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Shoulder Injuries in Pediatric Athletes

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KEYWORDS

- Pediatric shoulder injury • Shoulder overuse injuries • Adolescent shoulder instability
- Shoulder fractures

KEY POINTS

- Shoulder injuries in pediatric athletes may be acute injuries or caused by repetitive overuse.
- Acute injuries in skeletally immature shoulders tend to be fractures or sprains, as opposed to tendon or muscle injuries.
- Chronic overuse injuries tend to occur in overhead athletes. Baseball pitchers who have high pitch counts are at highest risk.

INTRODUCTION

As the number of children and adolescents participating in competitive sports has increased, especially in overhead activities, there has been a corresponding increase in the number of injuries to the shoulder.[1] Skeletally immature athletes present with many of the same complaints as more mature athletes, but differences in anatomy and technique often lead to age-specific injuries. Although traumatic injuries, such as sprains or fractures, are common across the spectrum of competitive activities, overuse injuries predominate.

Overuse injuries in young athletes are typically caused by repeated stress and cumulative trauma to the developing physis of the proximal humerus as well as adaptive changes in the soft tissue stabilizers of the glenohumeral joint. Physeal injuries are usually diagnosed by history and physical examination and may be confirmed on radiographs. Soft tissue injuries such as SLAP (superior labrum anterior and posterior) lesions, glenohumeral instability, and rotator cuff disorders may be more difficult to diagnose definitively.

Traumatic injuries to the skeletally immature shoulder may occur with any activity, but are more common with high-energy collision sports such as football.[1] Traumatic injuries include ligament sprains, muscle strains, fractures of the humerus, and fractures of the clavicle. Knowing the anatomic differences of the developing osseous structures of the shoulder girdle is key in diagnosis and management.

Anatomy

During growth, the anatomy of the proximal humerus osseous and ligamentous structures undergoes multiple changes. The proximal humeral physis typically closes at between 14 and 17 years in girls and 16 to 18 years in boys. This physis also contributes about 80% of the overall humeral length, making an injury to this area at a young age possibly more consequential but also allowing extensive remodeling of acute fractures.[2]

Any activity that involves stress of the physis, such as overhead throwing or repetitive upper extremity activities, puts the physis at risk of injury. Injuries vary from chronic stress reaction caused by overuse to acute fracture of the physis. The

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physis is thought to be a weak point of the upper arm compared with the ligamentous structures. The ligaments of the glenohumeral joint provide static stability depending on the position of the arm.[3] The rotator cuff muscles, scapular stabilizers, and long head of the biceps also contribute to dynamic stability of the shoulder.

The clavicle is the first bone in the body to start the ossification process via intramembranous ossification.[4] It shows both intramembranous and endochondral types of ossification. The lateral clavicular epiphysis typically does not ossify until 18 years of age. The medial clavicular epiphysis is the last to appear, at approximately 18 to 20 years of age, and does not fuse until 23 to 25 years of age, making the clavicle the last bone in the body to completely fuse.[5] Strong ligaments provide significant stability at the medial and lateral ends of the clavicle, thereby making fractures in the middle of the clavicle more likely.[5]

OVERUSE INJURIES

Introduction

Pediatric or adolescent athletes involved in repetitive overhead activities, such as baseball, swimming, or volleyball, are at risk for overuse injuries to the shoulder. Overuse injuries are very common, comprising approximately 60% of all sports injuries in children and adolescents. Female athletes typically present more often with overuse injuries, but male athletes participating in certain demanding team sports, such as baseball, are at highest risk.[6] It is estimated that 50% of overuse injuries in physically active children and adolescents may be preventable.[7] Volume of activity, whether measured in number of repetitions or quantity of time, may be the greatest predictor of overuse injury.[8] Shoulder pain, fatigue, and/or decreased velocity should be an indication to coaches and parents that an overuse injury may exist. Educating players, coaches, and trainers about these symptoms may help identify overuse injuries early.[9,10]

Baseball in particular has been the focus of extensive research with regard to pediatric shoulder injuries. Seasonal incidence of shoulder pain ranges from 32% to 35%, with nearly 9% of all pitching performances resulting in shoulder symptoms.[9,11] The incidence of injury for pitchers was found to be 37.4%, whereas it was only 15.3% for position players. Overall, pitchers experienced 47.1% of all shoulder injuries in baseball.[12] In a study of youth baseball players by Olsen and colleagues,[10] athletes who underwent surgery for shoulder or elbow injuries caused by pitching were more likely to have increased number of pitches thrown per inning and per game, more likely to pitch with pain, and pitched with higher velocity. There was no significant difference between injured and uninjured athletes with regard to injury prevention programs, types of pitches thrown, or private pitching instruction.

