UPPER EXTREMITY INJURIES IN YOUNG ATHLETES

Mary Lloyd Ireland, MD, and Mark R. Hutchinson, MD

Upper extremity injuries in the skeletally immature athlete are unique because of joint laxity, undeveloped musculature particularly about the shoulder, physeal plates, articular surface softness, bone immaturity, and plasticity. Appreciation of these factors enables the health care professional to diagnose injuries earlier and treat the injured youngster more effectively. Examples of specific cases of upper extremity fractures and overuse microtraumatic disorders will be presented. Although the numbers of children involved in organized sports has increased, there does not appear to be a greater incidence of epiphyseal fractures.[43, 44] The young athlete has a lower injury rate than the adolescent.[26, 43, 53, 63] The routine management of fractures in the skeletally immature patient is not reviewed; for care of particular fractures, use of standard pediatric textbooks is suggested.[61, 70, 76, 81] Injuries commonly seen in certain sports, particularly as they relate to the shoulder and elbow in baseball, are reviewed.

Baseball serves as the earliest organized and regulated sport for the skeletally immature. Fortunately, regulations have been enforced in Little League baseball, restricting the numbers of innings pitched and enforcing days of rest for pitchers.[59] In the past, baseball injuries have been career ending and life and goal changing. Little League coaches and parents are willing to accept help from the medical community evidenced by publications such as *Play It Safe* and the willingness to have medical teams provide instruction.[48]

In female athletes, gymnastics and cheerleading are the cause of most upper extremity injuries. Distal radius epiphyseal and both bone forearm fractures, shoulder instability, and numerous elbow disorders are common in these young women. In tennis athletes, it has been reported the bone diameter and density of bone substance are increased, along with the length of the dominant arm when comparing dominant to nondominant upper extremities. This series was in athletes who begin playing highly competitive tennis by age 11.[41] The common

From the Kentucky Sports Medicine Clinic, Lexington, Kentucky (MLI); and University of Illinois at Chicago, Chicago, Illinois (MRH)

baseball injury is overuse due to the biomechanics and intensity of throwing, laxity of the shoulder, or stresses about the elbow. Macrotraumatic injuries do occur from sliding and contact involved in batting and base running, however.

BIOMECHANICS

Many sports have been studied by biomechanical and electromyographic (EMG) analysis. To understand and treat athletes in specific sports, the biomechanics of the sport must be understood.[9, 68] The Little League pitcher serves as a model for injuries in the skeletally immature. The phases of throwing are similar in the skeletally immature and mature athlete.[25, 39, 40, 90, 101] These five phases are wind-up (as the pitcher prepares for the throw); early cocking (from the ball leaving the glove until the foot hits the ground); late cocking (with the shoulder in maximal external rotation); acceleration (beginning with shoulder internal rotation and ending with ball release); and follow-through (starting with ball release). Studies which analyze joint forces and muscle activity in the young athlete are needed. Differences in the adult and Little League pitcher can be seen in all phases. Inadequate transfer of forces from the trunk owing to a shorter stride, more upright posture, and poor balance create more stresses on the upper extremity, particularly shoulder and elbow. Comparing ten fast ball pitchers at Little League and professional level, the Little Leaguers had less internal rotation velocity and shoulder compression forces; however, greater forces at the elbow in extension torque and follow-through, and prolonged elbow valgus movement were present.[91] Children who pitch with side arm motions are three times more likely to develop problems than those with a more overhand technique.[4, 82] The compression forces on the elbow laterally and tensile forces medially are of concern in the Little League pitcher who throws curve balls incorrectly.

EMG and biomechanical analysis of multiple sports has been done.[9, 27, 40, 68, 73, 74] In baseball, the pitching phases have been defined.[39, 40, 101] The skeletally immature athlete should be taught proper throwing skills by coaches. This can be important for injury prevention.

EPIDEMIOLOGY OF INJURY

More research needs to be done on injury patterns in the skeletally immature athlete. Ideal situations for studying injury patterns exist in organized Little League baseball, cheerleading, gymnastics, soccer, and swimming. Injury statistic studies at the elementary and high school level have been published.[19, 26, 61, 100] Most injuries involve the lower extremity. Tabulating 841 sports injuries in athletes from the ages 8 to 17 in the Netherlands, the top upper extremity injuries were phalanges (11%), wrist (4.4%), distal humerus (2.9%), and proximal humerus (2.8%).[10]

Most of the published literature regarding unique injuries has been written about the Little League athlete. In these immature athletes, shoulder and elbow injuries have been highlighted. Dotter described Little Leaguer's shoulder in 1953 as a fracture of the proximal epiphyseal cartilage of the humerus occurring in baseball pitching.[2, 22] Adams described "Little League shoulder" as osteochondrosis of the proximal humeral epiphysis in boy baseball pitchers.[3] Concerns were raised regarding the nature and severity of shoulder and elbow injuries in

Little League.[4, 18, 47, 87, 88, 90] Six case reports of humerus fractures were published by Weseley.[92]

Upper extremity epiphyseal fractures have been reported in several large series. Three large series (Table 1) are shown.[57, 62, 69] Neer's [57] series consisted of 1760 fractures, Peterson 232,[69] and Ogden 457.[62] Of the upper extremity, the distal radius was the most common physeal fracture ranging from 42% to 62%. The distal radius was number one in all series, followed by distal humerus, phalanges, distal ulna, proximal radius, and proximal humerus epiphyseal fractures. Documentation of mechanism of injury and relation to organized sports or free play was not included.[57, 62, 69, 83]

SHOULDER

Growth and Development

Appearance and fusion of the ossification centers of the humerus, clavicle, acromion, and scapula are shown diagrammatically (Fig. 1*A–B*).[84] The average ages of appearance are noted with the proximal humeral epiphyseal ossification center present at about 3 months. The greater tuberosity center appears between 6 and 18 months. By 4 to 7 years of age these two centers fuse. The scapula, coracoid, acromion, and clavicular ossification and appearance and closure are later. The medial clavicular secondary ossification center appears at age 17 with closure age 18 to 24 years. The acromion secondary ossification center appears at age 15 to 18 and fuses at 18 to 19 years of age. Failure of acromial fusion to the scapula is an os acromiale. The coracoid tip fuses by age 18 to 21. Knowledge of the appearance and closure of secondary ossification centers is necessary to treat the skeletally immature athlete.

Physical Examination

Particularly about the usually physiologic lax shoulder, the lack of muscular development may result in force imbalance during repetitive acts like baseball

Table 1. UPPER EXTREMITY EPIPHYSEAL FRACTURES

	Ogden		Peterson		Neer	
	Number	**%**	**Number**	**%**	**Number**	**%**
Distal radius	197	43.1	98	42.2	1096	62.3
Distal humerus	108	23.6	20	8.6	332	18.9
Distal ulna	13	2.8	21	9.1	136	7.7
Proximal radius	12	2.6	1	0.4	124	7.0
Proximal humerus	41	9.0	22	9.5	72	4.1
Phalanges (fingers)	55	12.0	39	16.8		
Metacarpals	9	2.0	10	4.3		
Proximal ulna	9	2.0	21	9.1		
Proximal clavicle	8	1.8				
Distal clavicle	5	1.1				
Total	457	100.0	232	100.0	1760	100.0

Adapted from Ogden JA: Injury to the Growth Mechanisms. *In* Ogden JA (ed): Skeletal Injury in the Child. Philadelphia, W. B. Saunders, 1990, p 97; with permission.

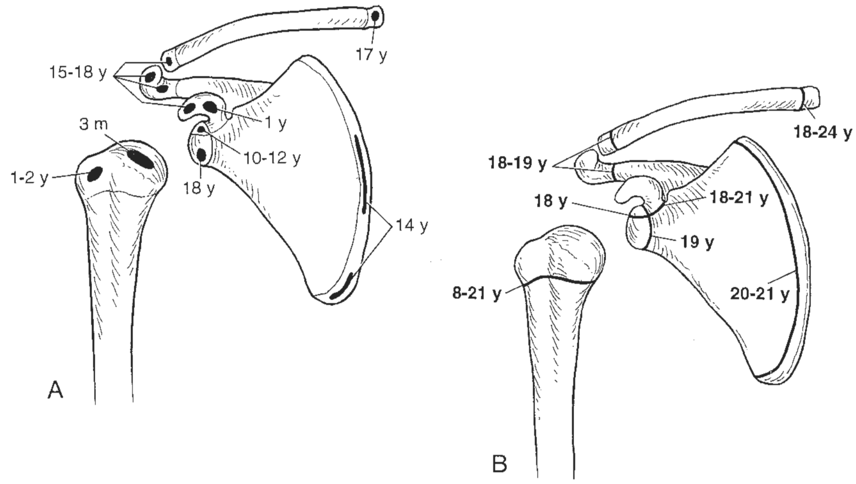

Figure 1. *A*, Average ages of appearance of epiphyseal ossification centers about the shoulder girdle, lines to appearances of greater tuberosity, proximal humerus, proximal and distal clavicle, to acromion, to coracoid, medial scapula, and to glenoid ossification center appearance times. *B*, Fusion of these ossification center ages are shown with lines to proximal and distal clavicle, coracoid, acromion, glenoid, medial scapula, proximal humerus.

throwing, tennis, or swimming. In addition, scapular winging is commonly seen. Figure 2 shows a right-handed, 10-year-old baseball pitcher with no specific shoulder complaints. His examination (Fig. 2*A)* shows significant asymptomatic scapular winging. The anterior glenohumeral subluxation test with the arm abducted, externally rotated, and posterior force applied to the glenohumeral joint is painless. A Lachman test of the shoulder stabilizing the acromion and anteriorly subluxing (Fig. 2*B*) and reducing (Fig. 2*C*) the shoulder also causes no pain. With the arm abducted and externally rotated, painless anterior humeral subluxation occurs (Fig. 2*D*). Posterior luxation is also painless (Fig. 2*E*).

The synchronized swimmer shown in Figure 3 had bilateral mildly symptomatic habitual posterior subluxability of her shoulders. With her arm in a forward flexed internally rotated abducted position, she voluntarily posteriorly subluxed her right shoulder. Radiographs with her shoulder in a posteriorly subluxed position show her face without pain. Radiographs in this position document the posterior dislocation. There were no radiopaque loose fragments or reverse Bankart or reverse Hill-Sachs' lesion.

The extreme forces and abnormal stress of improper techniques applied during the throwing act can result in shoulder injury. Glenohumeral instability usually is the primary diagnosis with secondary rotator cuff and scapulothoracic dysfunction. The incidence of complete rotator cuff tears in the adolescent population is less than 1% of patients of all ages who are diagnosed with a rotator cuff tear.[38, 60] Most injuries are due to microtraumatic forces. Occasionally, the young athlete participates in other sports in which he or she may sustain macrotraumatic injuries like a dislocation. Little League rules limit number of innings pitched on the field during a game but not elsewhere.[59] The normally underdeveloped muscles of the scapulothoracic articulation can result in winging and further contribute to anterior glenohumeral subluxation.

Complaints of shoulder slipping, deep popping associated with pain, loss

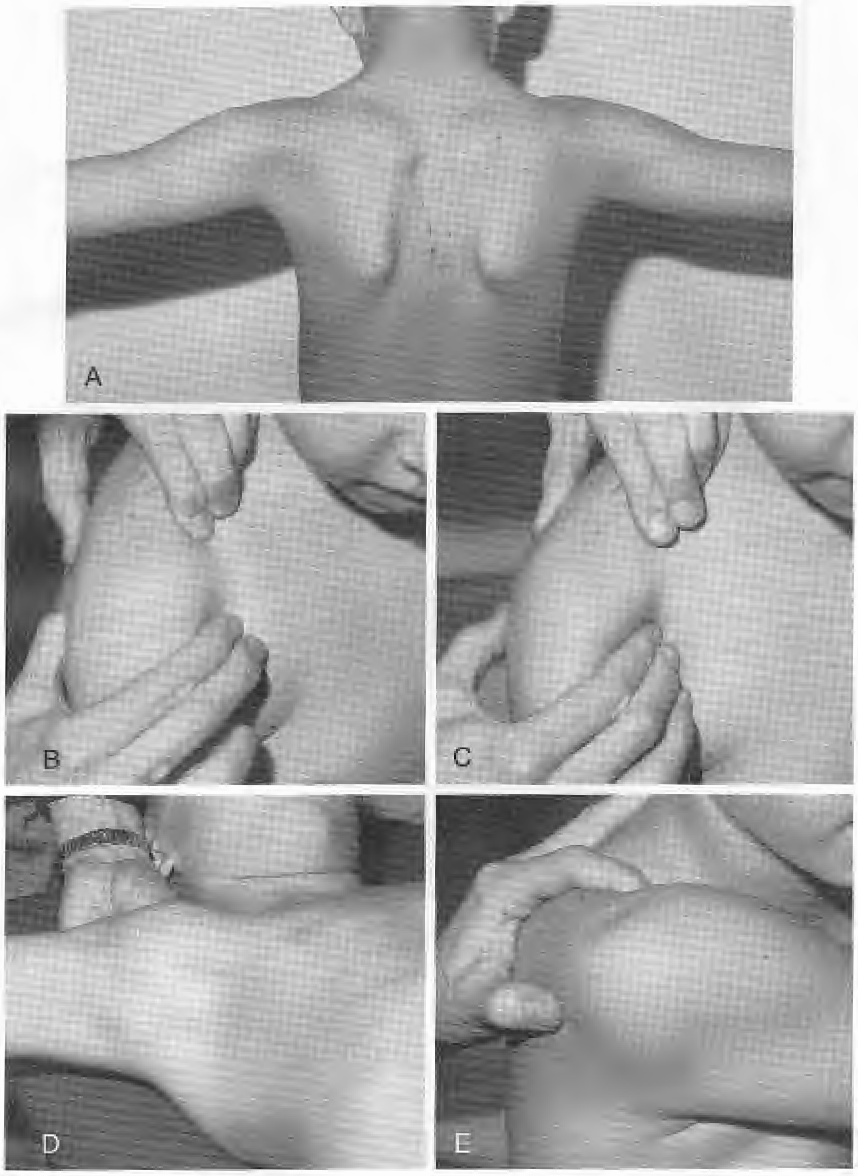

Figure 2. *A,* Scapulothoracic winging that is often present in skeletally immature persons. This 10-year-old pitcher has no shoulder problems. Scapular winging is shown when he resists forward flexion, abduction. *B,* With the athlete relaxed, arm at his side, anterior humeral translation test can be done where the humeral head is subluxed forward and reduced; and *C,* reduced with posterior forces. Note the painless expression in *B* when this maneuver is being done—physiologic anterior laxity is present. *D,* With the arm in an abducted externally rotated position, the humeral head is felt to anteriorly sublux painlessly. *E,* Posterior subluxation with the arm horizontally adducted and internally rotated is also painless.

