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CHAPTER 25

Shoulder Injuries

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INTRODUCTION

The glenohumeral joint has the greatest range of motion of any joint in the body. In order for a pitch to be biomechanically correctly thrown, in the dominant shoulder external rotation must be greater and glenohumeral joint placement more reproducible than in the nonthrowing limb. The shoulder, during the throwing act, is like a whip. Stability proximally at the scapulothoracic articulation, acromioclavicular and sternoclavicular joints, represents the person holding the whip. If there is no support of the scapula on the trunk, the absorption forces proximally are minimized and transferred distally in the chain. In the young athlete, prior to musculoskeletal maturity, the physiologically lax, and the incompletely developed anterior shoulder is at risk for injury (Fig. 1). During throwing the repetitive, excessive tensile forces on the anterior capsule, ligaments of the glenohumeral joint, and rotator cuff may produce a painful shoulder. As intensity of throwing increases, recurrent anterior subluxation occurs, and rotator cuff weakness ensues. The kinetic chain of scapulothoracic articulation, shoulder, and elbow, must be in synchrony in order to reduce injury risk.

Microtraumatic, repetitive forces may cause shoulder problems in the young athlete. Dotter described a proximal humeral physeal plate fracture caused by repetitive stresses of throwing (1). Shoulder problems are second only to elbow problems in the skeletally immature baseball athlete. Underlying elbow problems also may lead to shoulder dysfunction (2). In immature pitchers, prevention programs that involve strengthening of the rotator cuff, and emphasizing skill and control should be included in practice (3). Accentuation of the velocity of the pitch should be delayed until skill and control have been achieved, and maturity has occurred.

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Biomechanics

The correct diagnosis and treatment of childhood injuries is possible when there is comprehension of the unique anatomy, physiology, radiography, and healing characteristics of the young athlete. Incorrect biomechanics and too much throwing will result in injury. The Little League pitcher, as compared to the adult pitcher, will often have a shortened stride length, a rushed balance point, an open stance, or an upright trunk. All of these factors prohibit an adequate transfer of power generated from the lower extremities and torso to the upper extremity (Andrew JA, Fleisig G. Unpublished data). With poor mechanical transfer of power, the amount of work required of the shoulder in each throwing act is effectively increased, and thus predisposes the shoulder to injury (4). When studied, the shoulder in the professional, (compared to the Little Leaguer), when throwing fast balls had a greater internal rotation moment, an increased maximum rotation velocity, and greater shoulder compression forces. More research projects should be directed toward understanding the forceful effects on the musculoskeletal anatomy of the young shoulder.

Shoulder injuries result from acute trauma or chronic repetitive forces as a result of excessive throwing, faulty biomechanics, and the uniqueness of the skeletally immature joint. Evaluation of the skeletally immature shoulder must include the acromioclavicular, sternoclavicular, and scapulothoracic articulations in addition to the glenohumeral joint.

Development

Knowledge of the temporal order for the appearance and closure of ossification centers is necessary to derive the correct diagnosis. Appearance and fusion of ossification centers of the humerus, clavicle, acromion, and scapula are shown diagrammatically (5) (Fig. 2). The

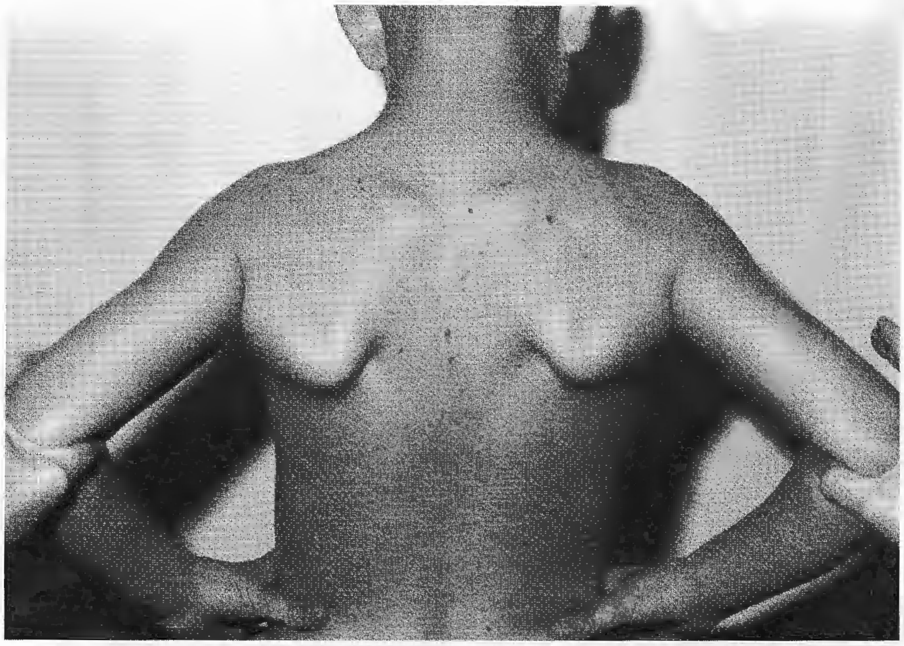


FIG. 1. Typical scapulothoracic winging that occurs in asymptomatic Little League athletes. The underdeveloped scapulothoracic articulation can lead to shoulder and elbow problems if the intensity and biomechanics of throwing are not monitored. Scapular winging is shown during a clinical examination in this asymptomatic Little League thrower. Symmetrical winging is demonstrated upon stressing the scapulothoracic articulation.

proximal, medial humeral epiphyseal ossification center is present radiographically by 4 months and occasionally is noted at birth. The greater tuberosity ossific nucleus is seen between 6 to 18 months and the lesser tuberosity shortly thereafter, but the latter is more variable in its presence as a separate structure. The greater tuberosity and the proximal humeral epiphysis fuse by 4 to 7 years of age. Proximal humeral physeal closure is usually complete in girls by the age of 14 to 16 years and in boys by 17 to 21 years. The sternal (proximal) end of the clavicle has a secondary ossification center, which appears between the ages of 15 and 18 years and fuses to the main body of the clavicle at 20 to 25 years of age. The acromial (distal) end of the clavicle rarely has a secondary ossification center; however, a thin distal epiphysis is normally present and fuses to the metaphysis of the clavicle by 19 years of age. The scapula has seven postnatal ossification centers—two of which are in the acromion and three located in the coracoid process. The two acromial centers develop between 14 and 16 years of age, fuse to each other by age 19, and then fuse to the scapular spine by age 25. An area of the acromion that fails to coalesce with the scapula is referred to as an os acromiale. The coracoid ossification centers are present at the middle, base, and tip of the coracoid and appear by ages 18 months, 10 years, and 14 years, respectively. Fusion of these centers is complete by age 18 (5).

