Shoulder Injuries in the Throwing Athlete

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Abstract

The throwing athlete with shoulder pain presents a diagnostic and treatment challenge to the orthopaedic surgeon. Because pitching a baseball requires the arm to accelerate at 7,000 degrees per second, tremendous forces are experienced at the shoulder joint. Electromyographic studies have shown that the larger scapular and trunk muscles are primarily responsible for arm acceleration. The smaller and more fragile rotator cuff muscles play a significant role in decelerating the arm. During the entire throwing mechanism, the rotator cuff and the capsulolabral complex act to stabilize the humeral head on the glenoid fossa. As a result, the labrum, the capsule, and the rotator cuff are frequently the site of shoulder injury in throwers. The diagnosis of injury to these structures is based on the findings from the history, physical examination, and imaging studies. The majority of throwing injuries respond well to a carefully designed rehabilitation program. Athletes who do not improve within 6 months are candidates for surgical repair. The procedure is planned so as to minimize the amount of surgical trauma and thereby to facilitate an early return to sport. Arthroscopy is a valuable first step to confirm the pathologic diagnosis. The arthroscope alone is used to perform subacromial debridement, labral repair, or debridement of undersurface partial-thickness rotator cuff tears. If the athlete has clinical evidence of shoulder instability and arthroscopic evidence of capsular stretch, an open stabilization procedure is performed.

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The act of throwing places extreme demands on the shoulder. The athlete must maximally accelerate and decelerate the arm over a short period of time and at the same time maintain precise control over the object being thrown. It is not surprising that such an activity, when performed repetitively, can lead to shoulder injury. All structures that restrain the humeral head in the glenoid fossa are at risk.

This article will review the biomechanics of the throwing mechanism. We will describe a clinical approach to the problem of shoulder pain in the throwing athlete, including the details of the physical examination, the use of diagnostic tests, and the role of rehabilitation. We will also discuss the role of arthroscopy and open surgical procedures when the rehabilitation program has failed.

Biomechanics of Throwing

The four primary stages of throwing—windup, cocking, acceleration, and follow-through—have been extensively studied. Recent studies using high-speed digital video recording have illustrated the three-dimensional patterns of motion during the throw.[1] These data reveal that the shoulder is maintained in an abducted position of approximately 100 degrees throughout the throw. In the horizontal plane, the arm at maximal cocking is horizontally abducted 30 degrees and finishes in a position of 10 degrees of adduction at follow-through. External rotation has been measured to maximize at approximately 175 degrees, but combines additional movement of the scapula and hyperextension of the trunk.

The speed of arm rotation has also been measured with the use of high-speed video technology. The shoulder, which is maximally externally rotated at 175 degrees during the late cocking phase, moves to 105 degrees of internal rotation during the throwing mechanism at an astonishing speed of 7,000 degrees per second. Using a mathematical model, the

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torque forces occurring in the shoulder during the throw have been estimated. The highest torques, approaching 52 newton-meters, are observed at follow-through, when the arm is being decelerated. [2]

Electromyography has permitted the evaluation of the muscular firing patterns about the shoulder during the throwing sequence.[3] The rotator cuff musculature and biceps are relatively inactive during the acceleration phase of the throw, whereas the pectoralis major, serratus anterior, latissimus dorsi, and subscapularis muscles show the highest activity during this phase of the throw. In contrast, deceleration is accomplished by the rotator cuff musculature and the larger trunk muscles acting in concert. It is during this phase of follow-through that the highest forces are measured, and the rotator cuff must act eccentrically. This information is important in understanding the possible mechanisms of rotator cuff failure and the methods of injury rehabilitation in the throwing athlete.[3]

In addition to the events that occur during throwing, it is important to understand the stabilizing effects of the joint and its surrounding soft tissues. The rotator cuff tendon units have been shown to provide direct compression of the humeral head into the glenoid fossa. Presumably, effective synchronized muscle firing helps to limit abnormal translation of the humeral head on the glenoid.[1,4] Abnormal motion is further limited by the glenohumeral ligaments and the glenoid labrum (the capsulolabral complex).[4-6]