Figure 3. *A,* Posterior dislocation, habitual, of the right shoulder in this synchronized swimmer. Note the prominence of the humeral head *(arrow).* Athlete has self-dislocated her shoulder with her arm in internal rotation and forward flexion, 100 deg abduction. *B,* Radiograph with the shoulder posteriorly dislocated, osteophyte coming off of the inferior aspect of the glenoid, probable reverse Hill-Sachs' lesion and empty glenoid sign.

of accuracy and endurance, shoulder soreness, arm feeling dead, and decreased ball velocity should alert the medical staff that instability may be present. In the skeletally immature, glenohumeral instability is more likely to be a primary derangement than rotator cuff injury.

Examination of many normal shoulders will enable the treating professional to distinguish the physiologic from the pathologic. Typically there is greater external rotation, tightness of internal rotator musculature, and physiologic anterior laxity in the dominant shoulder of a pitcher. Correlation of complaint, sport, and examination will lead to the correct diagnosis.

Fractures and Dislocations

There are excellent reviews of injuries to the sternoclavicular joint, proximal clavicular epiphysis, and dislocations of the sternoclavicular joint.[17, 75, 96] Clavicle fractures are the most common diaphyseal fracture.[21] The medial epiphyseal plate is the last to close with an age range of 18 to 24 years.[84] Figure 4 shows a fracture of the left medial clavicle that occurred 3 weeks previously from a fall on a shoulder playing baseball. The area of clinical tenderness was at the medial clavicle, not over the sternoclavicular joint. Close scrutiny of radiographs shows the healing fracture (Fig. 4). Computed tomography scan also is helpful in assessment of the medial aspect of the clavicle and sternoclavicular joint distinguishing physeal fracture from dislocation.

Injuries to the acromioclavicular joint occur but ligamentous injuries are rare in this age group. A traumatic pseudodislocation where the distal clavicle lifts up out of the periosteal sleeve has been reported.[13] Distal clavicular physeal injury should be considered in the skeletally immature athlete with pain over the acromioclavicular joint. Conservative management with a superior strap for comfort and to reduce the clavicle is the recommended treatment.[61]

The coracoid epiphysis also can be injured with acromioclavicular separation. Figure 5 shows a right-handed football athlete who fell while running directly on the ground. He had pain specifically at his coracoid anteriorly and no glenohumeral instability. Radiographs of Stryker view showed the fracture at the base of the coracoid (Fig. 5*A*). Note the open epiphyseal plate of the proximal humerus as well as the coracoid process. The fracture is shown with an arrow. Assessment of separation is documented by the computed tomography scan that showed the fracture to be nondisplaced (Fig. 5*B*). This healed uneventfully with a sling. Full activities were possible in 6 weeks. Avulsion

Figure 4. Medial clavicle fracture is shown *(arrow)* at 3 weeks postinjury. There is callous formation and clinically the patient has tenderness but no sternoclavicular instability. Conservative treatment resulted in complete healing at 8 weeks.

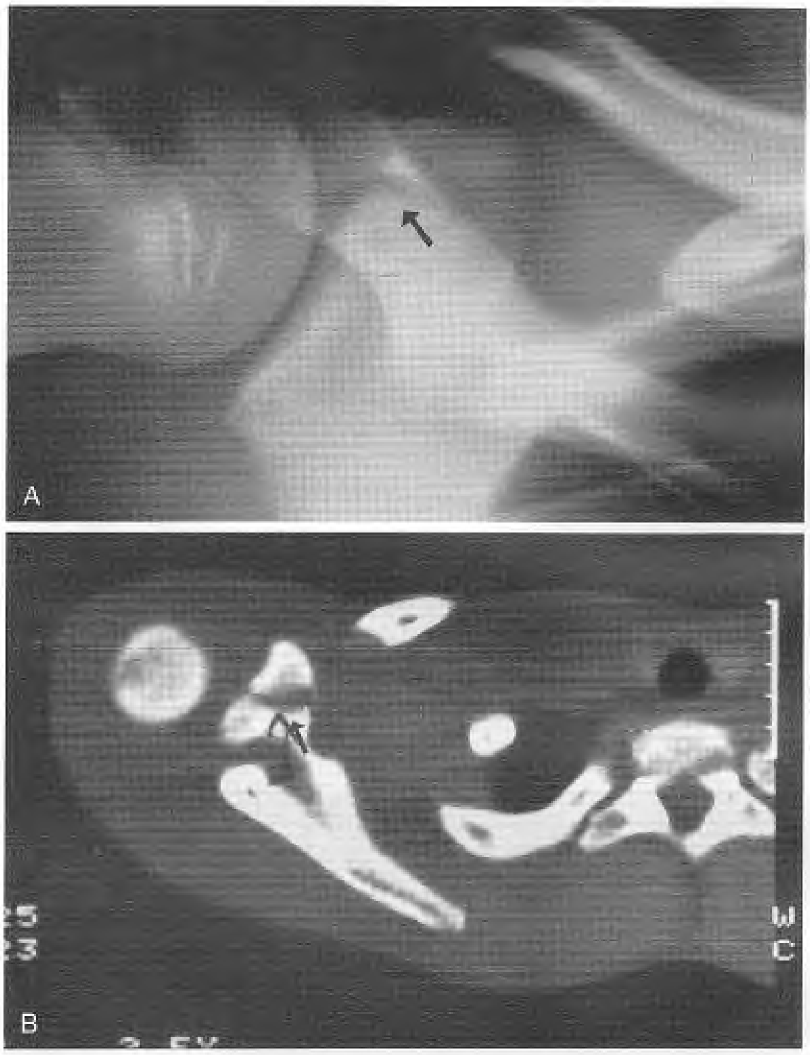

Figure 5. This patient sustained direct contact on the anterior aspect of his shoulder playing football and had tenderness directly over his coracoid. *A,* Stryker view of the right shoulder shows the fracture at the base of the coracoid *(arrow). B,* Computed tomography scan delineates the nondisplaced nature of the fracture *(arrow).* Healing occurred after 4 weeks in a sling and no contact for 12 weeks.

fracture of the coracoid epiphysis associated with AC separation has been reported.[55, 86]

An os acromiale may cause localized pain or be associated with superior impingement. Fusion of the secondary ossification center occurs at 18 to 19 years of age (see Fig. 1*B*). An os acromiale may occur bilaterally and may be symptomatic. The anomaly of os acromiale was described by Liberson.[46] Axillary lateral views and Stryker views best show the os acromiale. If the os shows increased activity by bone scan and is painful, open reduction internal fixation may be necessary. Bilateral os acromiale occurred in this swimmer with rotator cuff weakness that responded to conservative management. Axillary lateral views show the bilateral os acromiale (Fig. 6).

Overuse Injuries

Legitimate concerns regarding stresses on skeletally immature shoulders have been raised.[20, 47, 65] If possible, injuries like this should be prevented. Proximal humeral physeal fractures have been reported in Little League pitchers. Dotter[22] first described this and coined the term "Little Leaguer's shoulder." Figure 7 shows a right-handed white male athlete with proximal shoulder pain of 3 months' duration. Radiographs of the involved side show increased radiolucency of the proximal humeral epiphysis and osteopenia (Fig. 7*A*) compared with the noninvolved left side (Fig. 7*B*). The cause is microtraumatic: too much throwing, improper biomechanics, and the physiologic uniqueness of the immature shoulder.

A vicious cycle can occur in young throwers, with stresses involved during pitching. Osteochondrosis of the proximal humeral epiphysis also has been described in pitchers.[3, 47] Fortunately, this condition is rare.

Proximal humerus fractures are rare, usually secondary to contact mechanism. In Neer's series, they were 4% of all fractures, and in Ogden and Peterson's series they were 9% of all fractures (see Table 1).[57, 62, 69, 83] Usual management is

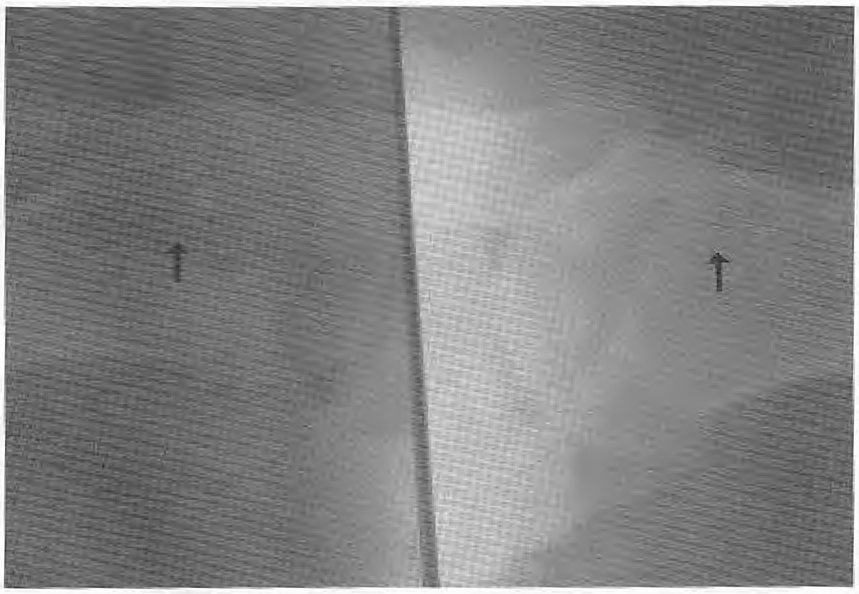

Figure 6. Bilateral os acromiale shown in a swimmer with rotator cuff symptoms. Arrows point to the os acromiale that is seen best on axillary views. Stryker view demonstrates the acromion and AC joint.

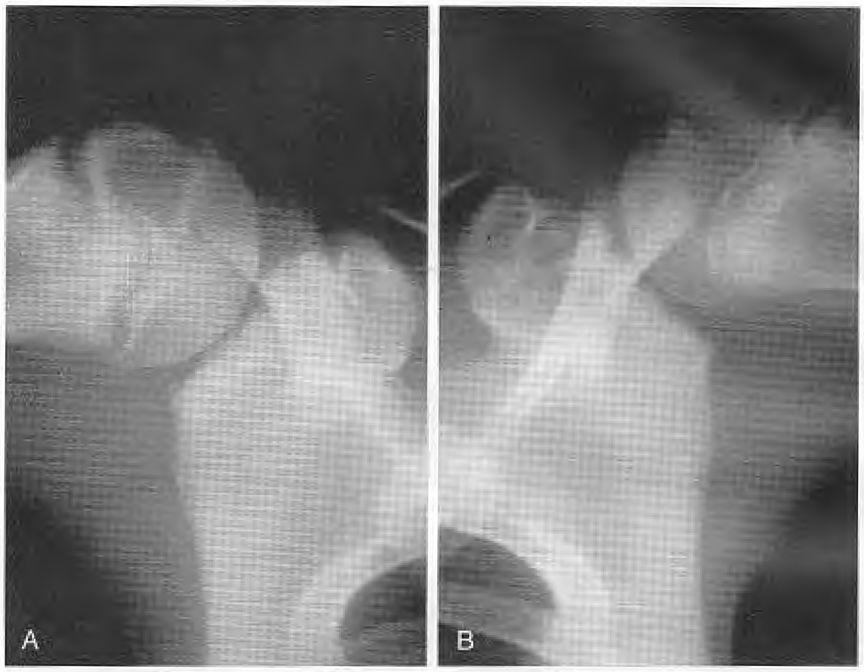

Figure 7. *A*, Proximal humeral Salter I epiphyseal fracture seen on Stryker view of the right shoulder shows widening of the epiphyseal plate and osteopenia. *B*, The noninvolved left side shows the normal undulating proximal humeral epiphyseal plate and bone density.

sling immobilization. Microtraumatic forces can result in Salter I proximal humerus fracture in pitchers.