RADIOGRAPHIC EVALUATION

In the throwing athlete, the routine radiographic projections obtained are the anteroposterior (AP) with the humerus in internal and external rotation, axillary lateral, Stryker notch, and supraspinatus outlet. A 40°, caudal tilt,

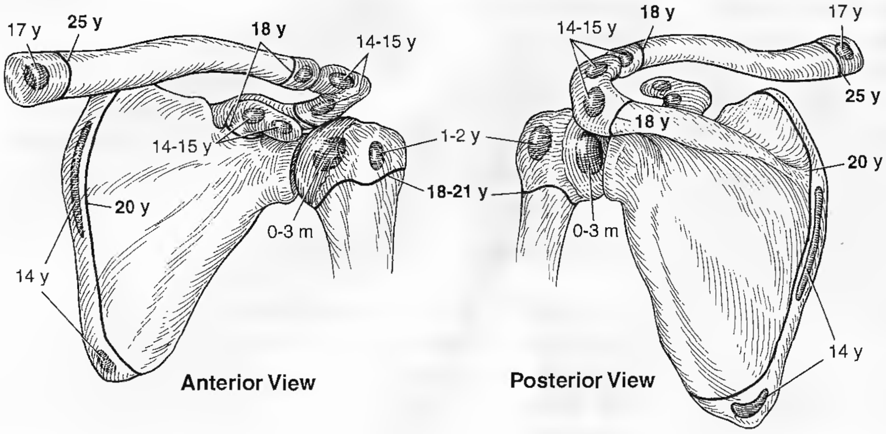
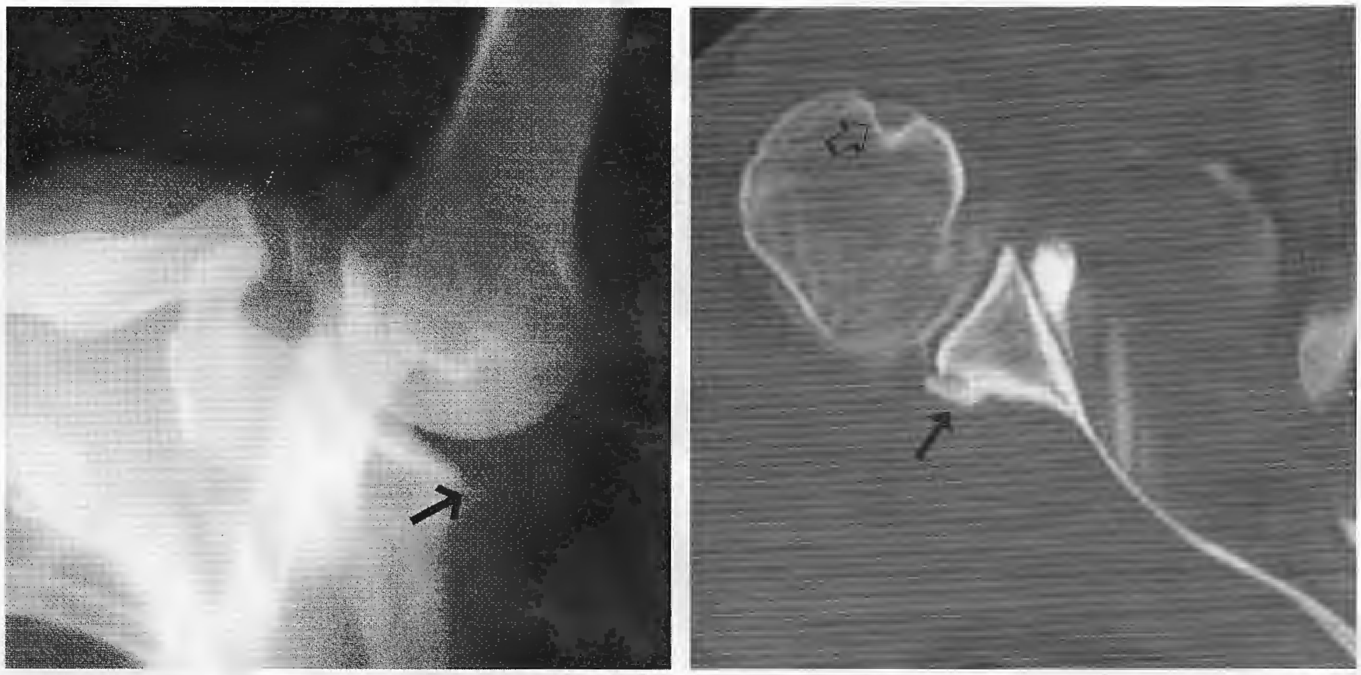


FIG. 2. The appearance and closure of ossification centers is pictured diagrammatically with ossification centers outline with years of appearance and darker lines showing fusion of the secondary ossification centers. (Adapted from Ogden JA, ed. *Skeletal injury in the child.* Philadelphia, PA: WB Saunders, 1990;84, Figs. 3-28 and 3-29. Drawing by Rich Pennell, medical illustrator).



A B

FIG. 3. A left-handed pitcher and quarterback developed a chronic glenoid exostosis without instability. **(A)** Arrow shows posterior, inferior exostosis seen on a Stryker notch view. **(B)** A CT scan with contrast reveals the posterior exostosis (*arrow*) dye anteriorly, and anteriorly normal lucency of the labrum. There was no associated instability.

