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**QUICK LOOK**

- The focus is the chronic and overuse injuries specifically related to baseball.
- Emphasis on those areas where diagnosis and treatment may be difficult.
- The mechanics of throwing is discussed in detail to understanding how most chronic injuries occur.
- Review specific injuries of the shoulder and elbow in adults and in the skeletally immature.

In the assessment of an injured baseball player of any age at any level, the physician must have a thorough and systematic approach to arrive at the correct diagnosis. In the acute setting one must rule out fractures, dislocations, ligament injuries, and musculotendinous injuries. In those with chronic symptoms, the differential diagnosis may include the following: stress fractures, osteochondral lesions, arthritic conditions, joint instability and subluxation, neuropathies, and tendonitis or tendinopathy.

**THROWING**

Throwing is a very important aspect of baseball for all players involved, not exclusively for the pitcher. Most chronic and overuse injuries in baseball are caused by throwing; it is an activity that has been extensively researched by many authors using electromyographic (EMG) analysis (Andrews et al., 1995; Hancock and Hawkins, 1996; Jobe et al., 1984). Studies have been performed on both professional and amateur pitchers, allowing interesting comparisons between the two groups. The pitch motion is a continuous flowing motion, but for the purpose of description and analysis it can be divided into five stages (Figs 32-1, 32-2, and 32-3) (Hancock Li Hawkins, 1996).

**Stage 1: Windup**

The *windup* occurs from the initial movement until the ball leaves the gloved hand. This is a very important phase whereby the leading leg is lifted and the pitcher's center of gravity is placed over the pitching rubber. From here the pitcher is well balanced to move into the cocking phase. There is little strain on any particular muscle group during this phase.

**Stage 2: Early Cocking**

This phase begins when the ball leaves the gloved hand and ends as the front foot strikes the ground. During this phase the arm is elevated and abducted 90° together with early external rotation of the shoulder. EMG studies show the deltoid is the dominant upper limb muscle during this phase and mainly acts to hold the shoulder in abduction (lode et al., 1983). During this phase there is also a lot of lower limb and trunk activity. The pelvis rotates toward the target, causing a coiling effect on the trunk. The leading leg is powerfully extended toward the home plate, which increases the coiling effect.
FIG 32-1 The five phases of pitching.

Stage 3: Late Cocking

This phase begins as the front foot contacts the ground and ends with the first forward motion of the ball. During this phase the enormous amount of energy that has been built up in coiling of the trunk is now transferred to the arm. As the trunk and lower body unwind and begin to translate toward the home plate, the hand and ball remain relatively motionless. To allow this to occur, the shoulder moves into a position of extreme external rotation. At the beginning of this phase the shoulder is usually in a position of approximately 90° of abduction and 90-120° of external rotation and by the end of the late cocking maximal external rotation will be reached that may be up to 180°. In nonathletes, 90° of shoulder external rotation is considered normal; therefore, one can begin to appreciate the enormous stress being placed on the pitcher's shoulder as it is rotated externally to almost 180°.

It is during this phase, as the shoulder and trunk move ahead of the hand and forearm, that the elbow, which is flexed to approximately 90°, is put under an extreme valgus load that stretches the medical structures and compresses the lateral structures. EMG studies show an enormous amount of rotator cuff activity during this phase. Infraspinatus and teres minor work concentrically during stage 2, acting as external rotators of the shoulder. During late cocking their activity peaks as these muscles function to stabilize the humeral head and draw it posteriorly, thus protecting against anterior subluxation. Supraspinatus contracts isometrically to help with humera, head stabilization. Subscapularis is inactive initially but then undergoes its peak activity late in stage 3 as it contracts eccentrically to decelerate the external rotation and protect the anterior of the joint from ligament damage and
subluxation. Latissimus dorsi and pectoralis major also act eccentrically during late cocking to decelerate the external rotation of the humerus (Jobe et al., 1984).

**Stage 4: Acceleration**

This phase begins with the first forward motion of the ball, which corresponds to the beginning of internal rotation of the humerus. The angular velocity achieved here is up to 7000° per second, and the ball velocity goes from 0-90 miles per hour in about 50 milliseconds. The large amount of energy stored in the previous stages is transferred to the ball during this phase with surprisingly little muscle activity required.

![Approximate time lengths for pitching phases.](image)

**FIG 32-1** Approximate time lengths for pitching phases.

![Rotation of shoulder in throwing motion.](image)

**FIG 32-3** Rotation of shoulder in throwing motion.
energy stored in the previous stages is transferred to the ball during phase with surprisingly little muscle activity required.

Strong contraction of triceps muscle forces the elbow into rapid extension, at velocities averaging over 4000° per second. During this phase triceps muscle, its tendon, and the olecranon are all exposed to injury.

EMG studies show that the rotator cuff muscles of professional pile are relatively inactive during this phase, although in injured and amateur pitchers this is often not the case. It has been shown that amateurs have levels of activity in both the rotator cuff and the biceps during the acceleration phase, and this may predispose them to an increased likelihood of overuse injuries and possibly to superior labral injuries (Fleisig et al., 1995).

The major activity in professional athletes is in the pectoralis major latissimus dorsi, which act concentrically to accelerate the humerus internal rotation. Triceps activity is also maximal during this phase, acting to extend the elbow, but it begins to fire in late cocking and may have s role in helping to stabilize the shoulder by its long head attachment (Jobe et al., 1984).

Stage 5: Follow Through

This phase begins with ball release and ends when motion ceases. It is a VI violent phase as the muscles of the upper limb attempt to resist the 200-lb ward force on the arm, mostly by the use of powerful eccentric contract] Despite the strong contraction of the biceps, the elbow still reaches full extension, and at this point, the olecranon strikes the olecranon fossa of the humerus.

EMG studies show activity particularly in the rotator cuff muscle which act to stabilize and decelerate the glenohumeral joint, and also in the trapezius, serratus anterior, and the rhomboid muscles, which control u decelerate the scapula. Teres minor is particularly active in this phase as it contracts eccentrically to decelerate the humerus, which is forcefully rotating internally at this point (Hancock and Hawkins, 1996).