Sequential cutting studies in cadaveric specimens have evaluated the specific role of the glenohumeral ligaments in limiting glenohumeral translation. The anterior superior portion of the capsule limits inferior and posterior motion of the humeral head on the glenoid when the shoulder is adducted. The inferior glenohumeral ligament complex limits anterior and posterior translation of the humeral head on the glenoid when the shoulder is abducted. The inferior glenohumeral ligament complex is defined by anterior and posterior bands, which are visible when the capsule is placed under tension.[6]

The labrum, which serves as the attachment site of the glenohumeral ligaments, plays an uncertain role in limiting glenohumeral motion, but may add to stability by increasing the depth of the glenoid.[4] In traumatic anterior shoulder instability, detachment of the anterior inferior labrum has been commonly noted. A cadaveric study that reproduced this type of labral detachment found that dislocation did not occur.[7] The results of that study suggest that in order for dislocation to occur, additional plastic deformation of the glenohumeral ligaments must also occur. This hypothesis is further supported by the work of Bigliani et al,[8] who demonstrated permanent deformation of the glenohumeral ligament prior to labral detachment in a cadaveric model of shoulder instability.

Ligamentous injury in the overhead-throwing athlete is frequently microtraumatic in nature. A classic Bankart lesion is rarely observed. This is in direct contrast to traumatic anterior instability, in which Bankart lesions, accompanied by a variable degree of capsular laxity, are commonly seen. The microtraumatic injury in the throwing athlete frequently results in stretch or plastic deformation of the capsular ligaments.

All of this information demonstrates that there are a number of systems that control the position of the humeral head on the glenoid. Muscular tension, ligamentous support, proprioceptive neuromuscular control, and osseous architecture all play a role. Muscular control is a dynamic system of control, while ligamentous support is a static system. A normally functioning asymptomatic shoulder requires a balance between these two systems and the osseous architecture, which is of particular importance in throwing. The ligamentous system allows the motion required to accelerate the ball, while the stability of the humeral head on the glenoid is maintained by muscular contraction and ligamentous tension. In the microtraumatic model of throwing injury, overload or injury to one portion of this restraint system shifts the burden to the other portion. This may account for the frequently observed combination of a partial-thickness rotator cuff tear and capsulolabral injury. One must keep in mind that in throwing athletes there is a fine line between the normal laxity that allows them to propel objects at high speeds and the pathologic instability that leads to their symptoms.

Clinical Evaluation of the Throwing Athlete

With this background information, a clinical approach to shoulder dysfunction in the throwing athlete has been developed. Beginning with a careful history, the examiner should identify the primary symptoms. The vast majority of throwing athletes will present with a chief complaint of pain, despite a wide range of underlying pathologic conditions. Instability may be subtle and may not be apparent from the history. Instability symptoms may include a feeling of the arm going dead or “coming apart” or a frank sensation of subluxation. However, throwers with occult subluxation often present with pain without any distinct symptoms of instability.

The examiner should determine which phase of the throwing mechanism or arm position is most likely to reproduce symptoms, which can be helpful in defining the type of instability pattern that is present. Patients with anterior instability typically will complain of pain, “dead arm,” or coming-apart symptoms during the late cocking phase or early acceleration phase. Patients with posterior subluxation typically will complain during the follow-through phase. In either case, there may be, in addition, pain or symptoms during other phases of throwing.[9]

In the thrower with microtraumatic injury to the shoulder, rotator cuff injury is not uncommon. Although full-thickness tears are unusual, partial tears, particularly those affecting the articular surface, occur frequently. Detecting such injuries on the basis of the history is difficult, however.