For displaced fractures, closed reduction and pinning is required. The football athlete's shoulder (Fig. 8) was hit with his arm abducted and externally rotated. Acute injury film shows displaced Salter type II fracture (Fig. 8*A*). Closed reduction under C arm image shows the single Steinmann pin and adequate reduction (Fig. 8*B*). At 6 weeks postoperation just prior to pin removal fracture has healed. Follow-up 1 year later is normal and he has returned to sport. The mechanism of injury for this fracture is humeral abduction and external rotation.[42, 94]

Humerus Fracture

Weseley described six cases of ball throwers' fracture involving the diaphysis of the humerus.[92] This baseball outfielder threw the ball toward home plate and felt acute pain in his arm (lateral radiograph—Fig. 9). The diaphyseal nonpathologic fracture healed in a long arm hanging cast after 6 weeks.

Tumors

Osteochondromas can occur in the proximal humerus. Figure 10 shows a young wrestler who sustained a direct blow over his proximal humerus and

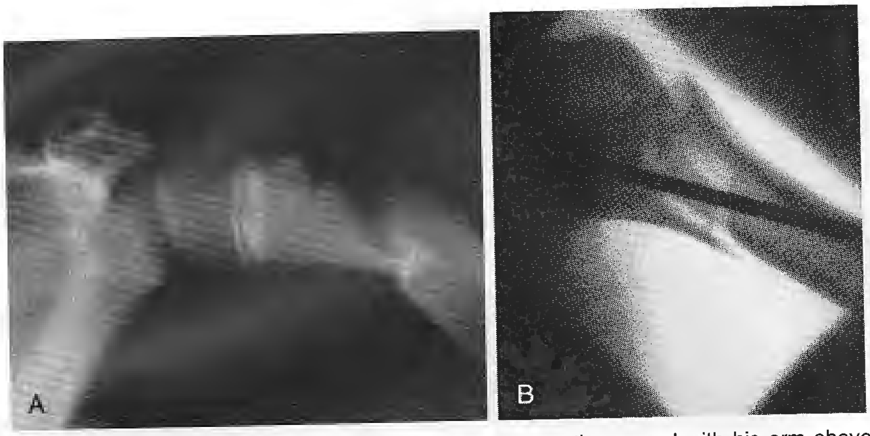

Figure 8. This football athlete was tackled and thrown to the ground with his arm above his head. *A,* Injury films show a displaced Salter type II. *B,* Closed reduction under C arm image shows single Steinmann pin following closed reduction.

Figure 9. Lateral radiograph shows humerus fracture in outfielder who had no previous complaints, as he was throwing the ball toward the plate, he had felt acute pain. This healed uneventfully in a hanging arm cast for 6 weeks.

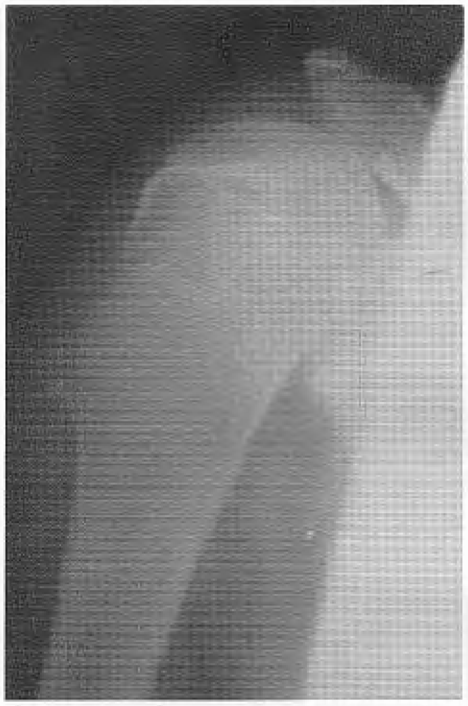

Figure 10. Radiograph shows proximal humerus osteochondroma; it was symptomatic because of its position and large cartilaginous cap under the deltoid causing stretching of the axillary nerve. Patient underwent uneventful excision.

noticed a firm mass. Radiographs showed a sessile osteochondroma of the proximal humerus, and the wrestler underwent excisional biopsy. The axillary nerve was under tension due to the size of the cartilaginous cap. Postoperatively he did well (Fig. 10). Other lesions of the proximal humerus that should be considered are giant cell tumor, tuberculosis, infection, and bone cyst.

THE ELBOW

Elbow injuries are very common in the skeletally immature. In his textbook, Mercer Rang begins his elbow injuries chapter, "Pity the young surgeon whose first case is a fracture around the elbow."[70] The most common cause of pediatric elbow injuries is macrotrauma.

Elbow injuries in football, ice hockey, or contact sports are usually secondary to collisions. Elbow injuries in gymnastics, cheerleading, and horseback riding commonly are due to falls. Elbow injuries in baseball, softball, or tennis are associated with the mechanics of throwing, overuse, or microtrauma. Overuse injuries in the skeletally immature athlete create problems unique to the growing epiphysis, the articular cartilage, and musculotendinous unit.[37, 52] Appropriate respect for injuries about the immature elbow is essential. A thorough knowledge of elbow anatomy and development, understanding of the biomechanics of specific sports and athletic motions, and a careful approach to diagnosis and treatment will lead to a good result.

Growth and Development

The development of the skeletally immature epiphysis progresses through a consistent, reproducible sequence of growth, lengthening, and ossification. The pediatric elbow is particularly complex because of the multiple ossification centers that unite to form the functioning hinge joint of the mature elbow. The elbow develops from six separate ossification centers: capitellum, trochlea, radial head, olecranon, medial, and lateral epicondyle.[56] Diagrammatically, the appearance and fusion of elbow secondary ossification centers are shown (Fig. 11*A–B*).[84] To best diagnose injuries in the immature elbow, knowledge of the timing and sequence of appearance of each ossific nucleus is necessary.[15, 30, 84]

Pneumonics of appearance of ossification centers are helpful. The order of progression of ossification by age range of ossification and order can be remembered as CRITOE (Fig. 12*A–B*).[30] *C* is capitellum at the age of 1 to 2 years; *R* is radial epiphysis, age 3 to 4; *I*, inner or medial epicondyle, age 5 to 6; *T*, trochlea, age 9 to 10; *O*, outer or lateral epicondyle greater than 10 years of age; *E*, epiphysis, age 14 to 16.[30] Routine radiographic evaluation of both elbows is highly recommended to allow the contralateral side to serve as a comparative normal.[56, 61]

The normal development of the associated ligaments and musculotendinous units also is important in the developing elbow.[14] In the skeletally immature athlete, the important ulnar collateral ligament attaches to the medial aspect of the humeral condyle distal to the physeal plate of the distal humerus and the medial epicondyle,[98] shown anteriorly (Fig. 13*A*) and medially (Fig. 13*B*). In the skeletally immature, most injuries involve the physis and not the ligaments. In this group the physis is the weak link. The forces that would cause ligamentous sprains in the mature athlete are more likely to cause physeal injury in the immature athlete.[29, 58]

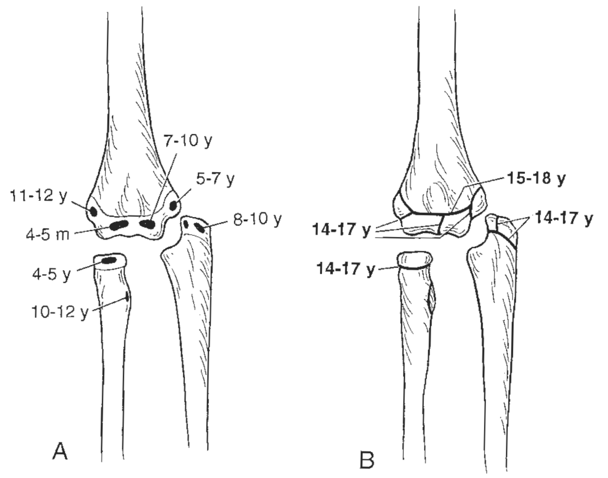

Figure 11. *A*, Appearance of ossification centers of the distal humerus and proximal radius and ulna is shown with lines. *B*, Closure of the epiphyseal secondary ossification centers of distal humerus, proximal radius, and olecranon is shown with lines.

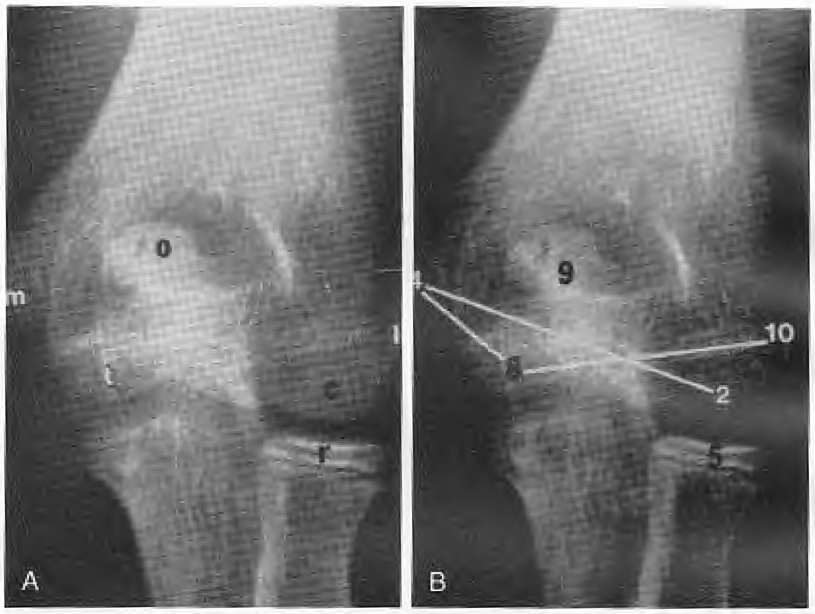

Figure 12. *A,* Normal left elbow showing the secondary centers: capitellum *(c);* medial epicondyle *(m);* radial head *(r);* trochlea *(t);* olecranon *(o);* and lateral epicondyle *(l). B,* The approximate age at time of appearance of these centers is indicated in years. The cross connecting the secondary centers of the distal humerus serves as a reminder of the order of ossification of these centers. (*Modified from* Brodeur AE, et al: The basic tenets for appropriate evaluation of the elbow in pediatrics. Curr Probl Diagn Radiol 12:1, 1983; with permission.)

Biomechanics

Acute trauma is the most likely cause of elbow injuries for athletes involved in contact sports and sports that risk significant falls. The mechanism of injury can often be discerned from the history: a cheerleader falls from a mount, a football player gets hit with a helmet, a rider falls from horse, and so forth.

Overuse injuries, the result of repetitive microtrauma, are specific to throwing athletes. The association of stresses across the elbow during the throwing motion and injuries is well documented.[1, 5, 11, 31, 32, 45, 47, 64] Children who pitch with sidearm motions are three times more likely to develop problems than those who use a more overhand technique.[4, 82] The specific stress depends both on technique and the phase of the pitching motion: wind-up, cocking, acceleration, release and deceleration, and follow-through. During the cocking phase considerable forces of tension and distraction on the medial side occur.[39, 90, 101] During this phase compressive forces occur on the lateral compartment. In the pediatric throwing athlete, the medial tension stresses can avulse the medial humeral ossification center.

The lateral compressive forces can lead to deformities of the radial head owing to compression of the growing physis. The lateral compressive forces also may lead to osteochondritis dissecans of the capitellum.[64, 90] Articular surface incongruity, loss of motion, loose bone fragments, and pain can result.

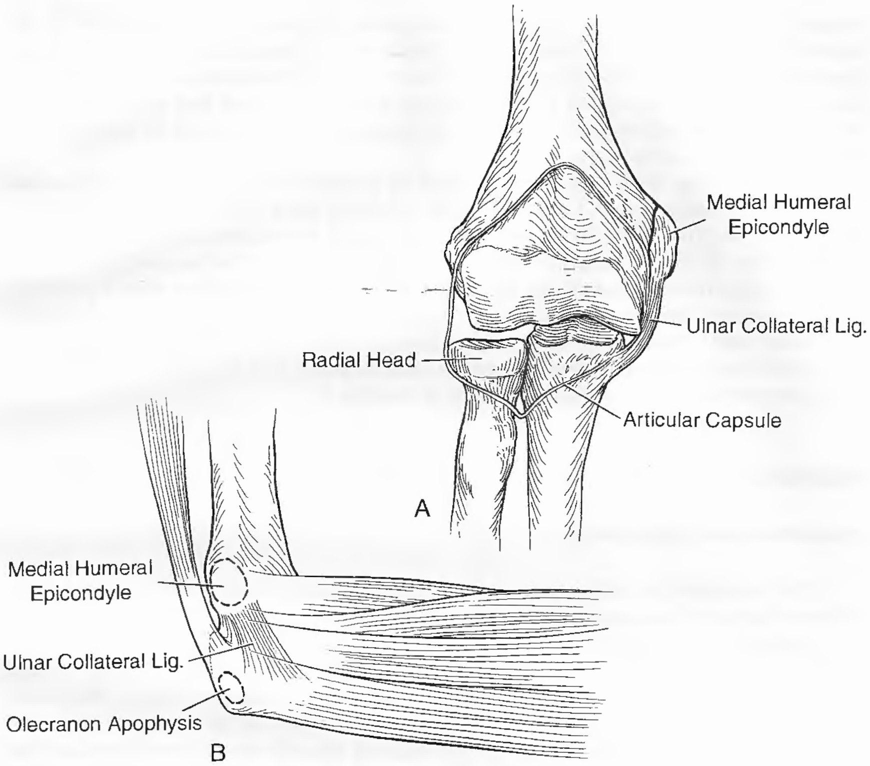

Figure 13. *A*, Anatomic attachment of the capsule and ulnar collateral ligament seen on frontal view. *B*, Medially the ulnar collateral ligament is shown attaching to the axilla just distal to the medial humeral epicondyle. The triceps insertion onto the olecranon apophysis is shown.