Biceps and brachialis have been shown to fire synchronously through this stage and are thought to act mainly to decelerate the elbow, which is undergoing quite violent extension (Basmajian and Latif, 1957; Jobe et al., 1983). The strong pull of the biceps may be important in the development of labral and superior labrum from anterior to posterior (SLAP) lesions in the shoulder (Fleisig et al., 1995; Snyder et al, 1990).

Understanding the mechanics of throwing helps the clinician to appreciate the extreme forces placed on the bones, ligaments, and muscles of the body. It is known that eccentric loading of muscles places them at most risk of injury and that is partly why the act of throwing is so stressful, particularly III the rotator cuff. If the rotator cuff is weakened or injured, then more stress is placed on the static stabilizers, especially the glenoid labrum and the anterior glenohumeral ligaments (Fleisig et al., 1995). The untrained or II II II red athlete often places even more stress on the rotator cuff and biceps they attempt to compensate for a deficiency in technique or shield an injury (Glousman, 1993). This may lead to an overuse injury and tendonitis of the rotator cuff that weakens the rotator cuff and
thereby predisposes the individual to further damage to the ligaments of the shoulder. Instability, through physiologic laxity or pathologic ligament damage, can then allow secondary rotator cuff damage owing to impingement, and thus a vicious circle is entered (Jobe, 1996).

In the elbow, pathology occurs owing to tension on the medial side of the I"nt, compression on the lateral side of the joint, and impaction posteriorly. IItL' region of the joint most affected is partly determined by the age of the uutividual and their skeletal maturity, as these factors determine which III atomic structures are most vulnerable.

**EPIDEMIOLOGY**

Baseball is one of the most popular sports in North America. In 1981 there were estimated to be approximately 13,000,000 children playing baseball. Approximately half of the amateur players are aged between 6 and 12. The number of amateurs playing some form of organized baseball had risen to estimated 16 million in the United States by 2000 (Yen and Metzl, 2000). A survey of over 2800 Little League baseball players in 1994 concluded that baseball was a safe activity with low rate of injury (Pasternack et al., 1996.). Severe injuries occurred in only 11 cases, giving a rate of only 0.08 severe injuries per 1000 player-hours. Impacts by the ball caused more than half of the severe injuries and were usually facial. There have been several cases of fatal comotio cordis associated with youth baseball, but it is a rare injury. Overuse injuries were generally not severe but accounted for 19% of the injuries incurred.

**SHOULDER INJURIES IN ADULTS**

Throwing places very high demands on the shoulder, and in the pursuit of speed the anatomic structures of the shoulder are put under loads that may be greater than can be tolerated. The shoulder enjoys the greatest freedom of motion of any joint, and this is owing largely to the lack of bony congruity between the humeral head and glenoid. The shoulder is mainly reliant on the ligaments and muscles to give it stability, and in particular the superior, middle, and inferior glenohumeral ligaments and the rotator cuff muscles, les playa key role. Athletes and especially throwing athletes tend to have relatively lax ligaments, allowing them the advantage of an increased ran of motion, but putting them at increased risk of instability. Throwing injuries in skeletally mature athletes can be grouped into two main categories macrotrauma and microtrauma (Jobe, 1996).

*Macrotraumatic injuries*, such as acute rotator cuff tears, acute should dislocations, and fractures, are generally specific events that are relative simple to diagnose. A large rotator cuff tear in a throwing athlete is likely to require investigation and surgical repair to optimize the final result. Dislocations require reduction and a short period of immobilization, but the rise of subsequent instability in young athletes is very high and surgical intervention will probably be required.

*Microtraumatic or overuse* injuries are more common; they tend to be insidious in their onset and may be difficult to diagnose. In understanding the biomechanics of throwing, one can appreciate those structures most risk of failure. The rotator cuff is placed under extreme loads and often co tracts eccentrically, which puts it under even greater stress.
Subscapularis is loaded maximally in late cocking and teres minor in the follow-through stage. Tendonitis, fatigue, or failure of the rotator cuff leads to further stress on the glenohumeral ligaments, particularly in the anterior quadrants. Excessive external rotation with reduced internal rotation of the shoulder is a common finding in pitchers and is presumably an adaptive phenomenon that allows greater velocity to be achieved. This, however, results in posterior capsular tightness that forces the center of rotation anteriorly, and this place further stress on the anterior ligaments and predisposes to impingement.

**IMPINGEMENT AND INSTABILITY**

These entities are discussed together, because they are interrelated and inter, dependent. Subacromial impingement was described by Neer (1973, 1983 and refers to the impingement of the superior portion of the rotator cu against the anterior acromion and coracoacromial ligament. Bigliani's work (1986) showed that hooked acromions were more commonly associated wit rotator cuff tears, and this added support to the concept of a mechanical injury occurring as the rotator cuff was impinging against the anterior acromion.

Associated with the mechanical impingement are subacromial and acromioclavicular spurs, subacromial adhesions, fibrosis, and bursal-sided partial-thickness tears. This type of impingement syndrome is usually seen patients over the age of 40 unless there is an anatomic variant, such as an os acromiale. Based on this, Neer (1972, 1983) described the anterior acromioplasty, and given the appropriate pathology good results have been achieved with this operative technique.

Unfortunately, shoulder pain became synonymous with impingement, and this led to some patients being treated inappropriately. In young, overhead throwing athletes treated with anterior acromioplasty, whether open or arthroscopic, fewer than 50% of cases were achieving good results and returning to their sports, leading to the conclusion that the pathology was different in this group of patients (Glousman, 1993; Tibone et al., 1985).

**Pathophysiology**

It is now clear that there are different types of impingement requiring different treatment regimes as discussed in the following sections (Jobe, 1996).

*Classic Anterior Impingement*

This is impingement syndrome as described by Neer (1972). It is rare under the age of 40 years and in throwing athletes, and therefore the clinician should consider other types of impingement syndrome. Anatomic variations, such as an unstable os acromiale or a type III (hooked) acromion, need to be excluded, because they will predispose an individual to this type of Impingement.