The role of specific types of pitches on shoulder pain incidence is inconclusive. Although some data exist that show higher levels of injury in curveball throwing, other studies have found higher mechanical demands with fastball throwing.[13] In general, many of the issues of the throwing shoulder are rooted in poor biomechanics, scapular dyskinesis, muscular imbalance, glenohumeral internal rotation deficit, and excessive throwing or overhead activity.[14]

Biomechanics of Throwing

The mechanism of baseball throwing is a complicated process involving the coordination of the upper and lower extremities as well as core musculature. Throwing is typically divided into 6 phases: wind-up, early cocking, late cocking, acceleration, deceleration, and follow-through (Fig. 1).[13,14]

During the late cocking phase, the arm is in an abducted and externally rotated position, creating an anteriorly directed force of the humeral head. This force is then counterbalanced by the static and dynamic stabilizers of the glenohumeral joint. During the acceleration portion of throwing, the arm moves at speeds of several thousand degrees per second, creating a large rotational force at the proximal humerus, often several times greater than the rotational strength of the proximal humeral physis.

Youth pitchers show several changes compared with mature pitchers. Younger pitchers tend to begin trunk rotation earlier in the throwing process. There is also a trend toward more open pelvic position during throwing. Both of these mechanisms have been proposed to increase the likelihood of injury to the developing physis because of higher rotational stress at the proximal humerus.[14]

LITTLE LEAGUE SHOULDER AND OVERUSE SYNDROMES

Shoulder overuse injuries are most common in boys aged 11 to 16 years. The most common age of presentation is 14 years in boys.[15] In adolescents, the most common causes of shoulder pain from overhead activities are Little Leaguer's shoulder, glenohumeral instability, and rotator cuff disorders.

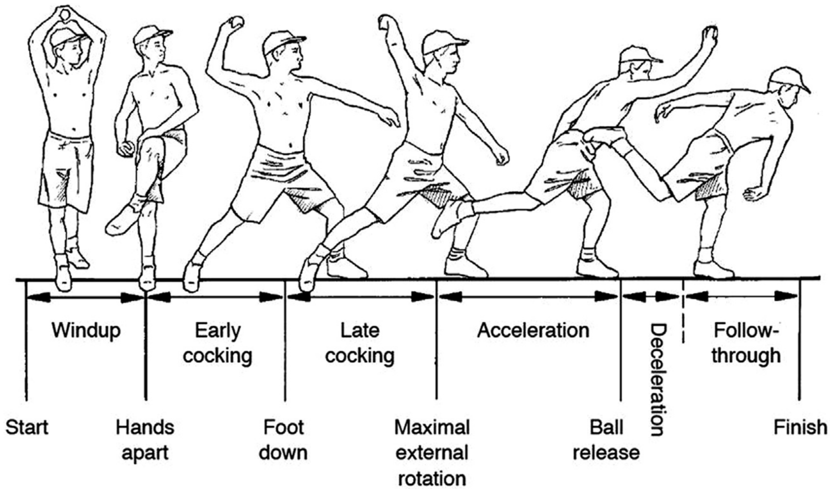

Fig. 1. Phases of throwing. (*Adapted from* DiGiovine NM, Jobe FW, Pink M, et al. An electromyographic analysis of the upper extremity in pitching. J Shoulder Elbow Surg 1992;1:16; with permission.)

Skeletally immature pitchers tend to develop problems with developing structures of the shoulder, including the proximal humeral physis, which may manifest in young pitchers with Little Leaguer's shoulder, which has been described as osteochondrosis, epiphysiolysis, and stress reaction of the proximal humerus.[15] Vertically oriented collagen fibers within the zone of hypertrophy are most susceptible to injury. Radiographs may show physeal widening and fragmentation, often appearing similar to the presentation of Salter-Harris I fractures. Repetitive stress may lead to microfractures in this area and hypertrophy seen on radiographs (Fig. 2).[16]

Once the proximal humeral physis has closed, the static and dynamic stabilizers of the shoulder are more likely to be injured. Skeletally mature pitchers more often develop disorders in the anterior and superior glenoid labrum (SLAP lesions).[17]