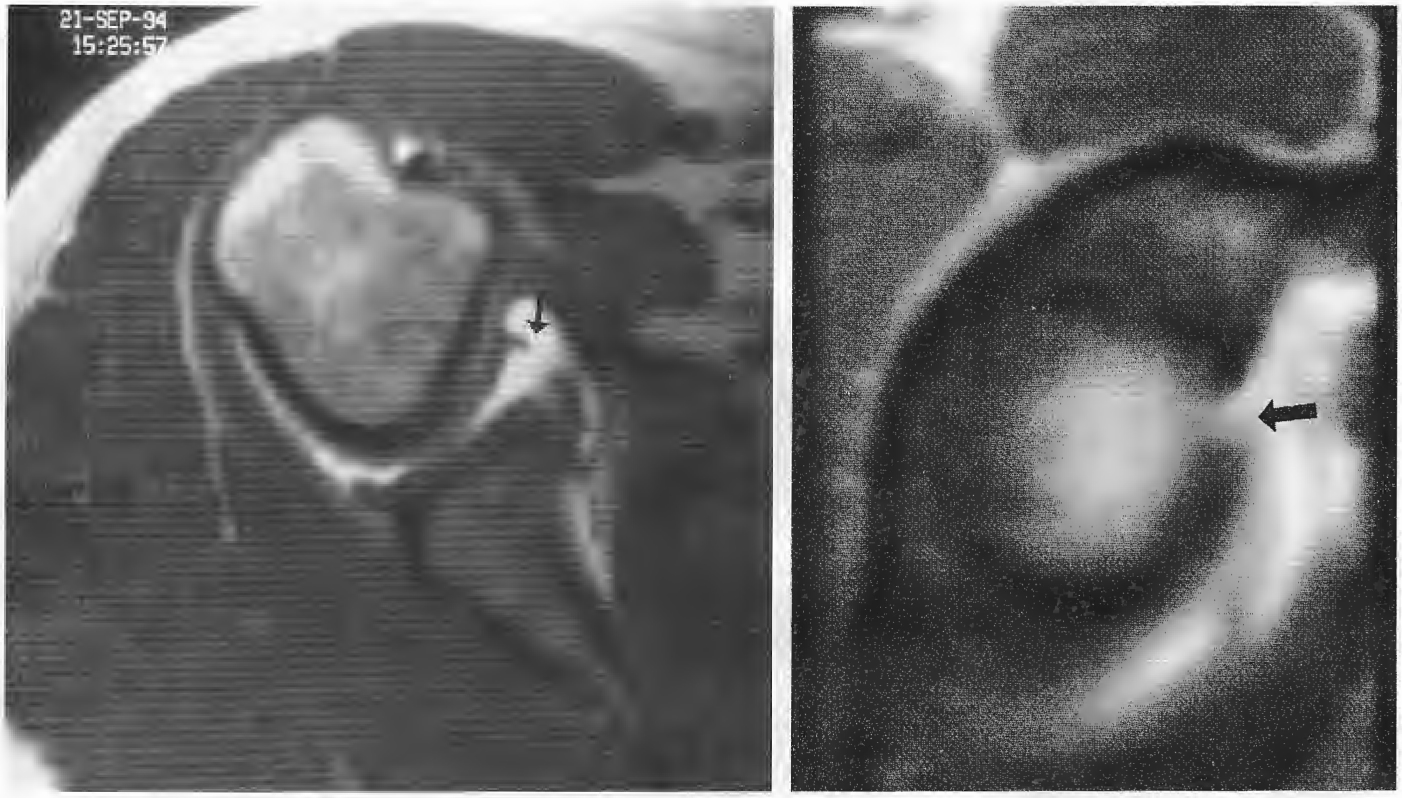
AP view is helpful for evaluating sternoclavicular injuries. Comparison views of the contralateral shoulder are obtained if the diagnosis is unclear. Understanding the development and radiographic findings about the shoulder is key to proper diagnosis and treatment of glenohumeral pathology (6).

The use of computerized axial tomography (CT) and magnetic resonance imaging (MRI) is limited by cooperation, size, and disposition of the age. CT elucidates specific bony injury. A left-hand–dominant Little League pitcher and quarterback had complained of loss of velocity and posterior shoulder pain worsening over the past 5 years. A Stryker view showed posterior glenoid exostosis (Fig. 3A). A CT scan with contrast was helpful to delineate the normal labrum and the posterior inferior glenoid exostosis (Fig. 3B). The eponym for this exostosis is a Bennett's lesion (7). At arthroscopy, findings were those of a labral tear and exostosis posteriorly and no instability. Contrast radiographic studies also are helpful.

Labral tears and instability patterns are diagnosed by history and physical examination. An MRI may be helpful in certain situations. Technological advances in MRI, with increased magnet size, use of contrast, new reconstructed views, and radiologist's advanced understanding, will improve its usefulness.

The overachieving, fast-pitching all-star, the family, and coach will accept the physician's diagnosis if abnormalities are shown to them. In the young athlete, shoul-

FIG. 4. Normal glenoid labrum appearance with gadolinium injection, axial flash image.



A B

FIG. 5. (A) Axial T_1W_1 image showing tear of the inferior glenohumeral ligament (*arrow*) with gadolinium passing through to the capsule. Also, there is stripping of the labrum just below the ligamentous tear. **(B)** Normal posterior glenoid labrum. Sagittal 3-D reconstruction demonstrates the anterior labral tear (*arrow*).

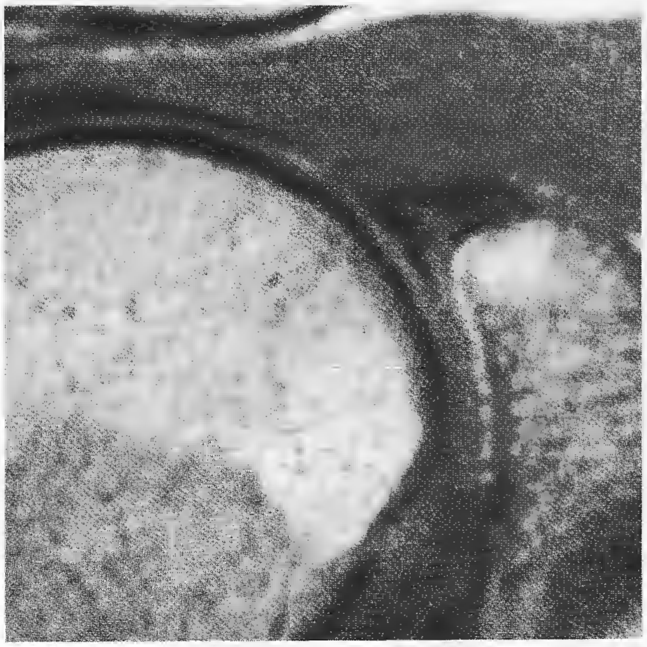


FIG. 6. Coned down, superior labrum, anterior–posterior lesion is seen on coronal T_1W_1 view (*arrow*).

der MRI should be considered when diagnosis is unclear, but the athlete desires to continue to pitch.

In the cooperative patient, an MRI with gadolinium contrast is useful to outline the labrum. A normal scan axial, flash image is shown (Fig. 4). Tear of the anterior labrum is depicted on axial T_1, W_1, (Fig. 5A), but sagittal 3-D reconstruction more clearly shows the labrum tear (Fig. 5B). A coned down, coronal T_2W_1 view reveals a superior labral anterior posterior (SLAP) lesion (Fig. 6).