*Anterior Impingement Secondary to Tight Posterior Capsule or Instability*

Posterior capsular tightness is a common finding in throwing athletes and can be recognized by an excess range of external rotation with a limited range of internal rotation.
Its effect is to shift the center of rotation anteriorly and predispose the individual to anterior impingement. Ligamentous laxity particularly in an anterior direction can also result in secondary interior impingement. Acromioplasty and coracocoracromial ligament resection are contraindicated in these instances, because it further destabilizes the shoulder.

**Internal Impingement (Superior Glenoid Impingement)**

More recently, the concept of internal impingement has been recognized, and this is especially important in throwing athletes (Jobe, 1997; Walch et al., 1992). Arthroscopic examination in many of these individuals did not show subacromial bursitis or bursal-sided rotator cuff pathology, but instead revealed incomplete articular-sided tears of the posterosuperior cuff, injury, and reaction of the posterosuperior labrum. This is owing to internal Impingement of the cuff against the glenoid and occurs with the arm in abduction and external rotation. (This can be visualized arthroscopically,) Bony changes on the greater tuberosity and posterosuperior glenoid were also occasionally seen.

The relationship that this type of impingement has with instability is not yet fully established. Jobe (1996) believes weakness of subscapular or incompetence of the inferior glenohumeral ligament results in hyperangulation and inferior subluxation of the shoulder during abduction and external rotation and that this allows impingement of the rotator cuff against the glenoid.

Pure instability can also occur without impingement and can be classified according to direction (anterior, posterior, inferior, or multidirectional), etiology (traumatic or atraumatic), frequency (acute, recurrent, or chronic), degree (subluxation or dislocation), and volition (Cofield and Irving, 1987). Typically, the throwing athlete has anteroinferior or multidirectional instability that is atraumatic (owing to overuse).

Having recognized that there is a spectrum of pathology from pure Impingement to pure instability, Jobe and colleagues have classified throwing athletes with shoulder pain into four groups (Glousman, 1993; Jobe et al., 1990).

- **Group 1**: pain secondary to pure impingement
- **Group 2**: pain secondary to instability owing to anterior ligament and labral injury with secondary impingement
- **Group 3**: pain secondary to instability owing to hyperelastic capsular ligaments with secondary impingement
- **Group 4**: pain secondary to pure instability without secondary impingement

**Evaluation**

Anterior impingement with rotator cuff tendonitis is suggested by should pain related to overhead activities and often by night pain. There is tenderness along the subacromial bursa, a painful abduction arc, and positive impingement test as described by Neer and Hawkins (Hawkins and Kennedy, 1980; Neer, 1983; Neer and Welsh, 1997).
Superior glenoid impingement gives a slightly different clinical picture with chronic dorsal shoulder pain that is characteristically worse in the acceleration phase of the pitch when the impingement is maximal (Jobe, 1996). Examination reveals tenderness along the posterior joint line with impingement in a position of 90° of abduction together with full external rotation and horizontal extension. This is the same arm position used to test for anterior instability in the apprehension test, although with superior impingement the athlete experiences pain rather than apprehension. Applying a posterior force to the proximal humerus while repeating the test often reduces the pain in much the same way as apprehension can be reduced using the relocation test in a patient with anterior instability (Kvitne and lobe, 1993).

Rotator cuff tears are unusual in young athletes, but can occur and i suggested by atrophy and weakness of the rotator cuff. Subscapularis is best assessed using the liftoff test, as described by Gerber and Krushell (1991). This is performed with the arm internally rotated so that the dorsal surface of the hand rests on the lower back. Actively lifting the hand away from the back and resisting force suggests integrity of the subscapularis. The external rotators, teres minor, and infraspinatus can be tested with the arm by t side and elbow flexed to 90°. In this position impingement should n be present so that painful inhibition of muscle activity is eliminate Supraspinatus can be most effectively isolated and tested with arms in 90° of scapular elevation and full internal rotation.

Instability usually takes the form of repeated transient subluxations that may be symptomatic to the athlete as a feeling of instability with the shoulder feeling loose, or it may cause pain that is usually felt over the posterior aspect of the shoulder in the late cocking or early acceleration phase. Occasionally, the subluxation may cause momentary traction on the brachial plexus giving rise to dead arm syndrome (Leffert and Gumley, 1987). On examination, shoulder instability may be anterior, posterior, or inferior, may be very obvious and easy to demonstrate, or it may be very subtle a difficult to diagnose. In all cases one needs a relaxed, cooperative patient and a gentle technique.

In the shoulder it is difficult to know if the translation felt is subluxation to an abnormal position or relocation to a normal position. It is also imprtant to remember that a normal shoulder has a degree of physiologic laxity and can translate significantly, and this can be particularly evident und anesthesia (Harryman et al., 1995). Comparison to the opposite side vital, as is very careful palpation to feel when the joint is properly located (Miniaci et al., 1995). Subluxation, apprehension, and the reproduction of the patient's pain may all be positive examination findings. The following examination, tests are used to determine the degree and direction of instability,

Load-and-Shift Test

With the patient comfortably seated and with hands in the lap, one can perform the anteroposterior translation or load-and-shift test. To perform this test the right humeral head is grasped with the right hand, while the left hand is positioned over the top of the shoulder girdle so that the scapula can he stabilized. Simultaneously, the posterior joint line is palpated with the thumb while the anterior shoulder is palpated with the index and middle fingers. The right hand then loads the joint to ensure concentric reduction and then applies anterior and posterior shearing forces. The direction and amount of translation can then be determined and graded using a scale of 0-3 (grade 0 for no instability; grade 1 for mild
translation of less than 1 cm; grade 2 for moderate translation of 1-2 cm, or to the glenoid rim; and grade 3 for severe translation of greater than 2 cm, or over the glenoid rim). The fingers of the left hand should be positioned with the middle finger on the coracoid and index finger on the humeral head. In this way abnormal anterior translation can be appreciated, as the index finger moves forward relative to the middle finger. To perform the apprehension test, move the right hand to the patient's right wrist and keep the left hand on the shoulder. With the arm in adduction and internal rotation the shoulder will not be anteriorly subluxated. From this position bring the arm into abduction and external rotation while using the left hand to palpate any anterior subluxation (Leffert and Gumley, 1987). Using the left thumb to push the humeral head forward can augment the test.