Glenohumeral internal rotation deficit is also seen in older throwers as a loss of internal rotation compared with the nonthrowing shoulder.[18] Alterations in shoulder and scapular motion can lead to changes in the labrum, including SLAP tears. Baseball and softball pitchers who sustained injury during the season had significantly decreased internal rotation compared with age-matched peers as well as the nondominant arm.[19] Rotator cuff disorders and impingement syndromes are also occasionally seen in overhead athletes, often related to instability.[20]

History and Physical Examination

Patients typically present with increasing shoulder pain during throwing motions, which may progress to activity at rest. Important information

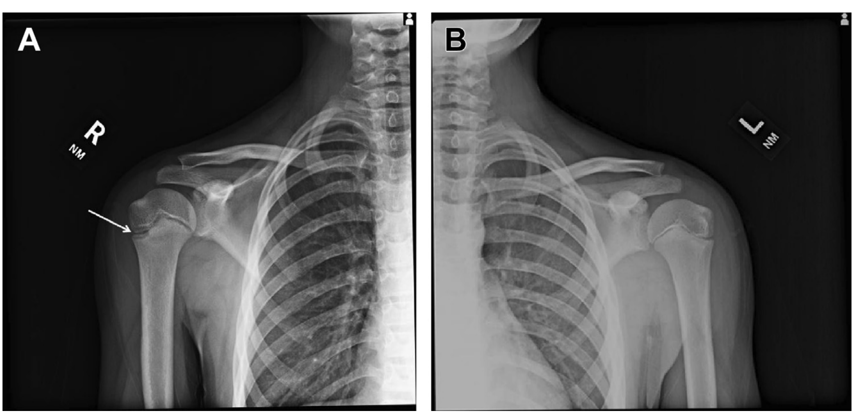

Fig. 2. (*A*) A 12-year-old boy with shoulder pain at the beginning of the baseball season. Radiograph of shoulder of throwing arm at presentation. White arrow shows widening of the proximal humeral physis. (*B*) Left shoulder radiograph taken for comparison at initial presentation.

to obtain includes the patient's sport, level of competition, previous injuries, amount of time spent playing, recent increases in activity, and pitch counts.

In skeletally immature athletes with Little Leaguer's shoulder, tenderness on palpation of the lateral proximal humerus is often seen.[14,16] Scapular dysfunction may also be noted with forward flexion and abduction of both arms. Shoulder motion, flexibility, strength, and other components of the kinetic chain should also be assessed.

Skeletally mature throwers often show increased external rotation along with decreased internal rotation of the throwing arm with the shoulder in abduction. The overall arc of motion may be maintained without corresponding pain or dysfunction.[21] Alterations in range of motion are often noted in young throwers as well, but the overall range of motion may be decreased.[22]

Radiographs of the proximal humerus in skeletally immature throwers should be obtained. Radiographs of the contralateral shoulder often aid in confirmation. Although physeal widening on radiographs is often confirmatory in patients with shoulder pain, many asymptomatic throwers also show widening.[23] It is hypothesized that physeal widening may also be caused by adaptive changes within the proximal humerus. Advanced imaging is typically reserved for patients with anterior instability or for refractory cases.

Treatment

Prevention of overuse injuries should be the goal of all athletes, coaches, and parents. Off-season condition focusing on pitching mechanics and strengthening of the kinetic chain is recommended. Monitoring players for pain during or after activities may alert coaches and parents that an overuse injury may be developing. Pitching limits should be established for players 9 to 14 years old: full-effort throwing should be limited to 75 pitches per game, 600 pitches per season, and 2000 to 3000 pitches per year.[11] Little League Baseball, with recommendations from the American Sports Medicine Institute, has instituted specific guidelines for pitch counts (Table 1) and for required days of rest (Table 2). Of note, pitchers who have pitched more than 41 pitches in a game are not permitted to switch positions to catcher.

The mainstay of treatment is rest from all throwing activities. Treatment algorithms vary, but most include a period of absolute rest from throwing, then gradual return to activities. Nonsteroidal antiinflammatory medication may also help with pain and inflammation during recovery. Strengthening exercises focusing on the rotator cuff musculature, core strengthening, and pitching mechanics are emphasized. Stretching exercises focusing on abduction and internal rotation are also recommended.[14] Most athletes are able to return to baseball in 3 months.[15]

For patients with SLAP lesions, a short period of physical therapy and rest may help to resolve symptoms. However, when there is continued pain and MRI consistent with labral injury, surgical repair may be indicated (Fig. 3).