During the acceleration phase of the throw, medial ligamentous tension and lateral compressive forces are reduced. Yet as those forces decrease, the extreme pronation of the forearm places the lateral ligaments under tension.[35] In the pediatric athlete, however, it is very rare to see lateral humeral epicondylitis or avulsion of the lateral epicondyle.

The final phase of pitching is the follow-through. During the followthrough, the elbow is in full extension with large stresses on the posterior joint resisting hyperextension.[35] Impingement can occur as the olecranon is forced into the olecranon fossa. Tension on the anterior capsule also can occur. Fractures of the olecranon can occur. After long-term, repetitive extension stress, bony spur, synovitis, and impingement can occur posteriorly whereas traction spurs can occur anteriorly.

Specific pitches, notably the curve ball, provide unique stresses to the elbow in the pediatric throwing athlete.[91] A curve ball forces an immature elbow to change rapidly from acute flexion to forced extension or to extreme elbow hyperextension with the forearm in supination. This stress is magnified by the sudden contractive forces of the wrist and finger flexors when the forearm is maintained in supination.[50, 64] This movement causes an excessive increase in muscular strain from the flexor-pronator muscle group and manifests in increased tensile force at the medial epicondyle of the distal humerus.[61] In contrast, throwing a fast ball creates less tension over the medial epicondyle because the flexor-pronator group is not firing violently. Instead, the fast ball generates more force across the radiocapitellar joint with possible increased risk of injury to the radial head and capitellum.

Gymnasts use their upper extremities as weightbearing joints and can create compression and traction injuries similar to those seen in throwing athletes.[24, 28] Valgus stress with the arm in extension can lead to collateral ligament strains, partial tears of the musculotendinous units, avulsion of the medial epicondyle and complete dislocation of the elbow joint. The most prevalent elbow problem in the gymnast, however, is posterior impingement secondary to repeated hyperextension and "lock-out."[8] Stress fractures of the distal humerus should be considered in gymnasts doing repetitive axial loading and high intensity training who present with elbow pain and loss of motion.[24]

INJURIES

Evaluation and Diagnosis

The majority of elbow injuries in the skeletally immature in organized athletics occur in baseball. For the skeletally immature pitcher, elbow complaints are common, but fortunately only 1% of pitchers have injuries sufficiently severe enough to keep them from continued participation in sport.[32] The term "Little Leaguer's elbow" has been used for a variety of pathologic lesions involving the pediatric throwing athlete.[2, 16, 31–33, 35, 45, 88] The term is, however, nonspecific and defines only an age group, a complaint, and an activity. A careful evaluation includes a detailed history, complete physical examination, and radiographic studies. The differential diagnosis can be categorized by anatomic region: medial, lateral, anterior, and posterior, and nature of acute or chronic (Table 2).

The history should include the patient's age, handedness, sport, and position. It also should document the phase of motion that exacerbates complaints as well as number of pitches thrown per week and any recent changes in technique. The localization, duration, character, temporal sequence, and activity level of the pain also are helpful.[14] Carrying angle, motion range of flexion-extension, and pronation-supination range of motion should be documented, and care should be taken to compare results with the opposite side. A complete shoulder and distal neurovascular examination, particularly of the ulnar nerve, is included routinely. Motor strength and ligamentous stability are assessed. Valgus stress in slight flexion is the best evaluation of the ulnar collateral ligament. The coach's assessment of technique also is helpful.

Imaging studies begin with anteroposterior, lateral, and olecranon axial views. Both elbows are often included for comparison. Some abnormalities that may be found are not necessarily pathologic. Adolescent pitchers may have a mildly increased carrying angle on their pitching arm compared with their nondominant side.[32, 87, 88] With increased blood flow to the dominant side in a Little League pitcher, overgrowth or hypertrophy of the medial humerus ossification center and widening of the epiphysis may occur (Fig. 14). Multiple ossification centers of the olecranon or medial epicondyle can occur and be confused with a fracture; however, they are generally not tender. Their appearance should be symmetric to the opposite side.[79, 80, 97] Additional studies can

Table 2. DIFFERENTIAL DIAGNOSIS ELBOW INJURIES

Medial
Acute
Avulsion fracture avulsion medial humeral epicondyle
Flexor/pronator strain
Fracture trochlea/distal humerus
Ulnar collateral ligament sprain
Ulnar nerve subluxation
Chronic
Fracture medial epicondyle
Ulnar neuropathy
Ulnar nerve instability
Medial humeral epicondylitis
Traction spurs coronoid process
Lateral
Acute
Osteochondritis dissecans capitellum
Osteochondrosis capitellum
Osteochondral fracture capitellum old osteochondritis dissecans
Avulsion fracture lateral humeral epicondyle
Fracture capitellum/distal humerus
Anterior subluxation radial head
Fracture proximal radius
Chronic
Lateral humeral epicondylitis
Radial head hypertrophy/overdevelopment
Loose bodies
Osteochondritis capitellum or radial head
Posterior
Acute
Olecranon fracture
Olecranon apophysitis
Olecranon spur with fracture
Triceps strain
Olecranon bursitis
Chronic
Olecranon traction apophysitis
Olecranon spurs
Loose bodies
Synovitis
Posteromedial spurs
Anterior
Acute
Biceps strain
Distal physeal humerus fracture
Chronic
Loose bodies
Adhesions
Synovitis
Capsular sprain

assist in making the proper diagnosis. Oblique views may help identify loose bodies.[37] Stress views can assess the medial collateral ligament. Advanced studies including arthrograms, computed tomography arthrograms, and MR imaging are rarely indicated but may be helpful in the particularly difficult or resistant cases.

Figure 14. Medial humeral epicondylar overgrowth in a Little League pitcher due to increased vascularity and stresses on the medial humeral epicondyle *(arrow).* The size of the epicondyle is larger and lucency of the epiphyseal plate is greater.

SPECIFIC INJURIES

Acute injuries are associated with a specific episode of injury or increased activity, or of intensity of training. Certainly the most worrisome and possibly catastrophic injuries are acute, traumatic fractures and dislocations. Acute fractures about the elbow in the pediatric population include avulsion, physeal, and apophyseal injuries.

Chronic injuries are related to long-term repetitive microtrauma and overuse. This chronic overuse can lead to physeal changes and fragmentation: bony changes including microfractures, osteochondritis, spurring or beaking, hypertrophy, or microtears of the musculotendinous unit.[50] Chronic valgus stress also can lead to ulnar neuritis and strains or tears of the ulnar collateral ligament.

Avulsion of the Medial Epicondyle

In the adolescent or preadolescent throwing athlete, avulsion of the medial epicondyle is the most common fracture encountered.[32] The avulsion may be caused by acute valgus overload that avulses the medial epicondyle or may be due to forceful terminal flexion during the pitching motion. The physeal injury to the medial epicondyle may occur without roentgenographic separation. Clinical suspicion is required. Treatment of nondisplaced fractures or stress fractures is conservative with reduced activity and range of motion for 4 to 6 weeks.[14]

Treatment of a displaced fracture with loss of medial stability or one that is locked in the joint is surgical reduction and fixation.[23, 39, 98] A baseball outfielder threw from the field and had acute pain medially; radiographs showed a displaced medial humeral epicondyle fracture (Fig. 15*A*). Treatment was open reduction and internal fixation with screws. Postoperative radiograph is shown (Fig. 15*B*).

Treatment of minimally displaced or stress radiographically displaceable medial epicondyle fractures is controversial. Epicondylar separation treated by closed reduction commonly heals by fibrous union. Micheli[51] argues that prolonged cast immobilization can lead to permanent loss of motion and that the fibrous union may be incomplete and painful. He suggests that medial instability of the elbow through the apophysis is best treated with open fixation.[51] Ireland and Andrews[37] recommend that if the fracture demonstrates displacement on plain or stress views or if the athlete desires to return to baseball after this type injury the medial epicondyle should be stabilized.

Ulnar Collateral Ligament Injury

Ligament injuries happen less frequently in the skeletally immature because the physis is generally considered the weak link. Nonetheless, chronic valgus stress also can lead to ulnar collateral ligament strains and laxity. Acute traumatic ruptures of the ulnar collateral ligament also can occur. A high index of suspicion should be maintained and additional radiographic evaluation includ-

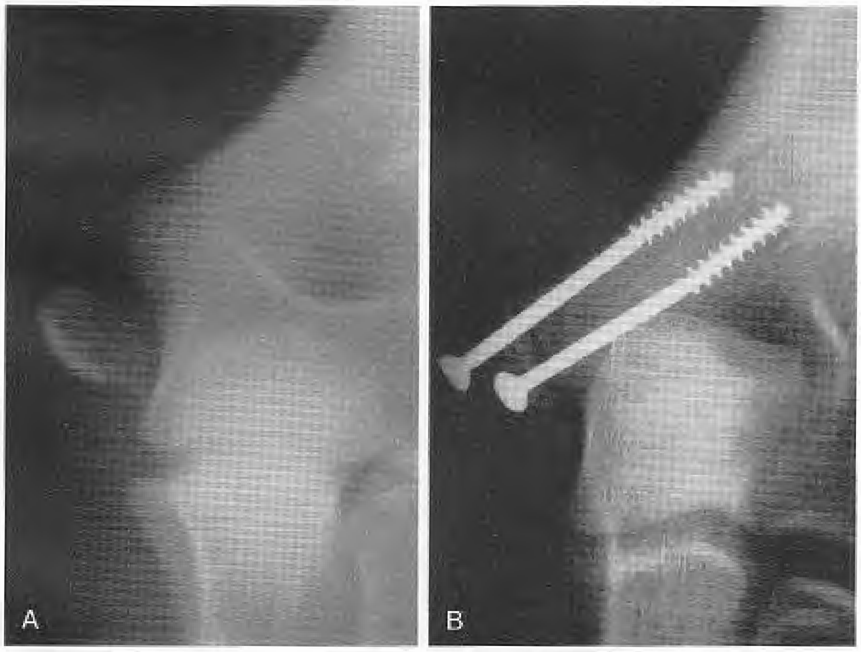

Figure 15. *A*, Avulsion of medial humeral epicondyle occurring during a throw from the field. *B*, Anteroposterior radiograph after open reduction internal fixation is shown.

ing stress views or arthrograms may be necessary to confirm the diagnosis. In the acute case of a throwing athlete, a direct surgical repair is recommended.[95] In a chronic case of instability, an ulnar collateral ligament reconstruction with a palmaris tendon graft can be attempted when the patient approaches skeletal maturity.[39]

Elbow Dislocation

Similar to supracondylar fractures, elbow dislocations are seen more commonly in contact sports of football or wrestling, and in noncontact sports where falls can occur such as gymnastics.[37] Protected range of motion should be instituted as soon as possible.

Although they are rare, elbow dislocations are serious macrotraumatic injuries that require immediate evaluation and treatment. Figure 16 shows a cheerleader who fell while doing a stunt on an outstretched arm. She sustained a posterolateral dislocation of her elbow. She arrived in the emergency room with a pulseless left upper extremity (Fig. 16*A*); the figure outlines the area of darkening in the antecubital fossa indicative of vascular injury. An arteriogram revealed discontinuity of the brachial artery (Fig. 16*B*). At surgery, the artery was repaired with a vein graft, and the anterior capsule was repaired. Ectopic bone was present on radiographs 3 months after surgery. The cheerleader's follow-up range of motion showed a 30 deg flexion contracture on the left (Fig. 16*C*).

This 7-year-old girl fell while doing gymnastics, sustaining a posterior dislocation of her right elbow (Fig. 17*A*). Her postreduction radiographs showed suspicion of displaced medial humeral epicondyle fracture. Stress views were done and showed significant medial opening and inferior displacement of the medial humeral epicondyle (Fig. 17*B*). At operative repair, the displaced medial humeral epicondyle was reduced and pinned, and the medial capsule repaired (Fig. 17*C*).

A left-hand dominant football athlete had his palm on the ground, elbow flexed to 90 deg when an opponent fell on his arm. He sustained a posterior dislocation of his left elbow. Lateral view of the posteriorly dislocated elbow documents the injury (Fig. 18*A*). Before reduction on anterior posterior view, the medial humeral epicondyle could not be seen. After reduction, however, the displaced medial humeral epicondyle was noted to be intra-articular. The displaced medial epicondyle and significant opening on valgus stress radiographs is shown (Fig 18*B*). Operative examination confirmed the severe medial instability. Repair of the capsule and ulnar collateral liagment back to the humerus and open reduction internal fixation of the medial epicondyle was performed. Postoperatively, the patient had normal range of motion, stability was restored, and he returned to full activities.