INJURIES

Epidemiology

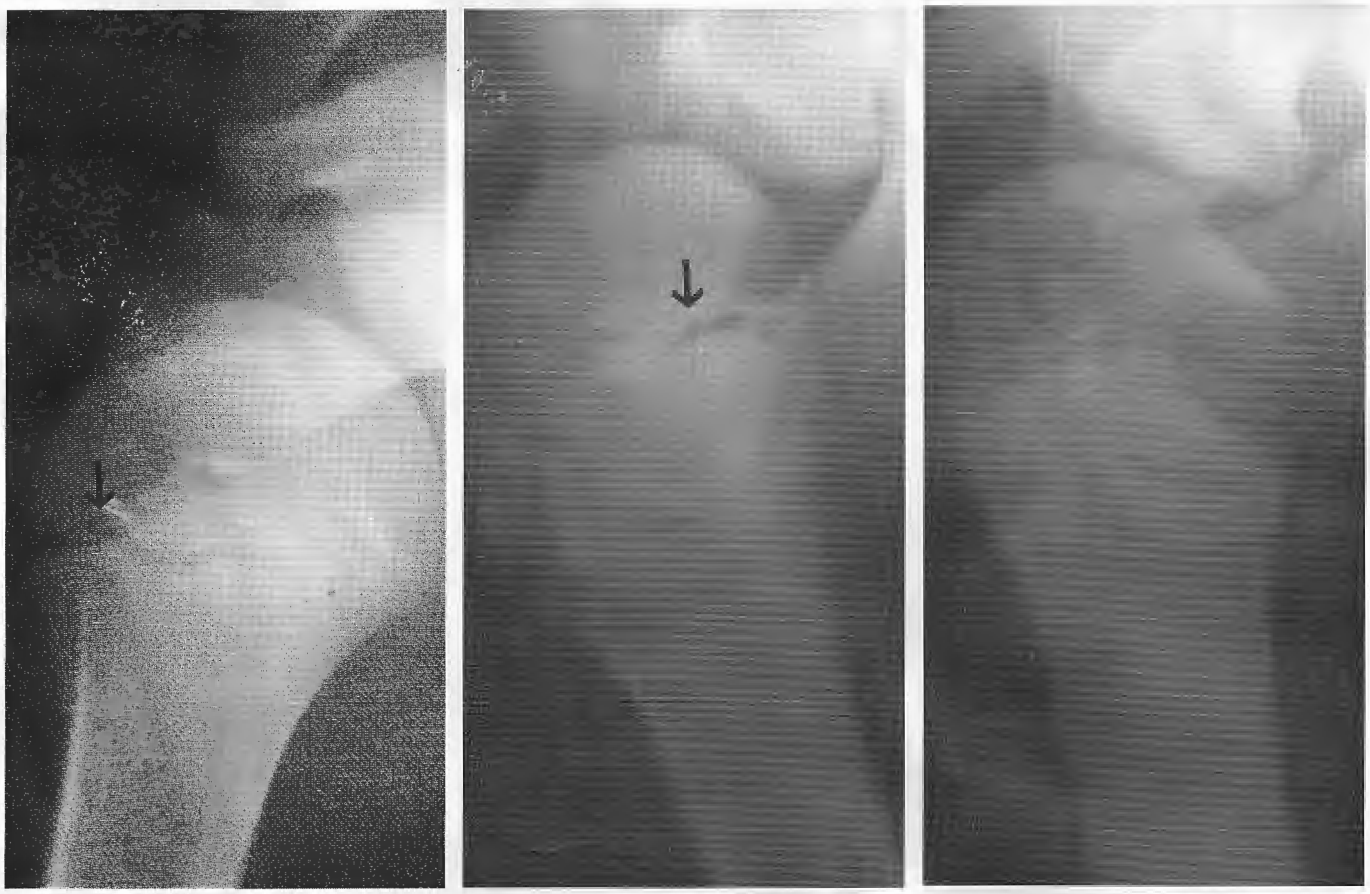
Andrish reviewed the number of patients who presented for evaluation of a sport-related injury to the Cleveland Clinic from 1977 to 1986. He found that 20% of the injuries evaluated occurred in patients 15 years of age or younger and that 15% of these involved the upper extremity. The most commonly involved joint was the shoulder—45% of upper extremity injuries. The most frequent diagnosis was shoulder instability; the second was rotator cuff injury (8). Contributing factors in these injuries were shoulder overuse, inadequate conditioning, and incorrect biomechanics.

Little Leaguer's Shoulder

"Little Leaguer's shoulder," initially described in 1953 by Dotter, is an injury that involves the proximal humeral epiphyseal growth plate in young baseball pitchers (1). Adams, in 1966, reported on five cases in adolescent pitchers and proposed a traction-type mechanism of injury (9). Repetitive high torsional stress results in this physeal fatigue fracture. The typical presentation is an athlete with a several-month history of mild shoulder pain that escalated to a severe level while pitching in a game (10,11). The coach may have noticed in the pitcher a progressive loss of throwing velocity and decreased accuracy. On physical examination, the shoulder is tender to palpation along the anterior glenohumeral joint and the proximal, lateral humerus.

Shoulder range of motion is decreased and painful (12). Plain radiographs of this right-handed pitcher demonstrate widening of the epiphyseal cartilaginous plate (Fig. 7A). Comparison views of the opposite shoulder are helpful to delineate differences from the normal to the abnormal (Fig. 7B). The glenoid ossification line should be noted. Occasionally there will be adjacent epiphyseal fragmentation or demineralization. An axillary view reveals a healed proximal humeral fracture (Fig. 7C). Because of the growth activity of the physes, a bone scan will reveal increased uptake bilaterally and thus may not provide useful additional information. If diagnosis is not confirmed by history or plain radiographs, or if the athlete, family, or coach is unbelieving, a bone scan will usually reveal increased activity asymmetrically. Initial treatment includes rest, daily gentle range of motion exercises, and, as pain resolves, a light rotator cuff strengthening program. No throwing activities of any kind are permitted for at least 6 weeks. When clinical and radiographic signs of healing are present, an advanced rotator cuff strengthening program is instituted. This is followed by a closely supervised throwing program. Also, any flaws in the pitcher's throwing mechanics must be corrected.