**Apprehension (Crank) Test and Relocation Test**

The remaining tests are best performed with the patient supine with the shoulder brought just beyond the edge of the examination table beginning with the apprehension or crank test. The test is performed by external rotation of the abducted arm. Classically, it is performed with the arm at 90° of abduction, but this can be varied to stress different portions of the glenohumeral ligament complex. While one hand rotates and abducts the arm, the other should be used to palpate the anterior and posterior shoulder to reference the direction of any movement. The test can be augmented by pushing the humeral head anteriorly from behind. Finally, the relocation test can be performed by pushing posteriorly on the upper part of the humerus. This part of the test is positive if the apprehension of pain is relieved, thereby allowing further external rotation before reemergence of the patient's symptoms. Patients with classical anterior impingement often experience pain without apprehension during the apprehension test, with the pain being relieved by the relocation maneuver.

**Sulcus Sign**

Applying inferior traction to the arm assesses inferior instability. Gross instability is demonstrated by visible widening of the subacromial space with a sulcus appearing in the adjacent area just distal to the lateral acromion (sulcus sign). It is important to remember that normal shoulders can translate, significantly (Harryman et al., 1990). It is also important to appreciate the significance of generalized ligamentous laxity, particularly in patients with multidirectional instability. The examiner should test for this by looking elbow, finger, and thumb hyperextension together with knee recurvatum and increased ankle dorsiflexion.

**Posterior Apprehension**

Posterior apprehension is elicited by maximally internally rotating the humerus with the shoulder in 90° of abduction and then applying a posteriorly directed force on the humeral head. In a positive test the patient feels as if the shoulder is about to dislocate. O'Driscoll (1991) found this test to be highly sensitive and specific for posterior shoulder instability. It can be differentiated from impingement by the absence of relief after injecting local anesthetic into the subacromial space. Often, however, posterior instability is not associated with pain or apprehension, and so most clinical tests rely on the detection of the subluxation that occurs in certain arm positions.
**Posterior Subluxation Testing**

Posterior subluxation usually occurs with the arm in adduction and intern rotation combined with some degree of flexion. Abduction and external rotation relocate the subluxated shoulder. This test, devised by the senior author, utilizes these observations in a clinical test similar to Ortolani's test for hip subluxation. To assess the right shoulder, the examiner stands in the axillary region of the patient who is supine with the right shoulder off the edge of the bed. The examiner's left hand takes the elbow and positions the arm in a position of adduction, internal rotation, and 70-90° of flexion. The examiner's right hand is positioned over the top of the shoulder with the thumb on the anterior shoulder and fingers on the posterior joint line. With the arm in this position, the thumb of the right hand is used to apply a posterior force on the humeral head to achieve posterior subluxation. With the shoulder subluxated the humeral head fills the normal hollow that is present below the acromion. From this position the arm is brought out slowly into abduction and external rotation and will, at some point, relocate with a clunk which is palpable with the right hand.

**Investigation**

Routine radiographic evaluations are an essential component of the assessment and should include an anteroposterior, axillary, and lateral view of the shoulder in the plane of the scapula. These can be supplemented with the caudal-tilt view (a 10° tilt of the x-ray beam) for assessing the supraspinatus outlet (Neer and Welsh, 1977). Pathologic findings predisposing to impingement include subacromial spurs, acromioclavicular spurs, a hooked acromion, or an os acromiale. Evidence of instability may include a bony Bankart lesion, glenoid erosion, a Hill-Sachs lesion, or subluxation of the glenohumeral joint. Supplementary radiologic tests such as arthrography, CT, and MRI are usually not necessary. CT is the best modality to assess any bony defects if required. MRI is very sensitive and shows signal changes in the rotator cuff in asymptomatic individuals. It is the modality of choice in the evaluation of suspected rotator cuff tears.

**Management**

**Group 1: Pain Secondary to Pure Impingement**

This is an uncommon group of athletes, usually over the age of 35, with impingement and no instability. Treatment is initially conservative with avoidance of throwing, stretching, and rotator cuff strengthening. Only after 6-12 months of conservative treatment should surgical treatment be considered. Arthroscopic acromioplasty may then be indicated if there are acromial spurs or an acromial hook together with bursal inflammation or bursal-sided rotator cuff pathology. If the athlete has a rotator cuff tear and no instability then operative repair may be indicated if conservative measures fail or if the tear is large. The prognosis for return to the athlete's former level of performance is, however, very poor (Tibone et al., 1986).

**Group 2: Pain Secondary to Instability Owing to Anterior Ligament and Labral Injury with Secondary Impingement**

This group has superior or anterior impingement owing to a definite anteroinferior ligamentous or labral injury. They do not have multidirectional laxity and therefore do not
have posterior subluxation. Initial treatment is conservative with rest from throwing activities and anti-inflammatory medication to resolve the rotator cuff tendonitis. This is followed by therapy with particular emphasis on rotator cuff strengthening, scapular stabilization, and posterior stretching. This leads to an improvement in some; however, others fail, especially if they have significant structural pathology, such as a large Bankart or Hill-Sachs lesion. Surgery may then be indicated in the form of a capsulolabral repair (unless there are very large bony defects requiring more complex reconstructive surgery).

**Group 3: Pain Secondary to Instability Owing to Hyperelastic Capsular Ligaments with Secondary Impingement**

This group is similar to group 2 except they tend to have multidirectional laxity that affects both shoulders and often have generalized ligamentous laxity. They also have features of rotator cuff tendonitis and impingement. For this group, nonoperative treatment is the mainstay of therapy with emphasis on rotator cuff strengthening and scapular stabilization. Surgery may be indicated if there is failure of nonoperative management, but without a discrete pathologic entity and in the face of laxity in all the ligaments, success cannot be guaranteed. Surgery usually takes the form of a capsulolabral reconstruction together with a capsular shift to effectively tighten the ligaments. In this case the balance between obtaining stability and not over-tightening the shoulder is difficult to achieve. The other concern is that over-tightening the anterior structures alone may accentuate a previous and subtle posterior instability. It is partly owing to these technical difficulties that nonoperative treatment is pursued so vigorously in these cases.