Triceps Tendinitis and Olecranon Apophysitis

In the acceleration phase of throwing, the elbow is rapidly extended from a flexed position. Repeated forceful contraction of the triceps may result in microtears of the musculotendinous attachment to the olecranon apophysis or triceps tendinitis, or more rarely, stress fracture. Overuse is the primary cause. The pain usually responds to conservative treatment of rest, ice, reduction in the number of throws, and stretching. Long-term overuse may lead to olecranon

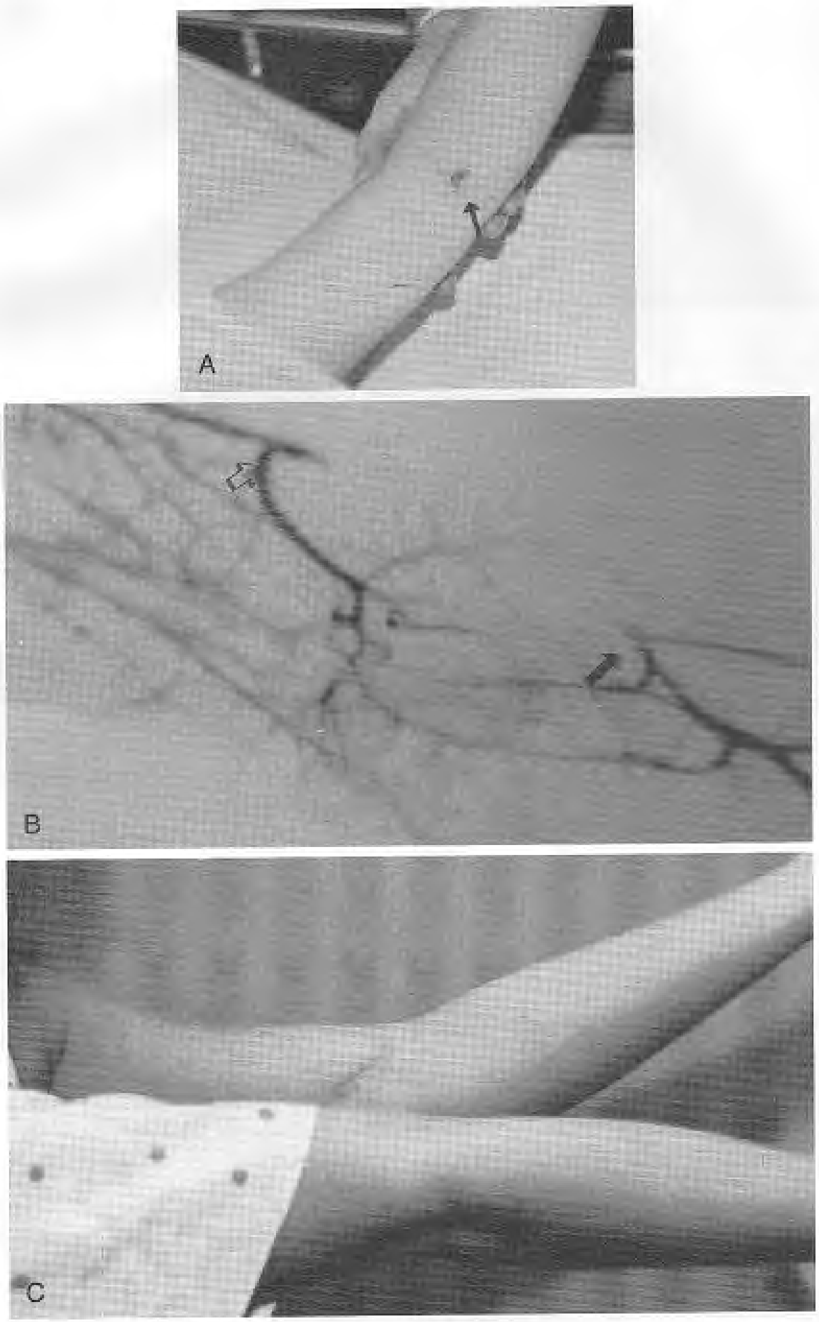

Figure 16. *A,* Dislocated left elbow with pulseless upper extremity from the injury. Note the discoloration in the antecubital fossa *(arrow). B,* Arteriogram shows discontinuity of the brachial artery *(arrows). C,* Three months following anterior exploration and vein patch to brachial artery she has a 30 deg flexion contracture.

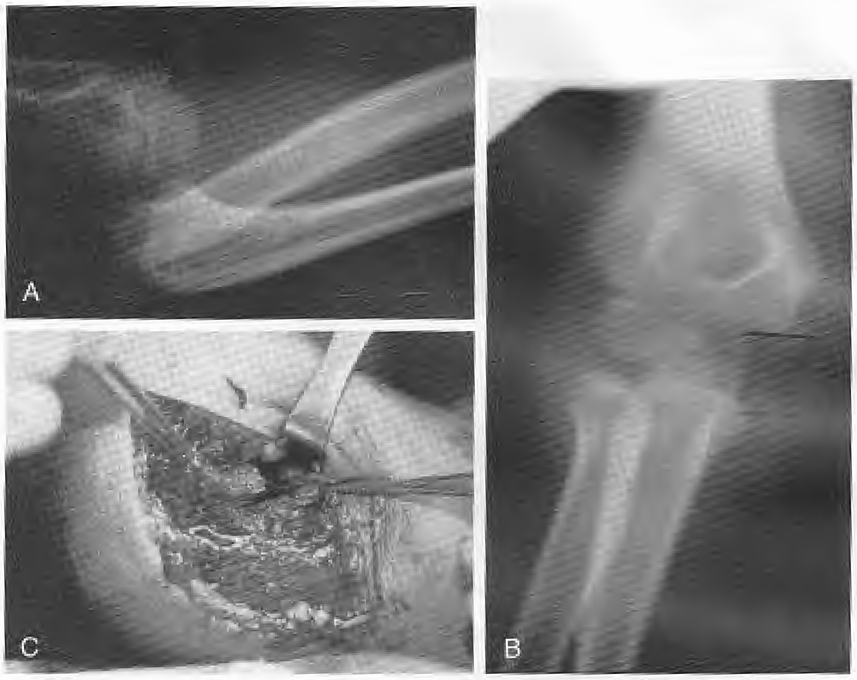

Figure 17. *A*, Posterior dislocation in a 7-year-old child doing gymnastics. *B*, Stress views show the displaced medial humeral epicondyle and significant opening. *C*, Open capsular repair and medial epicondyle fixation were performed. Medial humeral epicondyle is held by forceps on the left. The capsule is held by forceps on right. Significant soft tissue capsular injury was found and rejoined.

hypertrophy, spurring, and impingement in the olecranon fossa which, in turn, can form loose bodies.[29, 56, 95] Loose bodies are seen only rarely in the posterior compartment of the prepubescent and adolescent athletes, but much more commonly seen in mature, high level pitchers.[6, 29, 101]

Avulsion of the Olecranon Apophysis

Avulsion of the olecranon apophysis has been reported with pitching.[29, 56, 89] A history of olecranon apophysitis may contribute to the acute failure of the physis. If the traction created by the firing of the triceps and extension force exceeds a threshold, failure occurs. The avulsion can be nondisplaced, partial, or complete. A technetium bone scan can help to confirm nondisplaced fractures or stress fractures. If no displacement is present, treatment is conservative. If any degree of fracture is left untreated, nonunion may develop, however.[64, 67, 89]

Osteochondritis Dissecans of the Capitellum or Radial Head

The repetitive forces from throwing can injure both the articular cartilage and underlying subchondral bone. This, in turn, can lead to osteochondrosis or

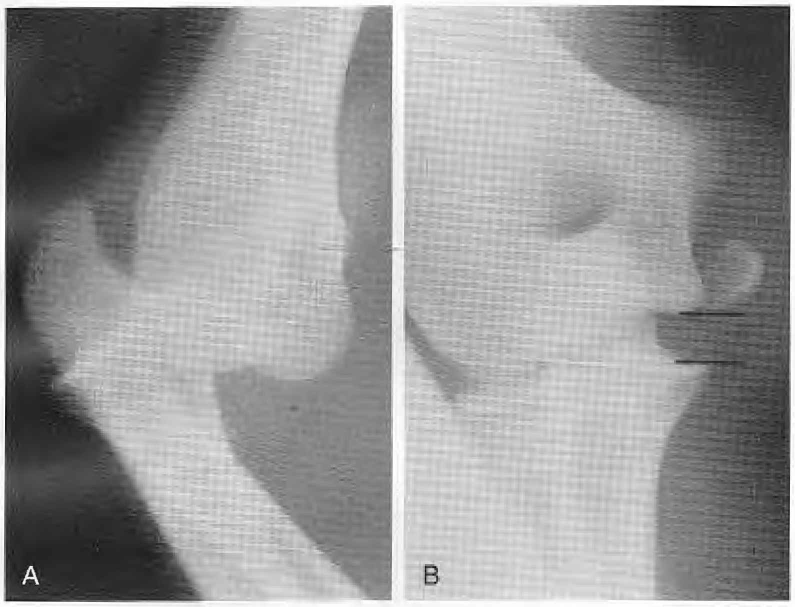

Figure 18. *A*, Posterior dislocation of elbow which occurred in a football player who was hit from the posterior aspect of his upper arm. The medial humeral epicondyle cannot be seen on this view nor on initial AP or the post reduction lateral. *B*, A displaced medial humeral epicondyle fracture is shown. Following reduction stress views show significant medial compartment opening *(lines)*.

osteochondritis dissecans. Andrews noted that it occurs in the youngest and least experienced pitchers.[5] The cause is probably vascular insufficiency magnified by the valgus compressive forces.[12] Pappas[64] noted that athletes prone to other osteochondroses, e.g., Koehlers, Legg-Perthes, or Osgood-Schlatter, are at increased risk of developing osteochondritis of the elbow.

Panner's disease is an osteochondrosis of the capitellum but is not related to traumatic osteochondritis of the thrower. Panner's disease occurs in a younger age group (ages 7–12), whereas osteochondritis dissecans is seen in the 13- to 16-year-old age group. Late deformity, collapse, and the formation of loose bodies are rarely seen in Panner's disease, whereas osteochondritis dissecans often leads to the formation of loose bodies. This defect may lead to long-term joint irregularity and arthrosis.[56, 101]

Figure 19 shows the radiograph of a right-handed former Little League pitcher during a follow-up clinical examination. He quit pitching at age 14 due to a flexion contracture and pain; he had osteochondritis dissecans with an irregular capitellum as well as radial head overgrowth. Loss of 30 deg supination is shown (Fig. 19*B*).

Arthroscopic treatment of osteochondritis dissecans is possible when there are loose fragments and minimal capitellar irregularity. One Little League pitcher presented with a 20 deg flexion contracture and inability to play either basketball or baseball due to posterior pain. His radiographs of anteroposterior (Fig. 20*A*) and lateral (Fig. 20*B*) view show irregularity of the capitellum and a large loose body in the posterior compartment.

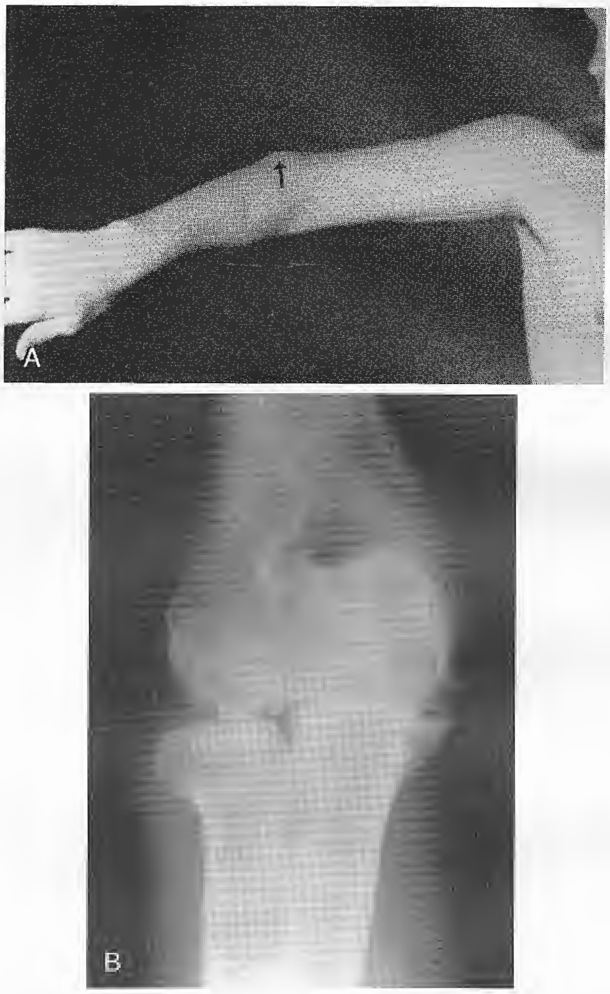

Figure 19. *A*, Radial head overgrowth and irregularity of the distal humerus is seen on anteroposterior view in this right-hand dominant former Little League baseball player now 18 years of age. *B*, Shows loss of supination and 30 deg loss of full extension.

Arthroscopic removal of loose body and debridement of capitellum was performed. At arthroscopy, chondromalacic changes and irregularity of the capitellum were found. A large loose body which measured 3 × 2 cm was present in the posterior compartment and is shown arthroscopically (Fig. 20C). There were some small loose bodies in the lateral gutter that also were removed.