In skeletally immature pitchers, proximal humeral epiphysiolysis or osteochondrosis of the proximal epiphysis



A–C

FIG. 7. Right-hand dominant pitcher had pain in the shoulder for 6 weeks. **(A)** On Stryker view, there is significant widening of the epiphyseal plate of the proximal humerus (*arrow*). **(B)** Axillary, lateral view reveals widening anteriorly (*arrow*). **(C)** Axillary view shows healed proximal humeral fracture. Note the undulation epiphyseal plate.

is a rare condition. Although a separate entity from the classic Little Leaguer's Shoulder, the same eponym is often used in the literature. A distinguishing characteristic is that, even though the physeal plate is normal, the proximal humeral epiphysis demonstrates signs of avascular necrosis with fragmentation and, possibly, loose body formation. Lipscomb reported a pitcher who developed osteochondrosis of his proximal humeral epiphysis that required arthrotomy for removal of loose bodies. The athlete did not return to sport participation (13). The diagnosis of proximal humeral epiphysiolysis has a much more guarded prognosis than a proximal humeral epiphyseal plate fatigue fracture.

Glenohumeral Instability

The kinetics and kinematics of the throwing shoulder have been well described in the scientific literature (14,15). Evaluation and treatment of symptomatic shoulder instability are successful if the implications of the extreme forces and torques applied to the shoulder during the cocking and deceleration phase are appreciated. The classification systems for shoulder instability have been discussed in Chapter 4. In the young, congenitally lax thrower, the mechanism of injury is usually produced by microtrauma without acute trauma. In a contact sport such as football, the multisport athlete may sustain a

A

B

C

FIG. 8. Anterior subluxation of the humeral head in an asymptomatic Little League baseball athlete. **(A)** Stabilizing the acromion and performing an anterior humeral translation provide excellent information on natural stability in this subluxation test. **(B)** Reduction test with the acromion continuing to be stabilized posteriorly, the humeral head is reduced. The athlete has no apprehension and this test does not bother him. **(C)** With the arm in an abducted, externally rotated position, forces on the posterior aspect of the humeral head, attempt to sublux and cause a negative apprehension test; but, there is significant subluxability anteriorly.

traumatic acute dislocation and then, later, exhibit recurrent subluxation complaints when throwing. The athlete who is in a rapid phase of growth may possess a tight posterior capsule with relative anterior laxity and then develop subluxation, loss of external rotation range, and muscle imbalance when external rotator strength exceeds internal rotator strength (16). In the young, the symptoms of recurrent anterior or multidirectional glenohumeral instability are similar to that noted in the physically mature thrower. The athlete may complain of shoulder pain, usually in the cocking phase. A sense of soreness and numbness, decreased velocity and reduced accuracy, and "slipping" and popping are complaints that should not be regarded by the coaching staff as attempts by the young athlete to be pulled from throwing or conditioning drills, practice, or even a losing game situation. On clinical examination, rotator cuff irritation with positive impingement signs often is demonstrated. However, in this age group, rotator cuff disorders with impingement syndrome are secondary. Joint laxity with anterior instability is the primary problem. Tests that are used to assess instability include a positive apprehension and relocation test, an increased load and shift test, an increased shoulder Lachman, and a positive sulcus sign. A Little League pitcher had no shoulder problems but demonstrated the typical laxity of a 10-year-old. With the patient in a relaxed, seated position while stabilizing the acromion and applying anterior translation forces to the humeral head, painless subluxation resulted (Fig. 8A). The posterior relocation maneuver (Fig. 8B) is performed. Subluxaton of the anterior humeral head in abduction and external rotation is not a bother (Fig. 8C). The normal-for-age, scapulothoracic winging, when present during throwing, places excessive forces on the glenohumeral joint. Bilaterally increased glenohumeral translation due to a generalized hyperelastic state is a common finding in the skeletally immature and makes the determination of "pathologic" laxity difficult at times. Techniques for radiographic evaluation of the shoulder are identical to that of the skeletally mature athlete. Special attention must be paid to the appearance of the physes and comparison views are often helpful. A bony Bankart or a Hill-Sachs lesion, which are pathognomonic for anterior instability, may be noted on axillary, Stryker, and Westpoint special radiographic views.

The clinical treatment for instability in the young thrower follows the same algorithm as in the older thrower, except, the conservative regimen should be pursued for a significantly longer time period in the immature. This conservative period allows for improved stability as a result of maturation of skills, techniques and coordination, and progressive diminution of soft tissue hyperelasticity that accompanies hormonal changes. Furthermore, decreased capsular laxity and the presence of physeal closure present a more ideal setting for surgical intervention, should it be deemed necessary. Significant bony defects, associated with acute traumatic instability, are more difficult to treat nonoperatively and may require early arthroscopic or open stabilization procedures.

Rotator Cuff Injury

The incidence of complete rotator cuff tears in the adolescent population is only 0.8% to 1.0% of patients of all ages diagnosed with a cuff tear (17,18). This low rate is attributed to several factors, which include the absence of any progressive degenerative changes of the rotator cuff tendon that is so commonly observed in the elderly. Also, in the skeletally immature, the physeal plate is the "weak link," not the musculotendinous unit. Thus, throwing, in the young, is more likely to produce a "Little Leaguer's shoulder" than an isolated rotator cuff tear. When a rotator cuff tear is found, it is usually a partial undersurface rotator cuff tear that is frequently associated with glenohumeral instability (17). Primary rotator cuff impingement, due to an os acromiale, may be treated by various methods, which include (a) subacromial decompression for an immobile but impinging os, (b) removal of the os fragment if it is very small, or (c) open reduction, internal fixation of the fragment if it is large and unstable with an inferior tilt toward the rotator cuff.

Rotator cuff strains are a common overuse injury seen particularly in pitchers who have not undergone an adequate preseason conditioning program, or who have exceeded the recommended limits on total throws allowed per practice, per game, or per week (19). With throwing, the athlete complains of pain especially during the deceleration phase. This phase requires a strong, controlled eccentric contraction of the rotator cuff muscles. Weakness and loss of accuracy and velocity commonly