**Group 4: Pain Secondary to Pure Instability without Secondary Impingement**

These athletes have instability without impingement. If the instability is multidirectional and associated with generalized ligamentous laxity as in group 3 then they are managed along similar guidelines with emphasis on nonoperative management. If they have a more discrete pathologic lesion such as a Bankart lesion, they are more likely to fail nonoperative management and have a better prognosis with surgery.

**SUPERIOR LABRAL AND BICEPS LESIONS**

The long head of biceps tendon runs up the bicipital groove under the transverse ligament and then runs through the shoulder joint to attach to the superior glenoid via the superior labrum. The biceps tendon and superior labrum can be involved in various pathologic processes, including bicipital tendonitis, biceps rupture, biceps tendon subluxation or dislocation, and tears of the superior labrum. Since the advent of arthroscopy, lesions of the superior labrum and biceps anchor have been more clearly defined (Snyder et al., 1990).

**Pathophysiology**

Throwing is associated with high activity in biceps, and this is thought to pre-dispose the athlete to superior labral tears, including SLAP lesions (Fig. 32-4).
Evaluation

Superior labral lesions are often associated with instability, and the symptoms may be nonspecific. Anterior shoulder pain, clicking, and popping may however, be due to labral or biceps lesion (Snyder et al., 1990). The following tests may help to isolate biceps or labral pathology.

Yergason's Test

In this test the elbow is flexed to 90° and the forearm is pronated (Yergason, 1931). At this point the examiner holds the patient's wrist to resist active supination by the patient. Pain in the bicipital groove is a positive test and indicates possible wear or tendonitis of the biceps tendon.

Speed's Test

This involves having the patient forward flex the shoulder against resistance while maintaining the elbow in extension and the forearm in supination. Pain or tenderness in the bicipital groove indicates bicipital tendonitis. Field and Savoie (1993) found this test to cause nonspecific shoulder pain in all of their series of patients with superior labral lesions, suggesting that it does test for the competence of the biceps anchor.

Clunk Test

The clunk test has been described, whereby the arm is rotated and loaded from a position of extension to one of forward flexion. A clunk-like sensation may be felt if a free labral fragment is caught in the joint. This test is similar to the McMurray's test of the knee. Studies have shown that a click on manipulation of the glenohumeral joint is a common finding in patients with labral tears even in the absence of joint instability (Glascow et al., 1992; Liu et al., 1996).
Investigation

These lesions are difficult to diagnose and certain investigations may be very valuable. Usually contrast is required to show the pathology with any degree of sensitivity. CT arthrography and MR arthrography have both been shown to be effective.

Management

Treatment depends on the degree of damage to the labrum and the stability of the biceps. In many cases involving young athletes there is superior labral damage and associated mechanical instability of the biceps anchor requiring fixation (Rames and Karzel, 1993). In most cases repairs of this type can be achieved arthroscopically.

BENNET LESION

Posterior ossification of the shoulder is a lesion first described by Bennett III 1947 (Fig. 32-5). He described a deposit of bone on the posterior inferior border of glenoid fossa that he thought was owing to traction by the origin of the long head of triceps and was an exostosis. He believed the lesion caused symptoms by local irritation of the capsule, synovium, and axillary nerve.

Further studies using arthrography, CT, MRI, arthroscopic and histologic evidence have provided further knowledge. The lesion extra-articular, in the region of the posterior band of the inferior glen humeral ligament complex (IGHLC) and is not related to the long head the biceps (Ferrari et al., 1994; O'Brien et al., 1990). The lesion is commonly associated with intra-articular pathology, most commonly tears of the posterosuperior labrum, but also posteroinferior labral tears, posterior instability, and posterior undersurface rotator cuff tears (Ferrari et al., 1994). Histologic and MRI studies have not demonstrated any cancerous bone or bon marrow, and this suggests that the lesion is neither an exostosis nor an
osteophyte. It has been shown to be reactive new bone formation at capsular insertion to the posterior glenoid.

Pathophysiology

The cause of the lesion remains unclear, but it seems most likely to be owing to traction on the posterior band of the IGHLC, either during late cocking when subscapularis contraction may cause posterior subluxation of the glenohumeral joint, or during follow-through when there are large distractive forces on these ligaments.

Evaluation

Symptoms may be gradual in onset or develop suddenly (Bennett, 1947). Pain is felt posteriorly with occasional radiation to the deltoid region. Pitchers can throw hard only for a limited time, and as pain increases performance declines. Often the shoulder is asymptomatic and functions normally unless the athlete attempts to throw hard. In a series of seven pitchers with Bennett lesions, all had posterior shoulder pain, mostly in the follow-through phase of the pitch; some experienced it only during cocking. All had posterior glenoid tenderness, two had evidence of posterior instability, and none exhibited any anterior instability (Ferrari et al., 1994).

Investigation

The lesion cannot usually be seen on standard shoulder radiographs. A modified anteroposterior radiograph with the arm in 90° of abduction and in maximal external rotation and the beam tilted 5° cephalad brings the abnormal area of the glenoid into relief (Bennett, 1947). CT is the investigation of choice to demonstrate the bony abnormality and shows extra-articular curvilinear calcification originating from the posterior inferior glenoid extending toward the humeral head. MRI shows the lesion, although it is not as good as CT in demonstrating cortical bone. It is, however, more sensitive in defining the commonly associated intra-articular pathology, particularly if combined with arthrographic techniques.