Treatment is based on the stability of the fragments.[49, 54] If the fragments are stable an attempt at immobilization and reduction in activity can be made. Range of motion should be instituted early, but resistive weight training should be withheld for 6 to 12 weeks. Most athletes can return to sports after 6 to 12 months. If the fragment is loose and small it may be excised.[99] Drilling or

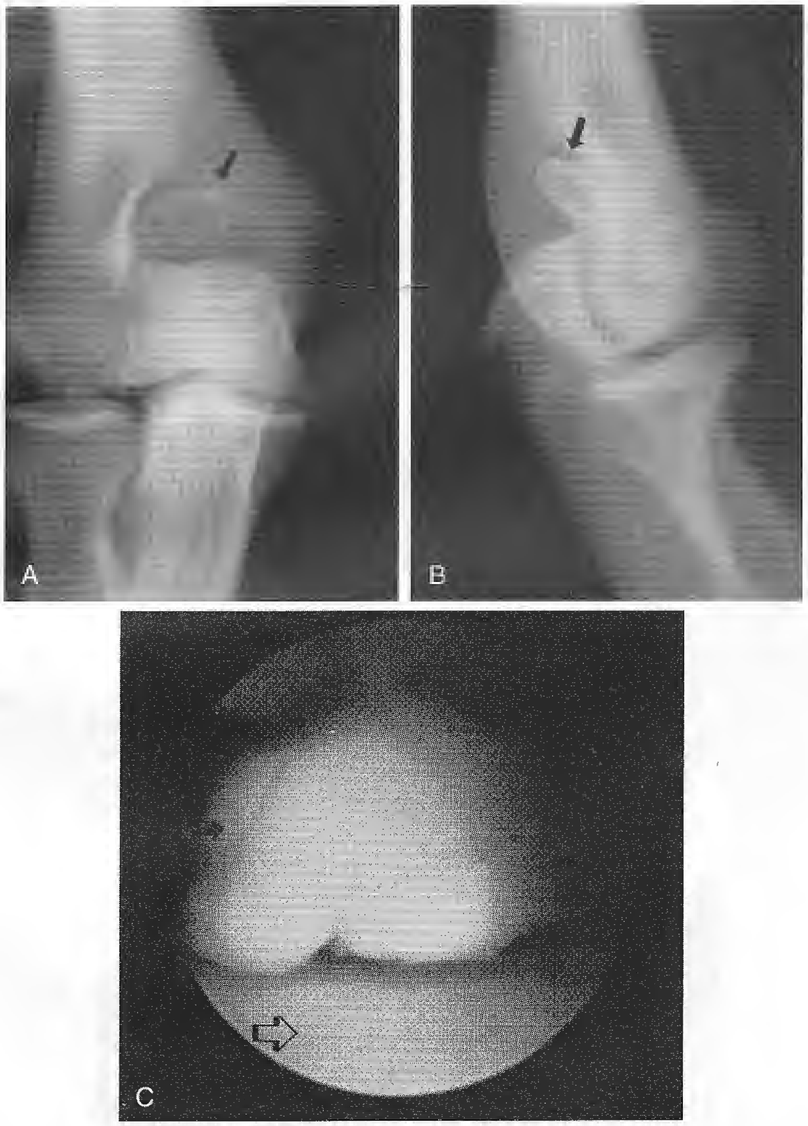

Figure 20. *A,* Round ossification *(arrow)* is seen on anteroposterior view of the right elbow in this former baseball pitcher. *B,* Oblique view shows a large loose body *(arrow)* in the posterior compartment, most likely originating from osteochondritis dissecans. *C,* The large loose body *(arrow)* measured 3 × 2.5 cm. The olecranon tip *(open arrow)* is at bottom.

curettage of the subchondral bone may stimulate active repair.[64] Poor results can be expected in patients with loose fragments who are treated nonsurgically or surgically after a long delay. Bone grafting or pinning is controversial. Andrews believed that an overly aggressive approach can lead to progressive loss of motion.[5] Although Jobe[36] has had good results with open arthrotomy and pinning of large fragments, others have not recommended bone graftings or pinning.[50]

Although arthroscopy often can visualize the lesion, an arthrotomy may be necessary for fixation or removal of fragments. This pitcher had persistent pain and loss of motion from osteochondritis dissecans. Owing to the extensive fragmentation of the capitellum an arthrotomy was required for removal of these loose pieces and drilling (Fig. 21). The patient was unable to return to sports activities.

Supracondylar Fractures

Supracondylar fractures are the second most common fracture of the skeletally immature following forearm fractures.[62, 93] The most common age range is 5 to 10 years. The mechanism is extension of the elbow.[93] In the athletic population, they are associated with contact sports or falls. Diagnosis and treatment have been well described.[62, 93] Anatomic reduction and careful evaluation of the neurovascular status are necessary.

Anterior Syndromes Secondary to Hyperextension

Repetitive hyperextension may lead to traction injury of the anterior joint capsule, fibrosis, and contracture. Young pitchers are more susceptible to these problems because of generalized laxity, poor strength, and improper mechanics.[7] Ten percent of Little League pitchers have a mild flexion contracture of less than 15 degrees.[32, 45] Persistent abuse or the association of other elbow lesions can result in a contracture of 30 deg or more.[7] Treatment is focused on rest, reduction of throwing, and supervised rehabilitation to regain motion. Arthroscopic treatment is indicated for loose bodies, pain, or progressive loss of motion.

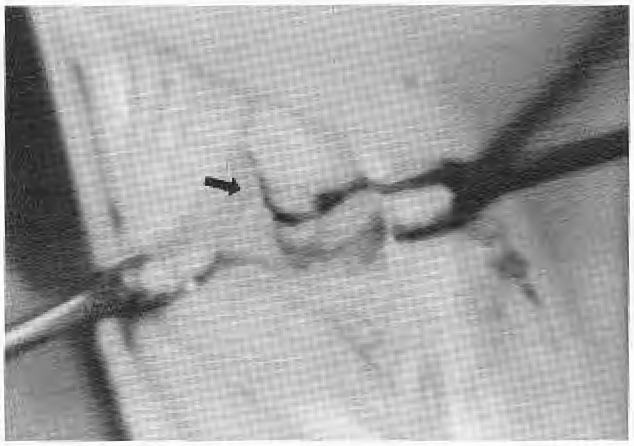

Figure 21. This athlete underwent arthrotomy, removal of osteochondritis dissecans loose fragments of his right elbow. The capitellum is seen using Kocher lateral approach. Note the fragmentation of the capitellum *(arrow).*

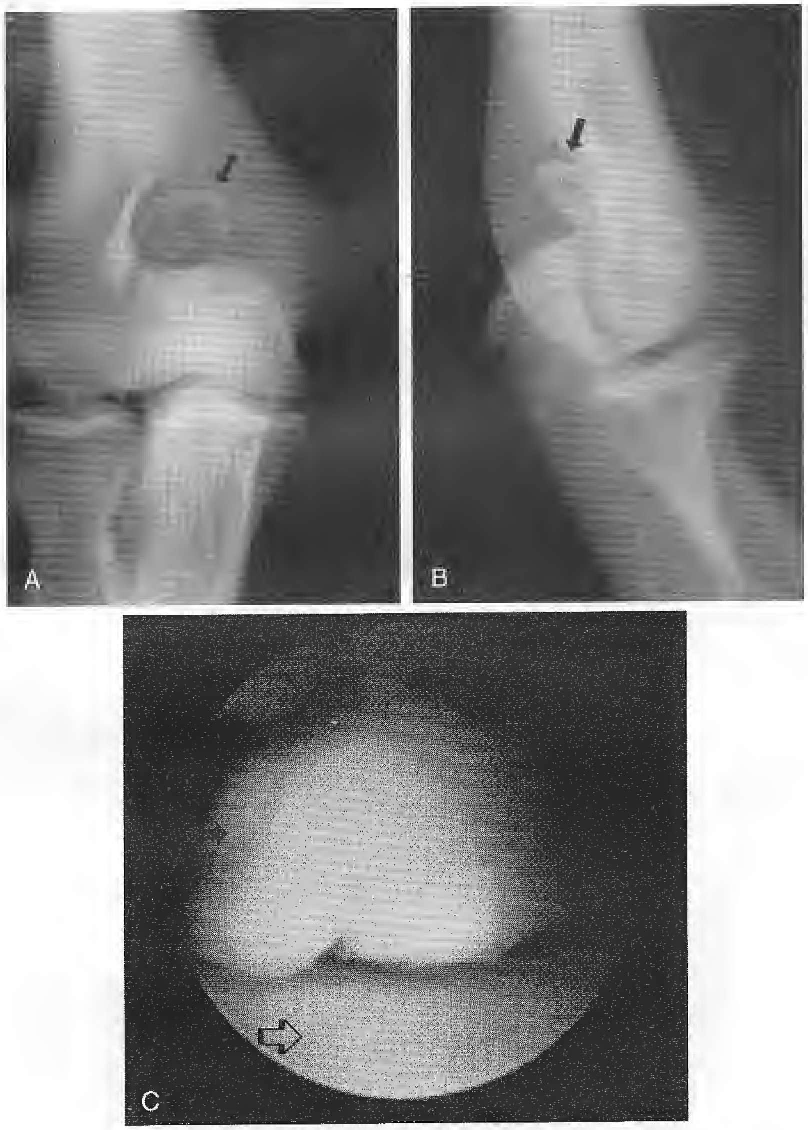

Figure 20. *A,* Round ossification *(arrow)* is seen on anteroposterior view of the right elbow in this former baseball pitcher. *B,* Oblique view shows a large loose body *(arrow)* in the posterior compartment, most likely originating from osteochondritis dissecans. *C,* The large loose body *(arrow)* measured 3 × 2.5 cm. The olecranon tip *(open arrow)* is at bottom.

curettage of the subchondral bone may stimulate active repair.[64] Poor results can be expected in patients with loose fragments who are treated nonsurgically or surgically after a long delay. Bone grafting or pinning is controversial. Andrews believed that an overly aggressive approach can lead to progressive loss of motion.[5] Although Jobe[36] has had good results with open arthrotomy and

Distal Humerus Fractures

The 8-year-old youngster shown in Figure 22 was seen after a fall on his outstretched left arm playing soccer. Initial radiographs (Fig. 22*A*) show a displaced Salter IV lateral humeral epicondyle fracture. This was not appreciated, as no treatment was instituted. Radiographs at 6 weeks (Fig. 22*B*) and 3

Figure 22. *A*, Untreated lateral humeral epicondyle, anteroposterior lateral view. *B*, Follow-up at 6 weeks showing some hypertrophy. *C*, At 3 months showing complete healing. There is clinical deformity but no functional complaints.

months are shown (Fig. 22C). The patient does have some deformity and prominence of the lateral humeral epicondyle but normal function. Fortunately, there was no significant deformity or delayed union. Suspected physeal injuries involving the elbow should have immediate orthopedic consultation.

A 14-year-old basketball player injured his left elbow when he came down from a rebound. Radiographs show anteroposterior lateral view of a Salter III of the lateral humerus (Fig. *A*). Note the open olecranon apophysis which is a

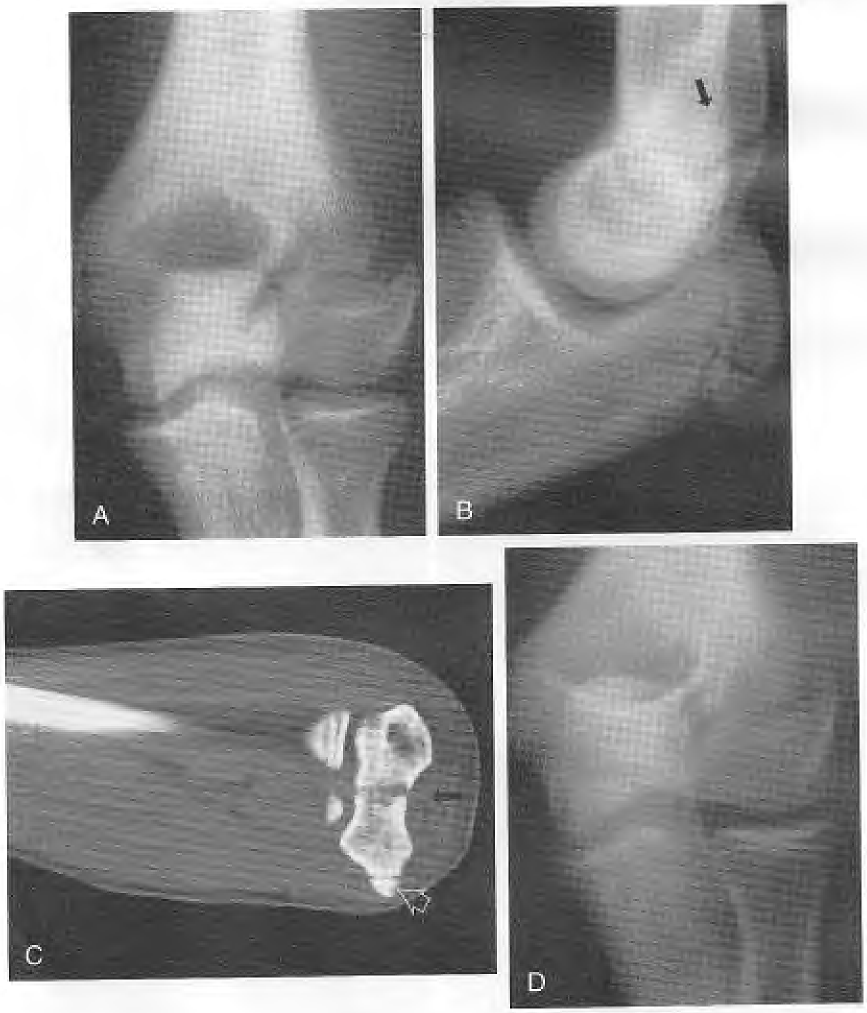

Figure 23. Salter type III lateral humerus fracture in a 14-year-old male athlete after coming down from a rebound during a basketball game. *A,* Anteroposterior view shows a possible displacement. *B,* Lateral view shows the fracture posteriorly *(arrow)*. The open olecranon apophysis *(open arrow)* can also be seen. *C,* Computed tomography scan *(arrow)* showing the fracture centrally. Open arrow shows the normal medial humeral epicondyle; this was treated with cast immobilization and follow-up radiographs. *D,* Complete healing with no growth problem, and a normal follow-up examination.

symptomatic sign on lateral view (Fig. 23*B*). Fracture also can be seen posteriorly of the distal humerus. Question of any significant intra-articular displacement was solved by a computed tomography scan that showed essentially no displacement (Fig. 23*C*). Follow-up radiographs at 3 months show healing. The patient has returned to full basketball activities. This fracture healed uneventfully. Fracture was casted for 6 weeks. Anteroposterior radiographs show healed fracture (Fig. 23*D*).