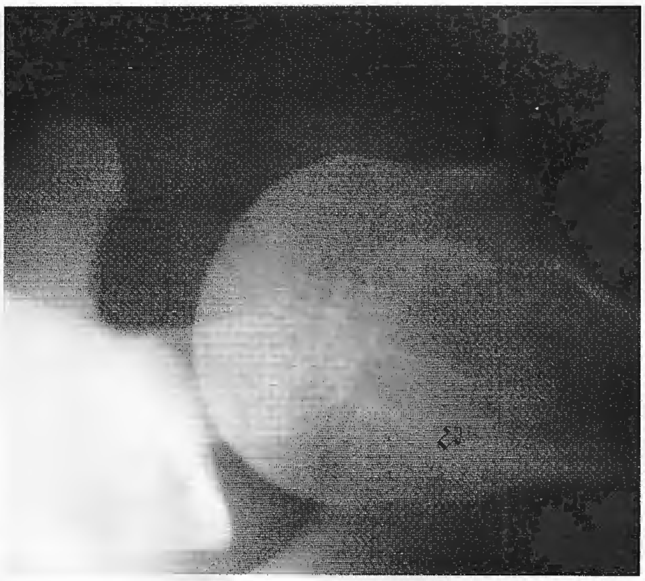


FIG. 9. Os acromiale is shown on an axillary view (*arrow*).

occur. On clinical examination, the rotator cuff is tender to palpation and weak to resisted muscle strength testing. A brachial plexus injury should be considered if rotator cuff or deltoid dysfunctional weakness or a coinciding sensory defect is present (20). Pitchers with shoulder instability problems are predisposed to rotator cuff strain. Thus, a complete assessment for glenohumeral instability should be performed. The recommended treatment for a rotator cuff strain includes active rest with range of motion exercises and a progressive, rotator cuff strengthening program. A supervised throwing program is begun when the athlete is pain-free and has normal rotator cuff strength. Although unusual in this age group, tensile failure of the rotator cuff can be seen. Primary rotator cuff impingement is an uncommon entity when defined as an abnormality in the coracoacromial arch that leads to direct compression and results in inflammation of the rotator cuff. Anatomical findings may include an os acromiale, a hooked acromion (Neer type III) coracoid hypertrophy, or coracoacromial ligament hypertrophy. Radiographic assessment of the acromial profile, coracoid site, and presence of os acromiale is performed. The athlete with rotator cuff disease complains of superior shoulder pain with repetitive throwing and overhead activities. Shoulder weakness or early fatigue and superior (subacromial) popping or catching may also be present.

On physical examination, there is tenderness to palpation of the anterosuperior or superolateral rotator cuff, of the coracoid tip or CA ligament anteriorly, or of an os acromiale fibrous union superiorly. Positive impingement signs and weakness may also be elicited. It is imperative that a complete glenohumeral stability examination be performed. The clinical treatment of rotator cuff disease in the immature begins with active rest, which includes

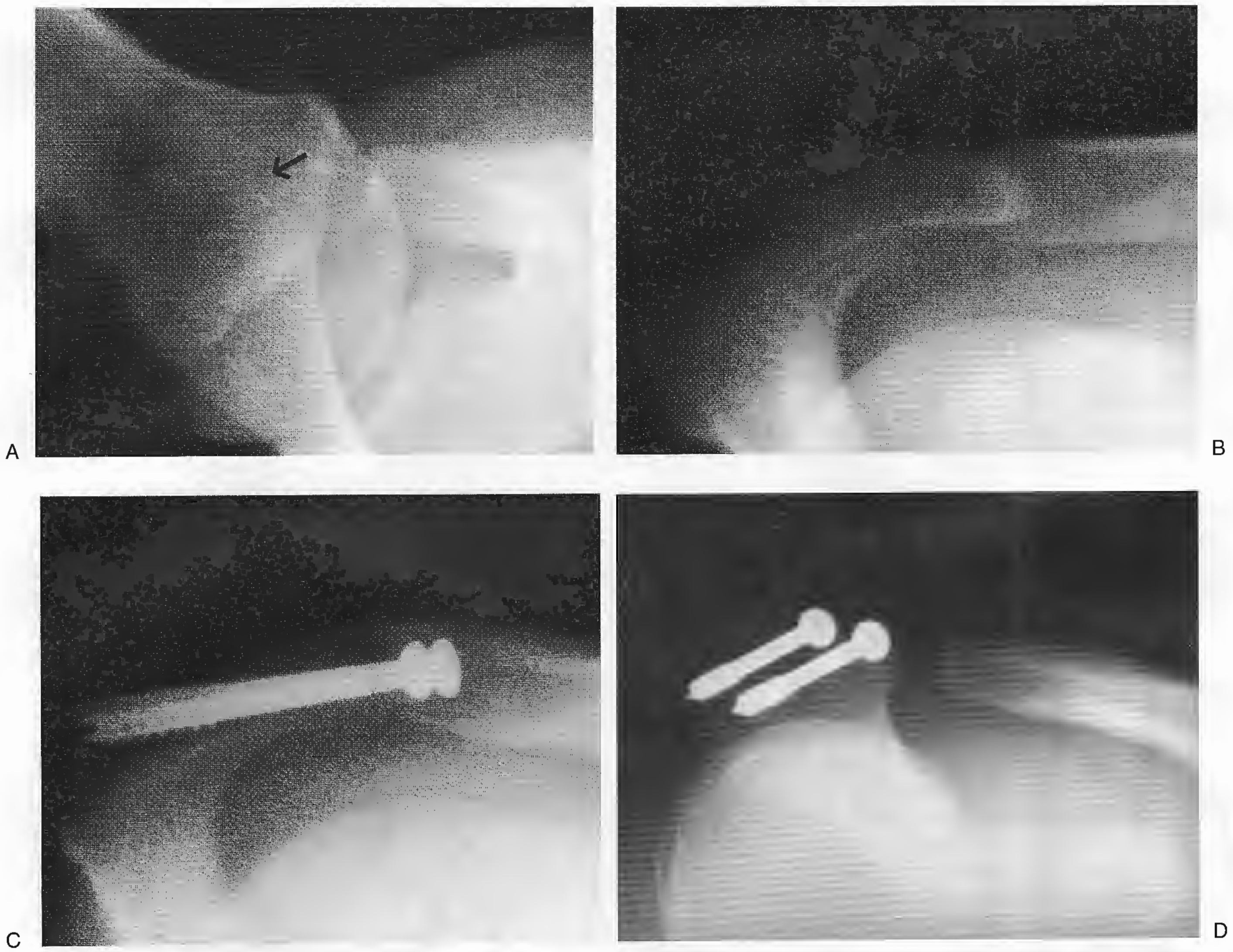


FIG. 10. (A) Acromion nonunion as seen on a Stryker view. **(B)** An outlet view reveals a step-off. An open reduction, internal fixation was performed because of persistent pain over the acromion. Two screws were placed in the acromion. **(C)** Reduction is seen. **(D)** Lateral outlet view and AP view.