If the rotator cuff injury is significant, a component of night pain often will exist. The location of pain can be of some help in localizing the lesion. Anterior pain may be associated with injury to the subscapularis or biceps tendon or with capsulolabral injury. Anterolateral pain is commonly seen with supraspinatus tendon injury, while posterior pain can be related to infraspinatus tendon problems or capsulolabral injury.

The physical examination is directed toward attempting to isolate the portions of the restraint system that are responsible for producing symptoms. Atrophy, particularly of the infraspinatus fossa, should be noted. This represents chronic rotator cuff dysfunction or suprascapular nerve injury. Palpation should be carried out to identify specific areas of tenderness.

The range of rotation is assessed in various degrees of shoulder adduction and 90 degrees of abduction. Increased external rotation of the dominant shoulder compared with the nondominant shoulder can be expected as a manifestation of normal laxity. In addition, some throwers will exhibit losses of internal rotation. Whether this represents a normal adaptive response to the repetitive stress of throwing or a pathologic contracture is not clear at present. On the basis of our clinical observations, we think that throwers with losses of internal rotation are more likely to experience shoulder pain than those athletes with symmetric internal rotation. Loss of internal rotation can result from contracture of the posterior capsule, which, when simulated in cadaveric models, results in excessive anterior and superior translation of the humeral head.[10] Conceivably, this abnormal movement could cause symptoms by producing impingement of the humeral head on the coracoacromial arch.

The rotator cuff is assessed both by testing for signs of impingement and by attempting to elicit symptoms or weakness on resistance maneuvers in abduction and external rotation.

Ligamentous stability is tested in the anterior, posterior, and inferior directions. These tests are performed on both shoulders, and the results are compared. In the injured throwing athlete, the examiner should expect to find increased laxity on the dominant side. Therefore, the goal of the examination is to determine whether translation of the humeral head on the glenoid has increased markedly, whether distinct subluxation can be produced, and whether these maneuvers reproduce the patient’s symptoms.

With the patient seated, we attempt to elicit a sulcus sign. The scapula is stabilized by grasping the acromion while the humerus is adducted. The examiner then applies distal traction to the arm. We grade the inferior displacement of the humeral head on the glenoid by the size of the sulcus seen on the skin. Throwers normally exhibit 1 to 2+ displacement (evidenced by a sulcus measuring 1 to 3 cm), whereas 3+ inferior displacement (sulcus measuring more than 3 cm) is usually associated with pathologic instability.[11] If the patient states that reproduction of his or her symptoms occurs when the sulcus sign is elicited, the examiner should consider the possibility of inferior instability.

We examine for anterior or posterior instability with the patient supine. The arm is supported in neutral rotation in the plane of the scapula. With one hand, the examiner applies an axial load at the elbow to center the humeral head on the glenoid; with the other hand, the examiner translates the humeral head anteriorly and posteriorly on the glenoid. Our grading system is as follows: 1+, increased translation compared with the opposite shoulder is observed without distinct subluxation of the humeral head over the glenoid; 2+, distinct subluxation can be produced; 3+, the humeral head can be displaced and locked over the glenoid rim.

It is expected that a thrower will have 1+ anterior laxity, while 2+ posterior laxity is not uncommon as a normal finding in the absence of symptoms. Anterior laxity of 2+ or greater is usually evidence of a pathologic condition. Throwers with labral tears will often have 1+ translation, which will cause grinding or clicking and reproduction of painful symptoms.[12]

Jobe has popularized the so-called relocation test to further evaluate patients with subtle forms of instability.[13] To perform this maneuver, the patient is placed supine with the arm abducted 90 degrees and maximally externally rotated. This position should reproduce the patient’s symptoms of pain or apprehension if there is symptomatic instability. The examiner then places a posteriorly directed load on the proximal humerus, relocating the humeral head and preventing anterior subluxation. If this relieves the patient's symptoms, the test is considered diagnostic for anterior instability.

