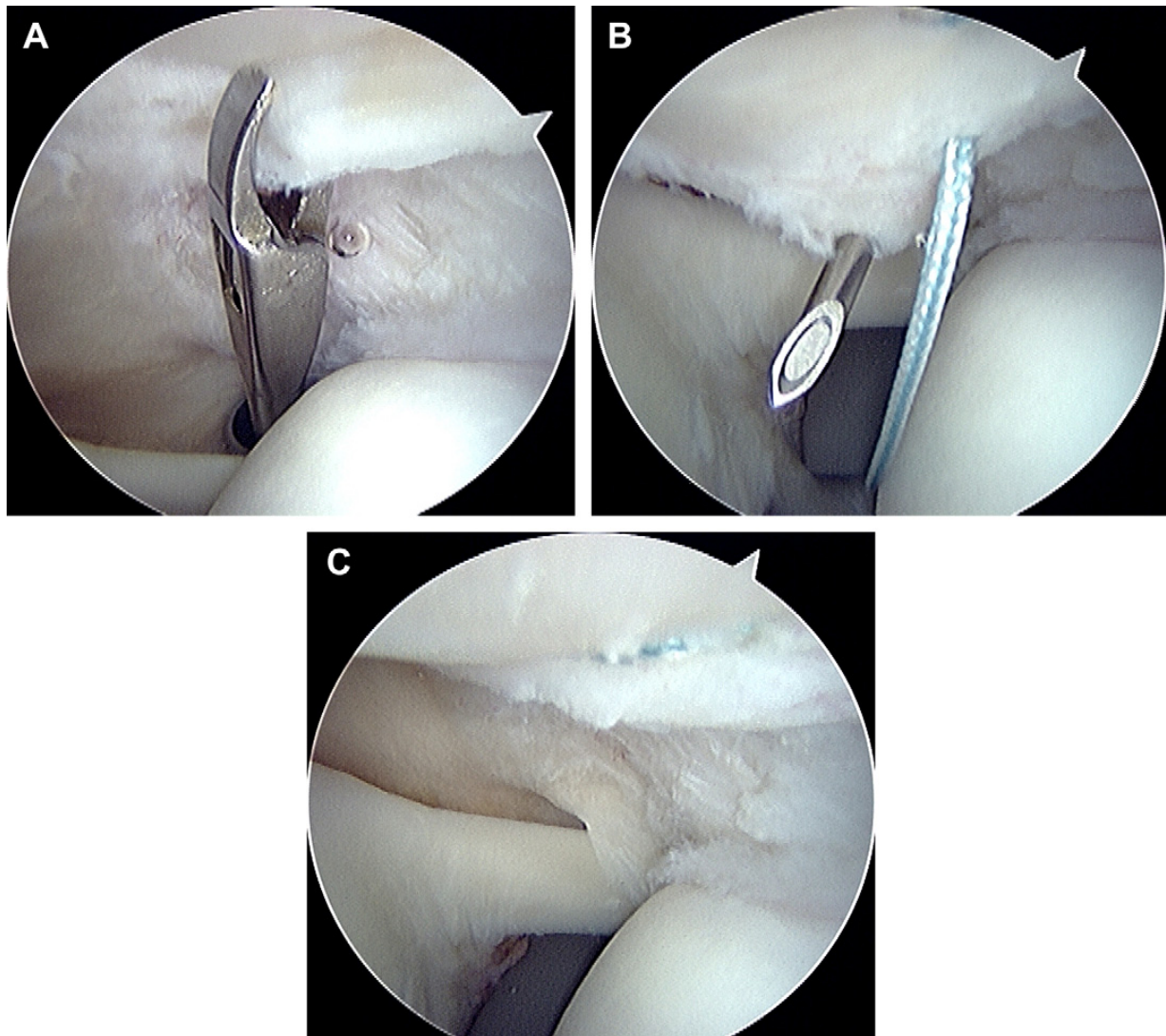


Fig. 6. Author's intralaminar tear repair technique. Arthroscopic view of a right shoulder in beach chair position. (A) An intratendinous partial-thickness tear with retraction. The tear is grasped to determine mobility and its anatomic repair site. (B) Spinal needle placement through both laminations of the tear, and sutures are passed. (C) Completion of the repair as visualized from the glenohumeral joint. (Courtesy of Columbia University, Department of Orthopaedics, New York, NY; with permission.)

a dominant arm repair returned to a high competitive level of baseball with no significant shoulder problems. The authors concluded that it is uncommon for a professional baseball pitcher to return to a competitive level of pitching after a full-thickness rotator cuff repair with a mini-open approach.

Postoperative Rehabilitation

The postoperative rehabilitation protocol after transtendon or laminar rotator cuff repair is similar to that for full-thickness rotator cuff repair techniques. After the procedure, the treated arm is placed at the side in a sling with a small pillow. The sling is worn continuously for 6 weeks, except during bathing and exercises. Active elbow flexion and extension are encouraged. Patients may begin passive external rotation exercises immediately

postoperatively; however, overhead stretching is avoided until after 6 weeks to avoid stressing the repair. At 6 weeks, the sling is discontinued and overhead stretches with a rope and pulley and internal rotation stretches are commenced. Isotonic strengthening is not begun until 10 to 12 weeks after surgery, at which point the authors begin rehabilitation of the rotator cuff, deltoid, and scapular stabilizers. Progressive activities are incorporated as strength allows, and unrestricted activities are usually resumed 6 to 12 months after surgery.

SUMMARY

Shoulder injuries in athletes are highly prevalent and debilitating. The treating orthopedic surgeon must pay special attention to the acuity and

severity of the injury with particular focus on the specific biomechanics of the sport in question. New understanding of the pathophysiology and management of shoulder injuries in various sports has improved outcomes. Nonoperative rehabilitation and arthroscopic and open techniques, applied judiciously, can improve shoulder biomechanics and return athletes to the sports arena as quickly and as wholly as possible.

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