FOREARM FRACTURES

Figure 24 shows a 13-year-old cheerleader who fell on her outstretched arm doing a double-back tuck. She sustained a volarly displaced, shortened, both-bone midshaft forearm fracture (Fig. 24*A* and *B*). Initial closed reduction under anesthesia resulted in bayonet apposition but was acceptable. She was in a cast for 4 months and radiographs showed complete healing with minimal radial deviation and no angulation seen on plain films laterally (Fig. 24*C* and *D*). The patient returned to gymnastic activities 6 months following the injury.

HAND AND WRIST INJURIES

The appearance and closure of the secondary ossification centers of the wrist are shown diagrammatically in Figure 25*A* and *B*.[84] Knowledge of wrist development and obtaining comparison views to determine fractures are important. Correlation of pain over the epiphyseal plate with any radiographic changes allows for diagnosis of Salter-Harris epiphyseal plate injuries and subsequent treatment with immobilization and education of the family that growth abnormalities can indeed occur.

This baseball athlete slid head and arms first into base. He complained of wrist pain, and acute films showed a displaced ulnar fracture with dorsal subluxation of the distal radial ulnar joint in his nondominant left wrist (Fig. 26*A* and *B*). Closed reduction and long arm cast in supination resulted in anatomic alignment, bayonet apposition, and reduction of the distal radial ulnar joint. Long arm casting was performed for 6 weeks with the arm in supination. Radiographs at 8 weeks after the procedure show healing and reduction of the distal radial ulnar joint (Fig. 26*C* and *D*).

Stress fractures of the ulna can occur.[66] Point tenderness over the ulna associated with stress reaction radiographically should suggest ulnar stress fracture. Bone scan can confirm the diagnosis.

Stress changes occur in the distal radial epiphysis in gymnasts and have been reported in gymnasts and in weightlifters.[77, 78, 81] Premature closure of the distal radial epiphysis can result in overgrowth of the ulna in an ulnar positive wrist with impingement going into ulnar deviation. Documentation of distal radial epiphyseal plate injuries and appropriate treatment with avoidance of repetitive loading may decrease the stresses on the growth plate. The possible need for ulnar shortening procedures does exist if there are distal radial ulnar joint symptoms.

Reviews of scaphoid fracture healing in competitive athletes have been performed,[71] as have reviews of hand fractures in children.[33, 71] Scaphoid fractures do occur usually as a result of contact. This football athlete shown in Figure 27

Figure 24. *A,* Lateral and anteroposterior views *(B)* show acute displaced both bone forearm fracture in a cheerleader. Anteroposterior *(C)* and lateral *(D)* views at 3 months show healing of both bone forearm fractures.

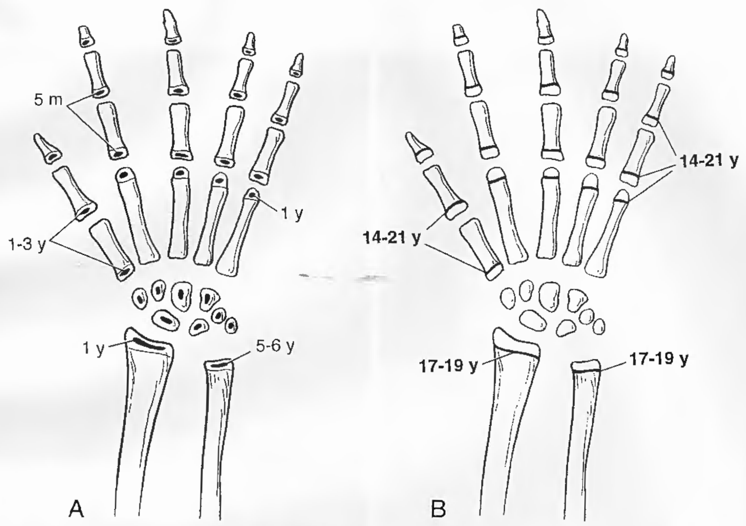

Figure 25. *A*, Appearance of ossification centers of the distal radius, ulna, and hand is shown by lines. *B*, Time frame for closure of ossification centers of distal radius and ulna is 17 to 19 years of age and of the hand is 4 to 21 years of age.

was injured during the season and complained of some wrist pain for several months. During winter workouts he was evaluated clinically and radiographically; a scaphoid fracture is shown in a skeletally immature wrist. Ulnarly deviated radiograph shows open growth plates and a mid-waist scaphoid fracture without displacement (Fig. 27). Treatment in a long arm cast for 4 weeks and short arm cast for 6 weeks revealed radiographic and clinical union (Fig. 27*B*).

Metacarpal fractures and phalangeal fractures are quite common in sports. Proper counseling of athletes and parents on potential problems with hand fractures should be performed. The youngster shown in Figure 28 was playing soccer and her long finger was stepped on. This resulted in nail abnormality and a tuft nonunion. This condition eventually became asymptomatic but nail contour was permanently affected.

SUMMARY

With the knowledge base of normal anatomy, development, biomechanics, and differential diagnosis, the sports medicine professional can treat injured young athletes with greater efficiency. In addition, microtraumatic injuries may be prevented by emphasizing safe parameters of participation, proper throwing techniques, and careful monitoring of the amount of practice time and intensity. Gymnasts using apparatus should always have spotters. The height of towers and basket tosses by cheerleaders should be limited by age and ability. Proper pitching techniques, not the fastest pitch or youngest curve, should be taught to baseball players. "Play it safe" should be the rule. Finally, by establishing an early and precise diagnosis, potential complications from injuries can be lessened.

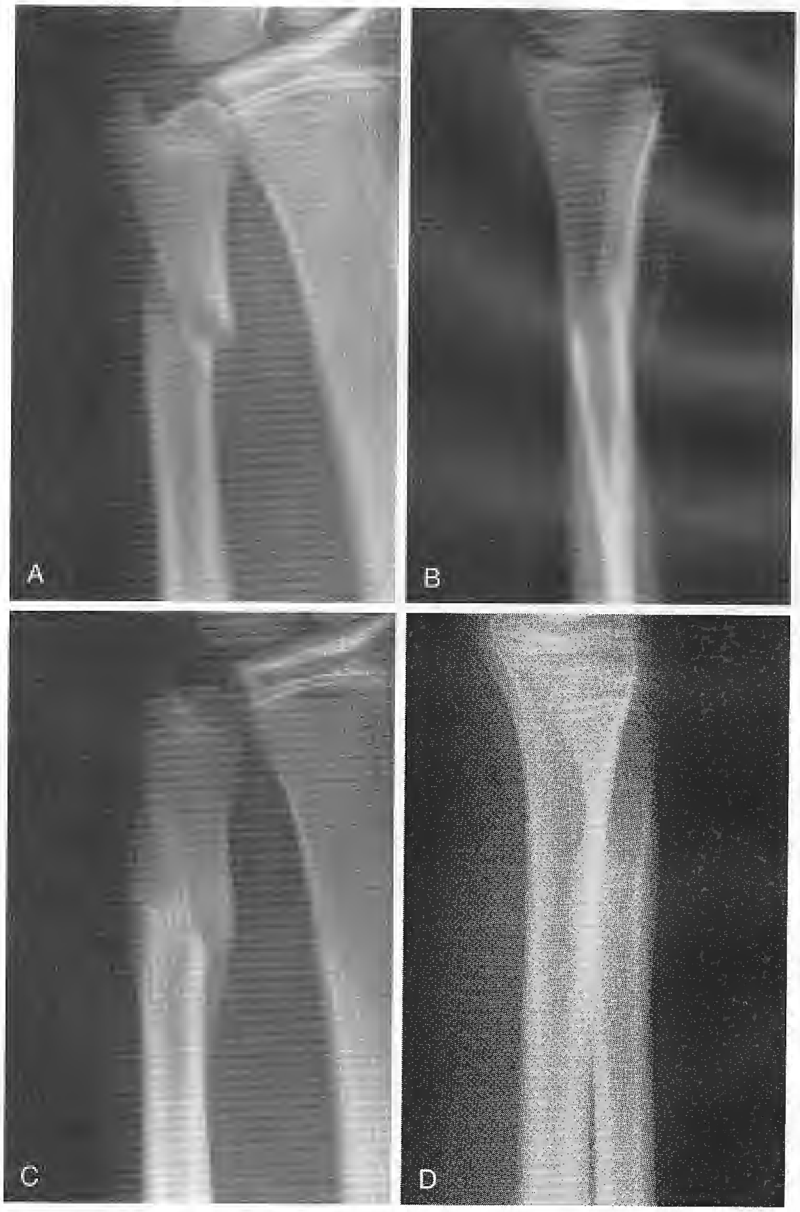

Figure 26. The baseball athlete slid into first base and complained of wrist pain. Anteroposterior *(A)* and lateral *(B)* radiographs show a dorsally dislocated distal ulna with displaced fracture. Anteroposterior *(C)* and lateral *(D)* views at 2 months follow-up show healed fracture.

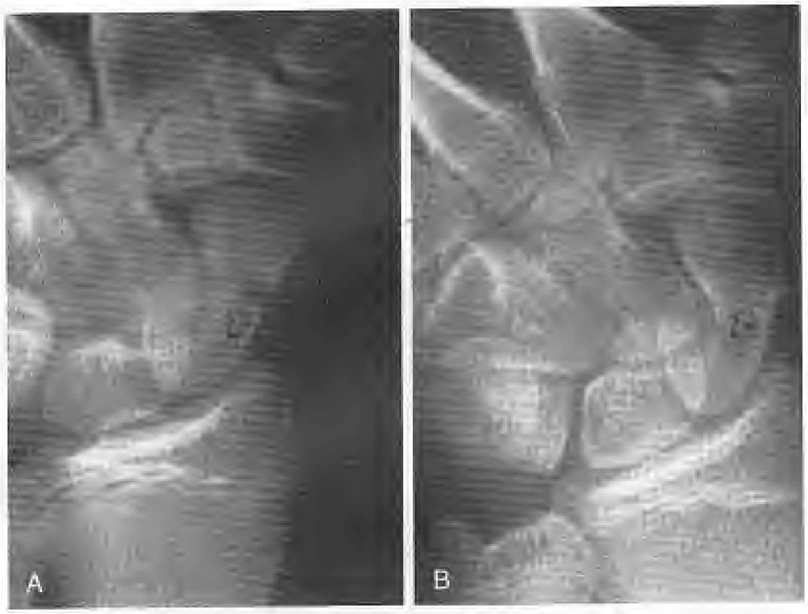

Figure 27. Football athlete who was injured during the season complained of some wrist pain for several months. During winter workouts he was evaluated clinically and radiographically and a scaphoid fracture is shown in the skeletally immature patient. *A,* The left wrist with open growth plates shows a mid-waist of scaphoid fracture without displacement *(arrow). B,* Treatment in a long arm cast for 4 weeks and short arm cast for 6 weeks revealed radiographic and clinical union *(arrow).*

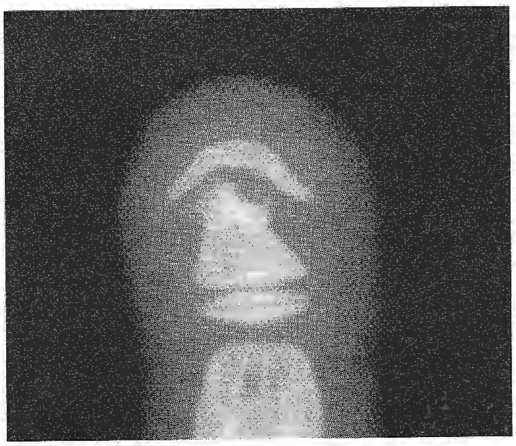

Figure 28. Nonunion of a tuft fracture, clinically a deformity, but no functional problems.

ACKNOWLEDGMENT

Special thanks to Rick Hood and Carolyn Large for their assistance in preparing this article.