Speer et al[14] evaluated the sensitivity and specificity of the relocation test. They found that although it was highly sensitive, specificity was poor if pain alone was evaluated. The specificity of the test improved markedly if the examiner was able to reproduce and relieve the symptoms of apprehension. In clinical practice, the relocation test and its modifications should be confirmed by other portions of the examination to make a firm diagnosis of instability.

The information obtained from the history and physical examination is then supplemented by findings from diagnostic tests. Radiographs are obtained in several planes, including anteroposterior, axillary, and outlet views. On the anteroposterior view, the glenohumeral joint should be clearly visible and should be assessed for signs of instability (Hill-Sachs lesion). The acromioclavicular joint will also be visible and should be assessed for undersurface spurring or degenerative changes. The axillary view is inspected for bone reaction along the glenoid margin. The outlet view is used to assess the subacromial osseous morphology. In most cases, plain views will rarely be diagnostic in this group of patients.

Magnetic resonance imaging is frequently used to further refine the diagnosis. Currently available software and the use of a shoulder coil should allow accurate imaging of the rotator cuff, but complete identification of labral injuries remains less precise.[15] At the present time, no imaging technique can measure capsular stretch.

Once the history, physical examination, and imaging studies are complete, the physician should be able to make a provisional diagnosis. A final diagnosis may not be possible, however. Coexisting pathologic changes, such as capsular injury resulting in subtle instability with a simultaneous partial-thickness rotator cuff tear, are not uncommon.

The athlete's response to rehabilitation often allows the physician to further refine the diagnosis. Rehabilitation is directed toward strengthening the rotator cuff and scapular musculature and improving any mechanical flaws in the throwing mechanism. In general, minor to moderate degrees of capsular stretch resulting in a small pathologic increase in glenohumeral translation can be compensated for by improved dynamic stabilization. In this situation, no further studies are required.

Treatment of Shoulder Injuries in the Throwing Athlete

Conservative Treatment

Initial treatment is directed toward decreasing pain and restoring strength and motion. Pain relief is achieved by avoidance of aggravating activities and by use of cryotherapy and nonsteroidal anti-inflammatory medications. It is our opinion that cortisone injections are not indicated in the youthful athletic population because of the possibility of tendon damage.

The most common loss of motion is that of internal rotation, due to contracture of the posterior capsule. Graduated stretching in adduction and internal rotation is performed by the therapist and the patient until motion is symmetric.

The strengthening phase of rehabilitation is directed toward the musculature needed for throwing. Because the trunk muscles play a significant role in throwing, our strengthening program is directed simultaneously at the lower extremities and the shoulder girdle. During strengthening of the shoulder girdle, the therapist must avoid overloading and thereby irritating the rotator cuff musculature. The data have shown that rotator cuff firing occurs primarily during the follow-through phase, when eccentric muscle contraction decelerates the arm.[16] Rehabilitation of the rotator cuff musculature must involve exercises that mimic this eccentric firing pattern. As a rule, we tend to avoid exercises that attempt to isolate a single muscle group, such as those performed on isokinetic devices. Instead, we recommend exercises that mimic the throwing activity, addressing the muscles of the lower extremities as well as the shoulder musculature. As pain diminishes and function improves, emphasis is placed on improving throwing mechanics by working with a coach. The capabilities necessary for a return to play are measured functionally, rather than by use of isokinetic testing devices. In our experience, this conservative treatment program can be helpful in a large percentage of throwing athletes.

Failure is defined as a lack of definitive progress by 3 months or an inability to return to competition by 6 months. If the rehabilitation program fails, a surgical solution must be considered.

Surgical Treatment

Surgical treatment of shoulder injury in the throwing athlete begins with a careful examination under anesthesia to confirm the direction of any occult instability. Such an examination, carried out as already described for the initial office examination, is crucial in deciding whether glenohumeral instability is present. For example, if we suspect instability and are considering the patient as a candidate for capsular repair, we require that the examination under anesthesia confirm the presence of excessive differences in the degree of translation between the shoulders. The minimum requirement for stabilization is the reproduction of 2+ translation.