Management

Bennett (1959) described how the lesion could be approached and removed using a posterior approach to the shoulder but stated that operative treatment was not advisable. There is no agreement as to the cause or treatment of the lesion. Most agree that a trial of nonoperative management involving rest, nonsteroidal anti-inflammatory drugs (NSAIDs), and rehabilitation should be undertaken before anything more aggressive is considered. Lombardo et al. (1977) reported on a series of four pitchers who failed nonoperative treatment and underwent open posterior excision of the lesion with "encouraging" results. It is not clearly stated if they returned to their former level competition. In Ferrari et al.'s (1994) series of seven pitchers (six professionals) all but one returned to their former level of performance after surgery, which involved arthroscopy and treatment of the intra-articular pathology without visualization or treatment of the lesion itself.
SHOULDER INJURIES IN CHILDREN

Even though the elbow is more commonly affected in skeletally immature baseball players than the shoulder, significant lesions can occur at this site owing to the unique stresses encountered as a result of pitching. The pathology seen in children is different from adults owing to the presence of growth plates, which are weaker than the surrounding ligaments and joint capsule. IC proximal humerus has three centers of ossification involving the head the greater and lesser tuberosities, which coalesce at age 7 and fuse to the shaft at approximately 20 years. Acute injuries to the shoulder girdle can occur in baseball owing to falls and collisions, and these may result in variety of fractures and growth plate injuries.

The chronic overuse injury that occurs due to repetitive trauma associated with pitching is Little Leaguer's shoulder. This was first described by Otter in 1953, who believed that the injury was owing to fracture through the proximal physeal plate. Adams (1966) reported a similar injury in five adolescent pitchers. He believed the injury was owing to a repetitive traction injury of the proximal humeral physis. All boys in his series were between 13 and 15 years of age and presented with vague shoulder pain at the end of hard throwing motions. All had over-development of the affected shoulder but there was little else to find on examination, except for occasional local tenderness and pain on jerking the outstretched arm. Comparative x-ray studies are the key to making the correct diagnosis, revealing widening of the proximal humeral epiphysis and demineralization of the proximal epiphysis, without evidence of avascular necrosis.

The condition usually responds rapidly to rest, and there is unlikely to be any long-term sequelae. Some authors have recommended that pitching be ceased until the physis has closed, although others suggest that one season of rest is usually adequate (Adams, 1966; Tibone, 1983).

ELBOW INJURIES IN ADULTS

Acute and chronic valgus and hyperextension stress produce a different set of pathologic entities in the adult than in the child. The weakest link in the lowing immature elbow is the growing epiphysis and the intervening physeal plates. In the young adult it is the ligaments that tend to fail initially (Pincivero et al., 1994). The medial collateral ligament complex consists of three parts: an anterior oblique bundle, a posterior oblique bundle, and a transverse band, which is of little functional significance. The anterior oblique band arises from the medial epicondyle and inserts into the medial border of the coronoid process, and it is the primary stabilizer against valgus stress with the elbow in extension. The posterior bundle is a fan-shaped ligament that uses from the medial epicondyle and inserts into the olecranon; it is taut with the elbow in flexion (Morrey and An, 1985; Regan et al., 1991).

Repetitive forceful valgus stress is associated with the development of medial stress syndrome that can involve a number of different pathological entities, including the valgus-extension overload syndrome, medial collateral ligament injuries, and ulnar neuritis.

Andrews and Timmerman (1995) found that in professional base pitchers undergoing surgery for elbow injuries, the most common types pathology were posteromedial olecranon osteophyte, ulnar collateral ligament injury, and ulnar neuritis.
Valgus-Extension Overload

Pathophysiology

Pitching results in very high valgus and extension forces on the elbow, and this can lead to a specific impingement syndrome in the posterior compartment of the elbow. Wilson et al. (1983) drew attention to this syndrome and the importance of recognizing the medial as well as posterior osteophyte formation that occurs on the olecranon owing to attenuation of the medial ligament. Hypertrophy of the distal humerus adds to the impingement narrowing the olecranon fossa.

Evaluation

Pain is felt posteromedially and often increases during the game. Pain is often associated with poor pitching control that the pitcher may attempt to compensate for by snapping the elbow, which may further reduce control. Localized tenderness with pain or valgus stressing in extension is the classic examination finding. There may be associated ulnar neuritis owing to impingement of the ulnar nerve on the osteophyte.

Investigation

Plain x-rays with axial images will usually demonstrate the posteromedia osteophyte formation on olecranon. Occasionally the lesion is cartilaginous and recognized only at arthroscopy.

Management

Rest and NSAIDs should be used initially to reduce any associated synovitis. An attempt should be made to improve the range of motion without producing pain using a careful stretching program. If this fails to resolve the symptoms, surgical excision is highly successful.

Medial Collateral Ligament Injuries

Pathophysiology

The anterior bundle is the most important stabilizer against valgus stress. Injury is usually a chronic overuse syndrome but may be an acute event.

Evaluation

Often there is a history of chronic medial-sided elbow pain related to throwing. Acutely there is tenderness and swelling that is maximal toward the ulnar attachment of the ligament, as this is where the ligament avulsion occurs. Stability testing of the medial collateral ligament can be performed by applying a valgus stress to the elbow held in approximately 25° of flexion, which unlocks the olecranon from its fossa. The clinician must look carefully for evidence of ulnar neuritis, which is often associated.
Investigation

Stress views comparing both elbows often aid in confirmation of the diagnosis. X-rays may show spur formation in the region of the coronoid process of the ulna and calcification in the region of the medial ligament. A quite distinctive change seen in baseball pitchers is single or multiple ossicles of bone seen along the course of the medial ligament (Bennett, 1959).

Treatment

Most athletes are managed conservatively with a period of rest, ice, and NSAIDs, followed by therapy to regain motion and strength. Chronic instability with pain and inability to throw after 6 months of conservative therapy may be an indication for ligament repair or reconstruction. Jobe et al. (1986) reported that 10 out of 16 throwing athletes returned to their former level of sport after a ligament reconstruction using autologous tendon grafts.

Ulnar Neuritis

Pathophysiology

Ulnar neuritis is common in throwing and pitching athletes and is usually owing to mechanical irritation, which can be from repetitive tension, compression, or friction. In the arm the nerve passes from the extensor compartment to the flexor compartment about 8-10 cm above the elbow joint. Here it passes through the fibrous arcade of Struthers where it may be compressed. It passes distally to course posterior to the medial epicondyle and enters the cubital tunnel. Within this tunnel the nerve lies adjacent to the medial epicondyle and medial edge of trochlea and is roofed by the triangular arcuate ligament, which extends from the medial border of the olecranon to the medial epicondyle. After exiting the tunnel the nerve then passes between the two heads of flexor carpi ulnaris. Compression of the nerve can occur at any point along its course but in the case of throwing athletes one of several pathologic entities tends to occur:

1. Traction neuritis may exist due to valgus deformity of valgus instability.
2. Compression of the nerve against posteromedial osteophytes that is seen as part of the valgus extension overload (Wadsworth, 1977).