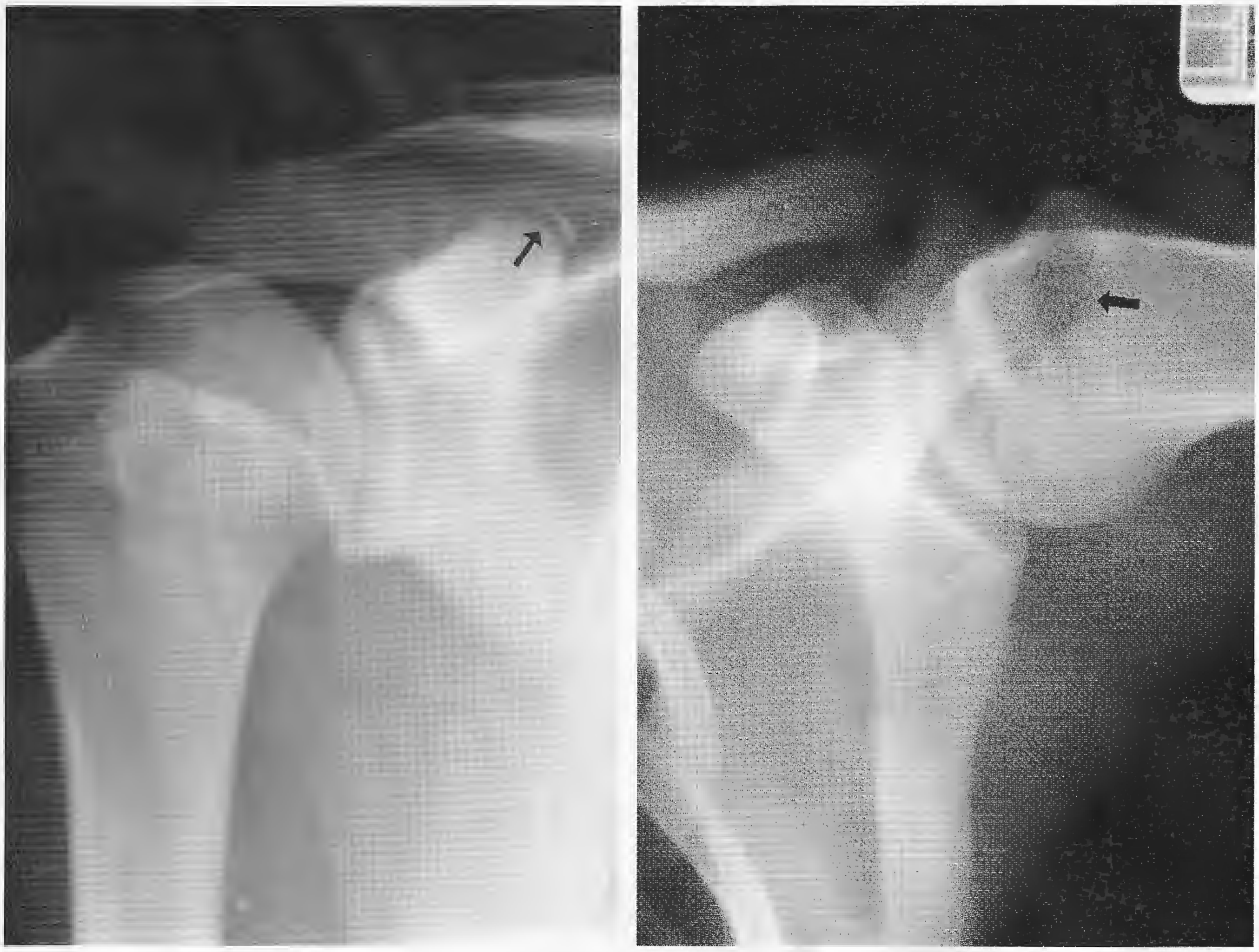
restoration of pain free range of motion and rehabilitative exercises for conditioning of the rotator cuff. Surgical treatment of secondary tensile rotator cuff disease requires stabilization of the glenohumeral joint. Concomitant arthroscopic debridement of the partial undersurface cuff tears usually leads to a resolution of symptoms (21).

Os Acromiale

An os acromiale results from a failure of an anterior ossification center of the acromion to fuse to the remainder of the acromial process. The acromion is first seen radiographically at ages 14 to 16 as two or three separate ossification centers. These ossification centers coalesce by 19 years of age and then fuse to the scapular spine between the ages of 20 and 25. A fibrous nonunion of the acromion ossification centers occurs most frequently at the level of the acromioclavicular joint. If an os acromiale is present, a separate bone may form at four different levels. Moving from distal to proximal, these are named pre-, mes-, met-, and basi-acromion. The most common nonunion is between the meso- and meta-acromion. The overall incidence rate is approximately 2.7%. Cases present bilaterally in approximately 60% of these shoulders (22). Pitchers who have a symptomatic os acromiale present with complaints and clinical findings of rotator cuff tendonitis with impingement. In addition, the acromion may be tender superiorly to direct palpation of the nonunion site. Motion of the acromial fragment may be detectable. An os acromiale is best visualized on an axillary or Stryker notch radiographic view.

Figure 9 is an axillary view that shows an os acromiale that was asymptomatic.

Surgical treatment of os acromial is variable and depends on the size and stability of the fragment. A stable, immobile, large os acromiale that has an inferior tilt



A B

FIG. 11. (A) A shoulder without weights and **(B)** with 10 lb of weight attached to the patient's wrist. Note the inferior luxation of the humerus. The patient had widening of the coracoclavicular distance as was noted by the increased distance to the coracoid tip (*arrows*). The injury was the result of a fall directly onto the right shoulder. After 6 weeks, healing was uneventful.

that causes primary impingement may be treated with a subacromial decompression if the decompression procedure does not destabilize the os. A small, mobile, unstable os acromiale may be excised if care is used to preserve the deltoid origin. Treatment of a large, mobile, unstable os acromiale requires debridement of the nonunion site and internal fixation using screws or a tension band, wire technique for stabilization of the fragment (23). Local bone grafting may be necessary. A right-hand dominant pitcher complained of pain for a year over the acromion and impingement-type symptoms. Preoperative views reveal an acromial lucency in the Stryker (Fig. 10A) and outlet (Fig. 10B) views. Open reduction, internal fixation is depicted in outlet (Fig. 10C) and acromial (Fig. 10D) views. Any inferior tilt of the os acromiale should be corrected at the time of reduction of the unstable fragment. Postoperatively, return to throwing is prohibited until bony union of the os fragment occurs. At 1-year postop, the shoulder was asymptomatic and allowed the return to sport without limitations.