Following this examination, the patient is positioned in a modified beach-chair position for arthroscopy.[17] We feel that this position has several advantages over the lateral decubitus position. It is well tolerated by patients who have undergone regional anesthesia (scalene block). In addition, the absence of traction on the arm allows the surgeon to assess capsular tension without distortion. Also, without having to prepare the area again and redrape, the surgeon can convert arthroscopy to an open procedure, which is a necessary next step in many cases.

Posterior and anterior arthroscopic portals are created initially to allow complete examination of the joint. The diagnostic arthroscopy begins with evaluation of the biceps attachment and the superior labrum. Labral injury in this zone may include detachment or tearing or both. The biceps tendon may be involved and should be carefully examined as well. The surgeon must be familiar with the variations of normal anatomy that exist in this area. Cooper et al[18] have demonstrated that the superior labrum is characterized by considerable variation in both attachment and shape. The anterior superior labrum in particular displays great variation: it may be absent, confluent with the superior portion of the middle glenohumeral ligament, or present but not attached to the glenoid margin.[18]

Before proceeding with labral repair in this area, the surgeon must demonstrate the presence of tissue injury. This will differentiate labral detachments that are due to injury from those that are merely anatomic variants. The anterior inferior labrum has little variability and is firmly attached to the glenoid neck. Tears or detachments in this region are significant and are usually associated with an anterior glenohumeral instability.

The anterior capsular ligaments are next evaluated. The superior glenohumeral ligament rarely is distinct, while the middle glenohumeral ligament usually is clearly present, draped over the subscapularis tendon. The inferior glenohumeral ligament is attached to the labrum by a normally robust anterior band.[19] This capsular ligament is frequently involved in the microtraumatic instability observed in throwing athletes.

Injury frequently causes plastic deformation of the inferior glenohumeral ligament, with a resulting loss of normal tension. Pagnani and Warren[19] have described the “drive-through” sign as an arthroscopic method of evaluating this ligamentous tension. When the ligament is uninjured, external rotation of the humerus will create tension in the anterior ligaments, and the surgeon will be unable to drive the arthroscope through into the anterior portion of the joint. As deformation of the ligament increases from capsular stretch, the resting length of the ligament elongates, allowing the arthroscopic drive-through to increase.

Next, the entire undersurface of the rotator cuff is examined. Partial articular-surface tears are commonly seen in this patient population.[19,20] To assess the bursal surface of the cuff in the same region as the partial undersurface tear, a spinal needle is placed percutaneously through this area. A monofilament suture is then passed and pulled out the anterior portal. Later, during the bursal examination, this suture is identified, and the superior surface of the rotator cuff in the area of the inferior partial tear is examined. As the posterior aspect of the cuff is viewed, the arm is externally rotated, and the posterolateral humeral head is examined for the presence of a Hill-Sachs lesion.

The posterior labrum is best viewed with the arthroscope placed in the anterior portal. Fraying of the posterior labrum is common in throwing athletes. Frank tears or detachments may occur and are recognizable.

Once the glenohumeral joint has been completely examined, the arthroscope is inserted into the subacromial space through the posterior portal. Evidence of bursal scarring or injury to the superior surface of the cuff should become evident.

After arthroscopic confirmation of the cause and direction of instability has been made, the definitive surgical procedure is carried out (Figs. 1 and 2). The choice of procedure is determined on the basis of the findings from the history, physical examination, imaging studies, examination under anesthesia, and diagnostic arthroscopy.