References

1. Adams JE: Bone injuries in very young athletes. Clin Orthop 58:129, 1968
2. Adams JE: Injury to the throwing arm: A study of traumatic changes in the elbow joint of boy baseball players. California Med 102:127, 1965
3. Adams JE: Little League shoulder—Osteochondrosis of the proximal humeral epiphysis in boy baseball pitchers. California Med 105:22, 1966
4. Albright JA, et al: Clinical study of baseball pitchers: Correlation of injury to the throwing arm with method of delivery. Am J Sports Med 6:15, 1978
5. Andrews JR: Bony injuries about the elbow in the throwing athlete. Instructional Course Lectures 34:323, 1985
6. Andrews JR, Craven WM: Lesions of the posterior compartment of the elbow. Clin Sports Med 10:637, 1991
7. Andrews JR, Schemmel SP, Whiteside JA: Evaluation, treatment, and prevention of elbow injuries in throwing athletes. *In* Nicholas JA, Hershman EB (eds): The Upper Extremity in Sports Medicine. St. Louis, CV Mosby, 1980, p 781
8. Aronem JB: Problems of the upper extremity and gymnasts. Clin Sports Med 4:61, 1985
9. Atwater AE: Biomechanics of overarm throwing movements and of throwing injuries. Exerc Sport Sci Rev 7:43, 1979
10. Backx FJ, Erich BM, Kemper AB, et al: Sports injuries in school-aged children: An epidemiologic study. Am J Sports Med 17:234–240, 1989
11. Bennett GE: Elbow and shoulder lesions of baseball players. Am J Surg 19:484, 1959
12. Bennett JB, Tullos HS: Ligamentous and articular injuries in the athlete. *In* Morrey BF: The Elbow and Its Disorders. Philadelphia, WB Saunders, 1985, p 502
13. Black GB, McPherson JA, Reed MH: Traumatic pseudodislocation of the acromioclavicular joint in children. Am J Sports Med 19:644, 1991
14. Bradley JP: Upper extremity: Elbow injuries in children and adolescents. *In* Stanitski CL, DeLee JC, Dree D (eds): Pediatric and Adolescent Sports Medicine. Philadelphia, WB Saunders, 1994, p 242
15. Brodeur AE, Silberstein MJ, Graviss ER: Radiology of the pediatric elbow. Boston, GK Hall, 1981
16. Brogden BS, Crow MD: Little Leaguer's elbow. Am J Roentgenol 83:671, 1960
17. Brooks AL, Henning GD: Injury to the proximal clavicular epiphysis. J Bone Joint Surg 54A:1347, 1972
18. Cahill RC, Tullos HS, Fain RH: Little League shoulder. J Sports Med 2:150, 1974
19. Chambers RB: Orthopaedic injuries in athletes ages 6-16. Am J Sports Med 7:195, 1979
20. Collins HR, Evarts CM: Injuries to the adolescent athlete. Postgrad Med J 49:72,1971
21. Curtis RJ, Rockwood CA: Fractures and dislocations of the shoulder. *In* Rockwood CA, Wilkins KE, King RE (eds): Fractures in Children. Philadelphia, J. B. Lippincott, 1991
22. Dotter WE: Little Leaguer's shoulder—A fracture of the proximal epiphyseal cartilage of the humerus due to baseball pitching. Guthrie Clinic Bulletin 23:68, 1953
23. Emans JB: Upper extremity injuries in sports. *In* Micheli LJ (ed): Pediatric and Adolescent Sports Medicine. Boston, Little, Brown & Co, 1984, p 65
24. Ferretti A, Papandrea P: Stress fracture of the trochlea in an adolescent gymnast. J Shoulder Elbow Surg 3:399, 1994
25. Gainor BT, Piotrowski G, Puhn J, et al: The throwing biomechanics and acute injury. Am J Sports Med 8:114, 1980
26. Garrick JG, Requa R: Injuries in high school sports. Pediatrics 61:465, 1978
27. Glousman R, Jobe F, Tibone J, et al: Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. J Bone Joint Surg 70:220, 1988

28. Goldberg MJ: Gymnastic injuries. Orthop Clin North Am 11:717, 1980
29. Gore RM, et al: Osseous manifestations of elbow stress associated with sports activities. Am J Roentgenol 134:971, 1980
30. Graviss RE, Hoffman AD: Imaging of the pediatric elbow. *In* Morrey BF (ed): The Elbow and Its Disorders, ed 2. Philadelphia, WB Saunders, 1993, p 181
31. Grana WA, Rashkin A: Pitcher's elbow in adolescents. Am J Sports Med 8:333, 1980
32. Gugenheim JJ, et al: Little League survey: The Houston study. Am J Sports Med 4:189, 1976
33. Hale CJ: Injuries among 771,810 Little League baseball players. J Sports Med Phys Fitness 1:80, 1961
34. Hastings H, Simmons BP: Hand fractures in children. Clin Orthop 188:120, 1984
35. Hunter SC: Little leaguer's elbow. *In* Zarins B, Andrews JR, Carson WG (eds): The United States Olympic Committee Sports Medicine Council: Injuries in the Throwing Arm. Philadelphia, WB Saunders, 1985, pp 228
36. Indelicato PA, Jobe FW, Kerlan RK, et al: Correctable elbow lesions in professional baseball players: A review of 25 cases. Am Sports Med 7:72–79, 1979
37. Ireland ML, Andrews JR: Shoulder and elbow injuries in the young athlete. Clin Sports Med 7:473, 1988
38. Itoi E, Tabata S: Rotator cuff tears in the adolescent. Orthopaedics 16:78, 1993
39. Jobe FW, Nuber G: Throwing injuries of the elbow. Clin Sports Med 5:621, 1986
40. Jobe FW, Tibone JE, Perry J, et al: An EMG analysis of the shoulder in throwing and pitching. Am J Sports Med 11:3, 1983
41. Krahl H, Michaelis U, Pieper H, et al: Stimulation of bone growth through sports. Am J Sports Med 22:751, 1994
42. Landin LA: Fracture patterns in children. Acta Orthop Scan 202:1, 1983
43. Larson RL: Epiphyseal injuries in the adolescent athlete. Orthop Clin North Am 4:839, 1973
44. Larson RL, McMahon RO: The epiphysis in the childhood athlete. JAMA 196:607, 1966
45. Larson RL, et al: Little league survey: The Eugene study. Am J Sports Med 4:201, 1976
46. Liberson F: Os acromiale: A contested anomaly. J Bone Joint Surg 19:683, 1937
47. Lipscomb AB: Baseball pitching injuries in growing athletes. J Sports Med 3:25, 1975
48. Little League Baseball, Inc: Play it safe. Williamsport, PA, LLB, 1989
49. McManama GB, et al: The surgical treatment of osteochondritis of the capitellum. Am J Sports Med 13:11, 1985
50. Meyers JF: Injuries to the shoulder girdle and elbow. *In* Sullivan JA, Grana WA (eds): The Pediatric Athlete. Park Ridges, IL, American Academy of Orthopaedic Surgeons, 1988, p 145
51. Micheli LJ: Elbow pain in a Little League pitcher. *In* Smith NJ: Common Problems in Pediatric Sports Medicine. Chicago, Yearbook Publishers, 1989, p 233
52. Micheli LJ: Sports injuries in special groups. *In* Harris M, Williams C, Stanish WD, Micheli LJ: Oxford Textbook of Sports Medicine. New York, Oxford University Press, 1994, p 595
53. Micheli LJ, Gerbino PG: The epidemiology of children's sports injuries. Orthop Trans 3:88, 1979
54. Mitsunaga MM, Adishan DA, Bianco AJ: Osteochondritis dessicans of the capitellum. J Trauma 22:43, 1982
55. Montgomery SP, Lloyd RD: Avulsion fracture of the coracoid epiphysis with acromioclavicular separation: Report of two cases in adolescents and review of literature. J Bone Joint Surg 59A:963, 1977
56. Morrey BF: The Elbow and Its Disorders, ed 2. Philadelphia, WB Saunders, 1993
57. Neer CS II, Horwitz BS: Fractures of the epiphyseal plate. Clin Orthop 41:24, 1965
58. Newberg AH: The radiographic evaluation of shoulder and elbow pain in the athlete. Clin Sports Med 6:785, 1987
59. 1994 Little League baseball: Official regulations and playing rules. Williamsport, PA, Little League Baseball, Incorporated, 1994
60. Norwood LA, Barrack R, Jacobson KE: Clinical presentation of complete tears of the rotator cuff. J Bone Joint Surg 71A:499, 1989
61. Ogden JA: Skeletal injury in the child. Philadelphia, W. B. Saunders, 1990

62. Ogden JA: Injury to the growth mechanisms. *In* Skeletal Injury in the Child. Philadelphia, W. B. Saunders, 1990, p 97
63. Orava S, Saarela J: Exertion injuries to young athletes. Am J Sports Med 6:68, 1978
64. Pappas AM: Elbow problems associated with baseball during childhood and adolescence. Clin Orthop 164:30, 1982
65. Pappas AM, Zawacki RM: Baseball: too much on a young pitcher's shoulders? Phys Sportsmed 19:107, 1991
66. Patel ME, Iretarry J, Stricevic M: Stress fracture of the ulnar diaphysis: Review of the literature and report of a case. J Hand Surg 11A:443, 1986
67. Pavlov H, et al: Nonunion of the olecranon epiphysis: Two cases in adolescent baseball pitchers. Am J Roentgoenol 136:819, 1981
68. Perry J: Anatomy and biomechanics of the shoulder in throwing, swimming, gymnastics, and tennis. Clin Sports Med 2:247, 1983
69. Peterson CA, Peterson HA: Analysis of the incidence of injuries to the epiphyseal growth plate. J Trauma 12:275, 1972
70. Rang M, Children's fractures. Philadelphia, J. B. Lippincott, 1974
71. Reister JN, Baker BE, Mosher JF, et al: A review of scaphoid fracture healing in competitive athletes. Am J Sports Med 13:154, 1985
72. Rettig AC, Ryan R, Shelbourne KD, et al: Metacarpal fractures in the athlete. Am J Sports Med 17:567, 1989
73. Richardson AR: The biomechanics of swimming: The shoulder and knee. Clin Sports Med 5:103, 1986
74. Richardson AR, Jobe FW, Collins HR: The shoulder in competitive swimming. Am J Sports Med 81:159, 1980
75. Rockwood CA: Injuries to the sternoclavicular joint. *In* Rockwood CA, Green DP, Bucholz RW (eds): Fractures in Adults. Philadelphia, J. B. Lippincott, 1991
76. Rockwood CA, Wilkins KE, King RE: Fractures in children, vol 3. Philadelphia, J. B. Lippincott Co., 1984
77. Roy S, Caine D, Singer KM: Stress changes of the distal radius epiphysis in young gymnasts. Am J Sports Med 13:301, 1985
78. Ryan JR, Salciccioli GG: Fractures of the distal radial epiphysis in adolescent weight lifters. Am J Sports Med 4:1, 1976
79. Silberstein MJ, et al: Some vagaries of the medial epicondyle. J Bone Joint Surg 63A:524, 1981
80. Silberstein MJ, et al: Some vagaries of the olecranon. J Bone Joint Surg 63A:722, 1981
81. Smet LD, Claessens A, Lefevre J, Beunen G: Gymnast wrist: An epidemiologic survey of ulnar variance and stress changes of the radial physis in elite female gymnasts. Am J Sports Med 22:846, 1994
82. Stanitski CL: Combating overuse injuries: A focus on children and adolescents. Phys Sportsmed 21:87, 1993
83. Tachdjian MO: Pediatric Orthopedics, vol 4, ed 2. Philadelphia, W. B. Saunders Co., 1990
84. Tachdjian MO: Introduction. *In* Pediatric Orthopaedics, vol 1, ed 2. Philadelphia, WB Saunders, 1990, p 1
85. Tachdjian MO: Fractures and dislocations. *In* Pediatric Orthopaedics, vol 4, ed 2. Philadelphia, WB Saunders, 1990, p 3013
86. Taga I, Yoneda M, Ono K: Epiphyseal separation of the coracoid process associated with acromioclavicular sprain: A case report and review of the literature. Clin Orthop 207:138, 1986
87. Torg JS: The Little League pitcher. Am Fam Physician 6:71, 1972
88. Torg JS, Pollack H, Sweterlitsch P: The effect of competitive pitching on the shoulders and elbow of preadolescent baseball players. Pediatrics 49:267, 1972
89. Torg JS, Moyer RA: Nonunion of a stress fracture through the olecranon epiphyseal plate observed in an adolescent baseball pitcher: A case report. J Bone Joint Surg 59A:264, 1977
90. Tullos HS, King JW: Lesions of pitching arm in adolescents. JAMA 220:264, 1972
91. Volk CP, Campbell KR, McFarland EG, et al: Kinetic analysis of the elbow and

shoulder in professional and Little League pitchers (Abstract). American Orthopaedic Society for Sports Medicine, Twentieth Annual Meeting, Palm Desert, California, 1994
92. Weseley JS, Barenfeld PA: Ball throwers' fracture of the humerus: Six case reports. Clin Orthop 64:153, 1969
93. Wilkins K: Fractures of the distal humerus. *In* Rockwood CA, Wilkins KE, King RE (eds): Fractures in Children. Philadelphia, JB Lippincott, 1991, p 526
94. Williams DJ: The mechanisms producing fracture separation the proximal humeral epiphysis. J Bone Joint Surg 63B:102, 1981
95. Wilson FD, et al: Valgus extension overload in the pitching elbow. Am J Sports Med 11:83, 1983
96. Winter J, Sterner S, Maurer D, et al: Retrosternal epiphyseal disruption of medial clavicle: Case and review in children. J Emerg Med 7:9, 1989
97. Wood VE, Campbell S: The supratrochlear dorsale accessory ossicle in the elbow. J Shoulder Elbow Surg 3:395, 1994
98. Woods GW, Tullos HS: Elbow instability and medial epicondylar fractures. Am J Sports Med 5:23, 1977
99. Woodward AH, Bianco AJ: Osteochondritis dessicans of the elbow. Clin Orthop 110:35, 1975
100. Zariczny B, Shattuck LJ, Mast TA, et al: Sports-related injuries in school-aged children. Am J Sports Med 8:318, 1980
101. Zarins B, Andrews JR, Carson WG: Injuries to the throwing arm. Philadelphia, W. B. Saunders, 1985.

Address reprint requests to

Mary Lloyd Ireland, MD
Kentucky Sports Medicine Clinic
601 Perimeter Drive
Lexington, KY 40517