Evaluation

Usually there is insidious onset of ulnar-sided elbow pain with associated paresthesia in the ulnar nerve distribution. Examination may reveal tenderness or instability of the nerve at the elbow together with a positive Tinel's sign. Neurologic abnormalities may be present, but are often subtle or absent.

Investigation

Radiographs of the elbow may reveal spur formation or calcification in the region of the ulnar nerve or medial collateral ligament. EMG studies should be done but may be negative in up to half of the cases.
Management

Initial treatment involves rest, activity modification, and NSAIDs followed by therapy, particularly aimed at strengthening of the flexor and pronator groups. The likelihood of resolution if symptoms are chronic is relatively poor, and surgery may be indicated. This usually involves anterior transposition of the nerve.

ELBOW INJURIES IN CHILDREN AND ADOLESCENTS

Chronic conditions affecting the elbow are rare in the general population but are relatively common among baseball players owing to the stress of throwing. The elbow is the most frequent area of complaint in children and adolescent baseball players (Gugenheim et al., 1976). As previously outlined, the main forces are tensile on the medial side of the elbow and compressive on the lateral and posterior aspects of the elbow.

Little Leaguer's elbow describes the abnormal changes that occur in the pitching elbows of the skeletally immature. It may refer to medial epicondylar abnormalities (accelerated growth and separation or fragmentation of the epiphysis), osteochondritis of the capitellum, or osteochondritis of the radial head in any combination (Adams, 1965).

It is important to have some understanding of the way the elbow ossifies and the order in which the epiphyses appear and fuse. At birth the entire elbow is a radiolucent cartilaginous anlage. During childhood the different regions of the elbow undergo ossification in a predictable sequence starting with the capitellum, which begins to ossify at approximately 2 years of age. This is followed by ossification in the radial head epiphysis at about 4-5 years, the medial epicondylar epiphysis at about 5-7 years, the trochlear epiphysis at 8-9 years, and the lateral epicondyle and olecranon that appear between 9 and II years of age. There is quite a significant amount of variation, depending on the physiologic maturity of the individual; for this reason the epiphyses tend to appear earlier in girls. Fusion of the ossified epiphyses to the shaft of the bone occurs at between the ages of 13 and 16 in boys and II and 14 in girls, with the trochlea being the first to fuse (Pappas, 1982). Pappas uses skeletal maturity to define three stages of development that render the elbow susceptible to different pathologic processes.

1. Childhood -This includes children up to the age of about 11-12, when the secondary ossification centers are appearing but have not yet fused to the shaft. During this time the cartilage anlage is being vascularized and ossified, and is highly vulnerable to excess physical forces. Injury at this time is likely to cause degeneration and necrosis of the epiphysis followed later by regeneration. This is an osteochondrosis and it may affect the medial epicondyle, olecranon, trochlea, or capitellum. Osteochondrosis of the capitellum is known as Panner's disease.

2. Adolescence -This is the period that begins when all secondary centers have appeared and ends when all long bones physes have fused (up to the age of approximately 14 in girls and 17 in boys). In this time period, the secondary center has been formed and is now most vulnerable at its periphery, which is at its junction with the physis (growth plate) and at its articular surface. Injury at this time results in subchondral avascular necrosis (osteochondritis dissecans), which usually affects the capitellum, and physeal separations and nonunions, which usually affect the medial epicondyle or olecranon.
3. *Young adult* - This period encompasses the first 3-5 years after closure of the physes. During this period we begin to see the emergence of adult types of pathology, but one can still see late presentations and sequelae of the adolescent problems.

**Osteochondritis Dissecans of the Capitellum**

*Pathophysiology*

In this condition there is fragmentation and possible separation of a portion of the articular surface (Pappas, 1982). Repetitive compressive and shearing forces are thought to be important etiologic factors (Clanton and Delee, 1982; Pappas, 1982). In adolescents it is commonly seen in conjunction with abnormalities of the medial epicondyle together with enlargement and deformity of the radial head, and it is then often called Little Leaguer's elbow (Adams, 1965).

*Evaluation*

The first symptom may be pain after a season of pitching, which later becomes more severe and activity related, and may be associated with intermittent swelling. As the disease progresses there is often a loss of full extension followed by the loss of pronation and supination. Catching, locking, and intermittent severe pain suggest the presence of loose intraarticular fragments. Examination may reveal a joint effusion, local tenderness over the capitellum, loss of range particularly in extension, and crepitus on movement.

*Investigation*

Sequential changes can be seen on plain x-ray, although CT scanning may be more sensitive in evaluating the more subtle changes. Evaluation of the overlying articular cartilage requires the use of either arthrography or MRI. The earliest changes on plain radiographs are an area of subchondral rarefaction surrounded by a sclerotic rim. Later there is flattening of the capitellum seen particularly on the lateral view, followed by fragmentation and possibly the development of loose bodies (Clanton and DeLee, 1982).

*Treatment*

The mainstay of treatment is conservative, with rest and avoidance of throwing. This needs to continue until healing of the capitellum, which can be followed by serial x-rays taken at 6-month intervals. Arthroscopic surgery is reserved for those cases where there is evidence of loose or unstable fragments causing mechanical symptoms (Morrey, 1994).

**Osteochondrosis of the Capitellum: Panner's Disease**

*Pathophysiology*

This is abnormal growth or ossification of the capitellar epiphysis and occurs at a younger age than osteochondritis dissecans. It was first described by Panner in 1927 and was likened to Legg-Perthe's disease of the hip. It is seen most commonly in children between the ages of 5 and 10 and is more common in baseball players and gymnasts than in the
general population. It is thought to occur as a result of vascular insufficiency during the critical stages of ossification.

**Evaluation**

Pain, local tenderness, and loss of motion are the most common features. The development of unstable or loose osteochondral fragments causing mechanical symptoms such as locking is unusual in this condition.