Acromioclavicular Joint

Acromioclavicular (AC) joint injuries occur in the baseball athlete by a direct blow on his shoulder while making a play or sliding into a base head first.

AC separations also may occur in the skeletally immature athlete. These AC injuries are likely to be physeal fractures of the distal clavicle. This thin epiphysis fuses to the metaphyseal portion of the clavicle at age 19 years (5). Until skeletal maturity, the physis is weaker than the stabilizing ligaments of the AC joint and, therefore, is

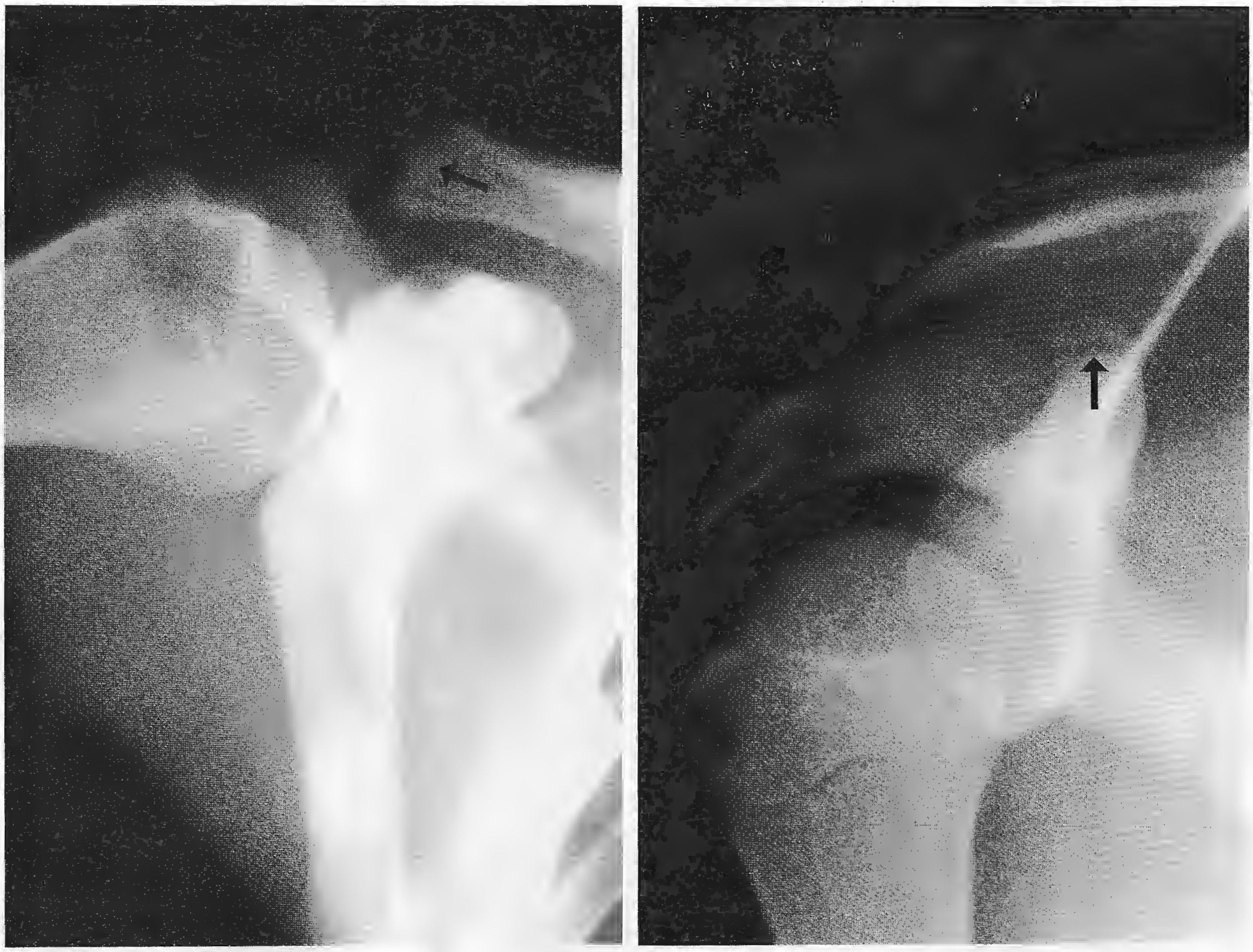


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FIG. 12. (A) A distal clavicular irregularity and distal clavicular osteolysis are seen in this right-hand dominant, multiple-sport athlete. There was pain with bench pressing (*arrow*). **(B)** A comparison view is shown of the normal, distal clavicle. Note the radiolucency, which is evident in the greater tuberosity in this age group (*arrow*).

more apt to be disrupted by trauma. The healing potential in the immature is excellent in distal clavicular injuries as a result of the thick periosteal sleeve. A pseudo-clavicular fracture occurs when the clavicle is superiorly displaced from its periosteal sleeve while the AC joint itself is intact (5).

Other shoulder injury patterns also occur. A baseball athlete, while running bases, fell on his left shoulder. AP distal clavicle views without (Fig. 11A) and with (Fig. 11B) wrist weights reveal widening of the coracoid ossification center. Pain was localized over the coracoid more than at the AC joint. This clinical picture represents coracoclavicular injury at the coracoid attachment. This figure also reveals inferior glenohumeral subluxation (24) (Fig. 11B). Distal clavicular irregularity can be seen after bench pressing, direct blows, and repetitive throwing (Fig. 12A). Normal AC separation is shown on the noninvolved side (Fig. 12B). Stryker views show irregularity on the right-involved side. Of note is the normal radiolucency in the proximal humeral epiphysis (Fig. 12B).

CONCLUSIONS

The physiologic laxity, lack of muscular development, and biomechanics of baseball combine to cause the shoulder to be at risk for significant injury. In the skeletally immature, emphasis on open growth plates, underdeveloped musculature, and physiologic laxity should be the primary concern. Specific diagnosis and institution of early treatment will usually result in the successful return to all activities, including baseball pitching. Anterior instability in the young throwing athlete is common. In unusual cases, the primary problem may be rotator cuff injury, os acromiale, acromioclavicular involvement, or developmental abnormalities. Appreciation of these unique situations that occur in the skeletally immature athlete will enable the practitioner to make early and prompt diagnosis. Evaluation of biomechanics, intensity and frequency of throwing will improve the success rate and decrease chance of repeat injury. The cry should be "throw it right" with proper biomechanics and *not* emphasizing the velocity of the pitch or numbers of throws.

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