During arthroscopy, partial-thickness articular-side rotator cuff tears are debrided of all torn flaps. This is performed with the hope of stimulating a healing response; however, no long-term data exist at present to confirm that this treatment is efficacious. If no distinct shoulder instability exists, pathologic labral detachments are repaired arthroscopically with use of an absorbable implant designed to allow fixation of soft tissue to bone (Suretac, Acufex Microsurgical, Mansfield, Mass). There are other techniques for arthroscopic labral repair, but we prefer the use of this material. Superior labral degenerative tears without labral detachment may be debrided; however, all labral detachments should be repaired in the manner already described. It has been documented that labral debridement without repair has a poor success rate when the labrum is detached.[12]

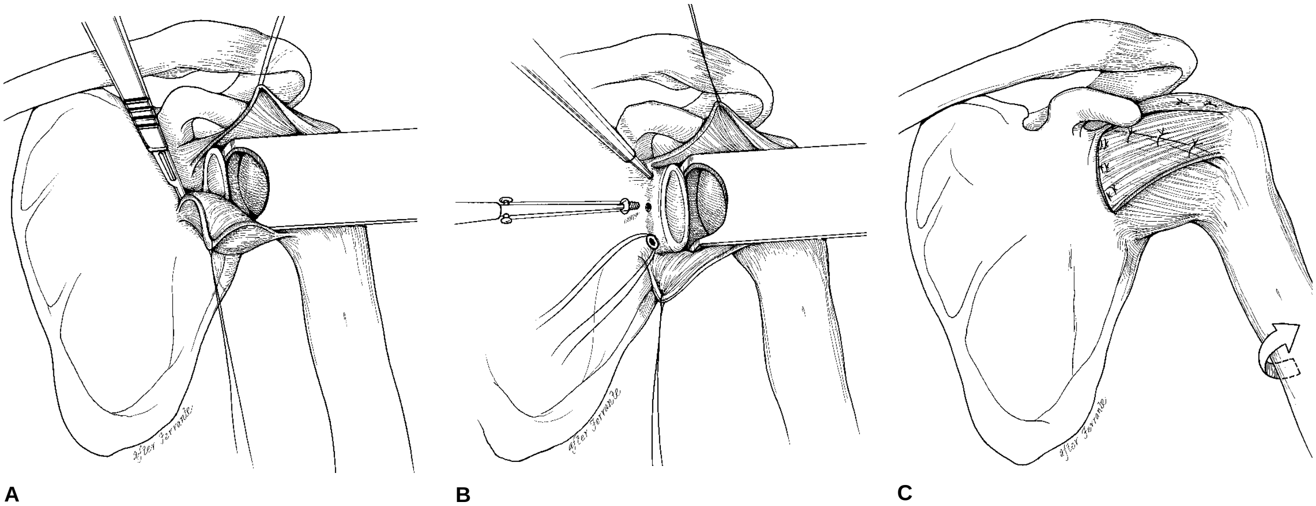

Fig. 1 Technique for capsular repair when the anterior inferior labrum is detached. **A,** The horizontal capsular incision is extended through the labrum into the glenoid neck. **B,** Suture anchors are placed at the glenoid articular margin. **C,** The completed capsular repair.

When bursitis is encountered in the subacromial space, an arthroscopic bursectomy is carried out. If the surgeon encounters a hypertrophic coracoacromial ligament that demonstrates evidence of an undersurface injury, the proximal portion of the ligament should be excised. In our experience, bone decompression or acromioplasty is rarely indicated in this youthful athletic population, in whom impingement is primarily a secondary phenomenon.[21]

If there is instability in the throwing athlete, in most cases there will be a plastic deformation of the anterior ligamentous complex. Large Bankart lesions of traumatic instability are rarely seen. For this reason, the majority of these athletes will not be candidates for arthroscopic stabilization. The goal of open stabilization is to restore capsular tension, thus eliminating pathologic translation without limiting motion.