**Investigation**

The radiologic changes are similar in sequence to those occurring in Legge-Perthe's disease, with sclerosis and fragmentation followed by lucency and later by re-ossification. MRI can also be used and shows the typical sequence seen when there is avascular necrosis of bone with loss of the high signal normally seen in healthy bone marrow on T1-weighted images. These changes occur much earlier than radiographic changes.

**Management**

Rest and cessation of throwing activities usually result in the resolution of symptoms. Radiologic follow up until there is re-ossification and healing should occur before consideration is given to resumption of activities.

**Osteochondritis of the Olecranon Pathophysiology**

The development of the condition is similar to what has already been lined in case of capitellum.

**Evaluation**

These adolescents present with pain, swelling, and tenderness.

**Investigation**

Radiologic investigation reveals fragmentation and irregularity of the l'pl physis, and in these cases comparison to the opposite side is often helpful

**Management**

Treatment is symptomatic with rest and activity modification until resolution, which may take several months.

**Olecranon Epiphyseal Nonunion or Stress Fracture**

**Pathophysiology**

This is owing to failure of fusion of the olecranon physeal plate, which normally occurs at about 16 years of age in boys. It has been reported in baseball players and may be related to the repetitive stress of pitching.
Evaluation

There is pain, swelling, weakness, and tenderness present. Radiographs may show widening of the physeal line or simply failure of the epiphysis to fuse. There is considerable variation in the appearance and position of the physeal line so comparison with the opposite side is vital.

Management

Treatment initially involves a period of immobilization in an achieve union, but it may require operative fixation if this fails.

Disorders of the Medial Epicondyle

Pathophysiology

The medial epicondyle is the site of origin of the medial collateral ligament and the powerful forearm flexors. Throwing and in particular pitching place enormous stresses through this region, and in those who are skeletally immature, it is the medial epicondylar epiphysis and the intervening growth plate that are most susceptible to injury. It is also important to consider ulnar nerve pathology, which may be coexistent. The ulnar nerve may be unstable in the ulnar groove, allowing irritation and an ulnar nerve palsy to occur.

Evaluation

The overuse syndrome is characterized by insidious onset of medial-sided elbow pain with localized tenderness and pain on valgus stressing of the joint. Occasionally, an acute separation of the epiphysis can occur with onset of severe pain.

Investigation

Adams (965) showed radiographic changes in 100% of Little League pitchers between the ages of 9 and 14. These changes included accelerated growth, separation, or fragmentation of the epiphysis as compared to the nonthrowing side. At least 45% of the pitchers were symptomatic but only till direct questioning, and the study concluded by recommending guidelines for young pitchers that limit the amount of pitching and abolish the throwing of curve balls, which places even more stress on the elbow.

Management

Separation of the epiphysis by 1 cm or more together with valgus instability is an indication for surgery, with open reduction and fixation of the fragment being the goal. Most cases are less severe without instability and can Ill' managed by rest and activity modification.

CONFOUNDING CONDITIONS

Overuse of the arm, especially in the pitchers, and performing activities that unduly stress the arm are significant factors in development of chronic injuries of the upper limb.
Disregard for proper fundamentals of pitching or throwing is an example of this. Introduction of off-speed pitches too early in the career of a young pitcher, which mechanically stress the elbow and shoulder, along with increased ligamentous laxity of younger players, can lead to serious and chronic injuries (Clark, 2002).

**PREVENTION**

Baseball is generally considered to be a safe sport. Nevertheless almost 500,000 baseball-related injuries are treated yearly in the United States. There are important preventative measures that can be utilized by parents and coaches to reduce the risk of both acute and chronic injuries. Equipment should be fitted and worn properly. This includes cleated baseball shoes and batting helmet, which should be worn while waiting to bat, at the plate, and while running the bases. Additionally, catchers should always wear a helmet, facemask, throat guard, long-molded chest protector, protective supporter, catcher's mitt, and shin guards. Position players need the appropriate baseball glove for their specific position. Facial protective devices that attach to batting helmets are available and can reduce the risk of serious facial injuries.

Stretching the muscles and taking time to perform the appropriate warm up are very important. Warm up should start with a 3- to 5-minute duration of jumping jacks, stationary cycling, or running, followed by slow and gentle stretching. Pitchers should concentrate on the shoulder, arm, and back muscles. Catchers should focus on the muscles of the legs and back.

Overuse is to be avoided, especially in pitchers. Different leagues have specific guidelines for number of pitches allowed per week. The usual number of innings allowed is between 4 and 10. The number of pitches throw should be carefully followed. It is reasonable to aim for maximum of 80-100 pitches in a game and 30-40 pitches in a practice. Finally, one must be able to recognize the signs and symptoms of injuries such as pain, swelling, an limitation of motion. One should not attempt to “play through the pain” (American Academy of Orthopaedic Surgeons, 2003).

**SIDELINE TIPS**

Knowledge of first aid is important and one must be able to treat facial cuts bruises, minor tendonitis, strains, and sprains. Ice is the universal first aid treatment and should always be available. One must remember that in children injuries that resemble sprains in adults could indeed be physeal fractures. One must have a plan for transferring the player safely to medical per, sonnel in case of more serious injuries such as concussions, dislocations, fractures (American Academy of Orthopaedic Surgeons).

**SUMMARY**

Baseball continues to be a popular sport with increasing numbers of participants over a wide age range. Falls, collisions, and direct impact injuries occur, but these are relatively easy to diagnose with appropriate diligence. Injuries that are relatively unique to baseball occur owing to repetitive chronic stress overload, most commonly owing to pitching. An understanding of the mechanics of throwing gives the clinician important insight into how
these injuries occur and which anatomic structures are most at risk. The clinician also needs to appreciate how the age of the individual significantly alters the likely spectrum of pathology encountered in a given joint or region. This is because the anatomic structures that are most susceptible injury change as the individual matures.

Appropriate injury prevention strategies are also important and can be logically developed with knowledge of the pathology that occurs with overuse particularly in the skeletally immature, who are most susceptible to long term complications, especially in the elbow joint.

REFERENCES


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