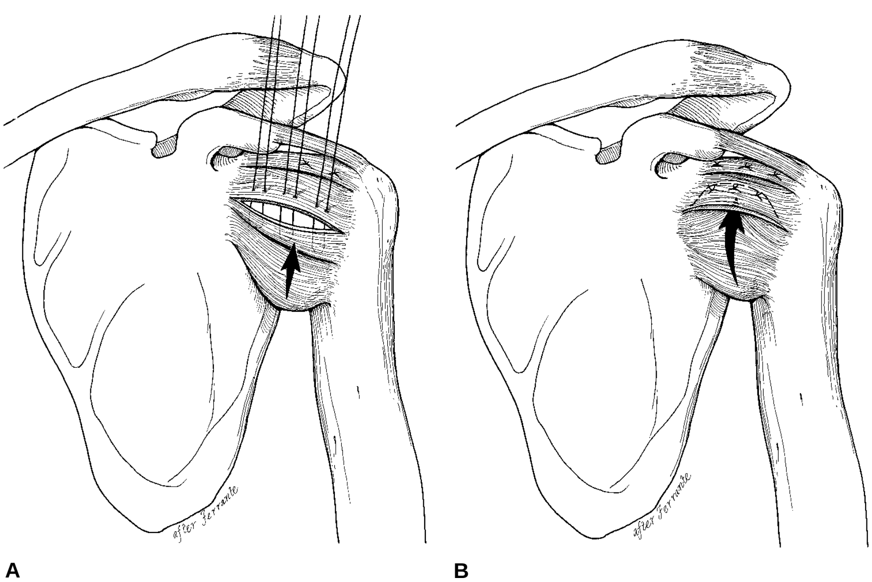

Fig. 2 Technique for capsular repair when there is no labral detachment. **A,** The horizontal capsular incision is plicated using mattress sutures. **B,** The completed capsular plication.

Open anterior repair is performed selectively on the basis of the pathologic changes present.[22] The following technique is our preferred method:

The shoulder is exposed by means of a typical deltopectoral approach. The capsule is exposed by splitting the subscapularis, rather than by vertically transecting the tendon. This approach, which was described by Jobe,[23] minimizes the risk that postoperative shortening of the subscapularis will occur. A horizontal incision is made in the lower third of the muscle. Once the capsule has been identified, the incision is extended laterally into the tendon and medially past the glenoid margin. The resultant musculotendinous flaps are undermined bluntly, exposing the underlying capsule. The capsule is divided horizontally, superior to the anterior band of the inferior glenohumeral ligament.

If the anterior inferior labrum is detached, the horizontal incision is continued through the labrum onto the glenoid neck. A subperiosteal flap, which contains in continuity the periosteum, the inferior labrum, and the inferior glenohumeral ligament (Fig. 1, A), is then elevated. After abrasion of the glenoid neck, the labrum is secured to the articular margin with the use of suture anchors (Fig. 1, B). Residual capsular laxity is eliminated by imbricating the horizontal capsular incision. The inferior flap is brought superiorly under the superior flap with use of a horizontal mattress suture. In our surgical protocol, the capsule is tensioned with the arm in at least 60 degrees of abduction and 90 degrees of external rotation in the plane of the scapula. The shoulder is reexamined before the capsular sutures are tied. Anterior instability should be eliminated, and 90 degrees of external rotation should be possible (Fig. 1, C), which will ensure enough laxity to return to normal throwing. If there is no labral detachment, the horizontal interval is simply imbricated, shifting the inferior capsular flap superiorly (Fig. 2).

Postoperative care is directed at gradual restoration of motion and strength over a 6-week period. Return to throwing is not allowed for at least 4 months. The throwing program is graduated, beginning with light tossing and progressing over a period of 4 to 6 months to full-velocity activity.

Summary

The diagnosis and treatment of shoulder dysfunction in the throwing athlete requires an in-depth analysis of the patient's symptoms and physical findings, which may be quite subtle. The physician must understand the role of the system of static and dynamic restraints that function to keep the shoulder stable during the complex throwing motion. Treatment is directed toward restoring the equilibrium between shoulder laxity and dynamic stabilization of the rotator cuff and scapular musculature.

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