Table 1
Pitch counts for Little League Baseball

Player Age (y)	Pitches Permitted Per Day
17–18	105
13–16	95
11–12	85
9–10	75
7–8	50

Data from Little League Baseball, Incorporated. The Little League pitch count regulation guide. 2008. Available at: http://www.littleleague.org/assets/old_assets/media/pitch_count_publication_2008.pdf. Accessed November 28, 2015.

ANTERIOR INSTABILITY

Anterior shoulder instability is a common problem in adolescent athletes, comprising 85% to 95% of all shoulder instability. Incidence is reported to be 11.2 occurrences per 100,000 person-years.[24] Younger male athletes are at particularly high risk, because nearly 40% of

Table 2
Days of rest required after pitching

Player Age (y)	Pitches Thrown Per Day	Days of Rest Required
≤14	≥66	4
	51–65	3
	36–50	2
	21–35	1
	≤20	0
15–18	≥76	4
	61–75	3
	46–60	2
	31–45	1
	≤30	0

Data from Little League Baseball, Incorporated. The Little League pitch count regulation guide. 2008. Available at: http://www.littleleague.org/assets/old_assets/media/pitch_count_publication_2008.pdf. Accessed November 28, 2015.

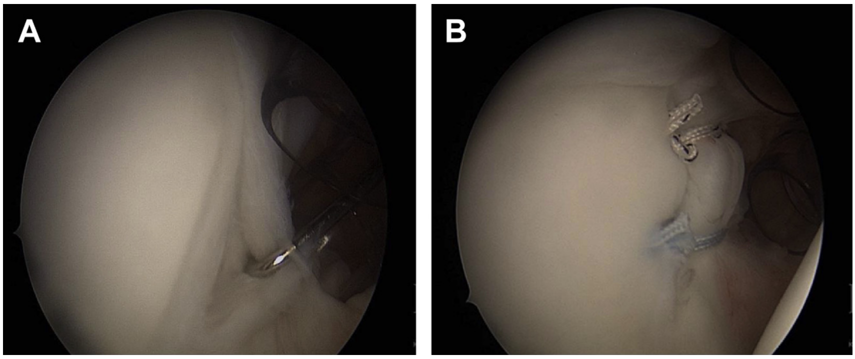

Fig. 3. (*A*) SLAP tear in 12-year-old baseball pitcher. (*B*) Labrum repaired with 2 suture anchors.

shoulder instability events occur in males athletes younger than 22 years.[25] The presence of an open physis seems to be slightly protective for anterior dislocation, with a lower percentage occurring in children younger than 13 years,[26] likely secondary to Salter-Harris fractures occurring through the proximal humeral physis rather than glenohumeral dislocation. Athletes participating in contact or collision sports are also at highest risk.[27]

Although the rates of initial anterior shoulder instability episodes are high in adolescents, perhaps more significant is the rate of recurrence. The rate of recurrence has been found to be 51% to 100%.[3,26,28,29] In a study by Lawton and colleagues,[30] of 70 shoulder dislocations in 66 patients aged 16 years or younger, 40% eventually underwent surgery. Those who underwent surgery were less likely to report continued instability at more than 2 years' follow-up compared with those treated with physical therapy alone.

A classic study by Rowe[31] of 500 shoulder dislocations found a high rate of initial dislocation in patients between 10 and 20 years old. The recurrence rate of instability in this group was 83%, with a 100% rate in patients less than 10 years old.[31] A report of 9 children with open physes and shoulder dislocation found a recurrence rate of 80%.[28]

History and Physical Examination

A history of traumatic dislocation from a single event is common in patients involved in contact or collision sports. Any reduction maneuvers performed, whether on field or in an acute care setting, should be documented. A history of pain or paresthesias with overhead activities, especially with the arm in external rotation and abduction, may be present without a frank dislocation episode. Pain with the arm in adduction and internal rotation may indicate posterior instability. This condition may be seen in football linemen during blocking or pushing against a heavy object.[3]

Initial physical examination should include a complete neurovascular examination of both extremities. Nerve dysfunction has been seen in 5% to 25% of shoulder fractures and dislocations, most commonly axillary nerve injuries.[32] Patients should be examined for loss of motion, both active and passive. Examination should include both shoulders to evaluate for differences of range of motion, scapular motion, muscle atrophy, swelling, or bruising.

Specific shoulder tests to be performed include the anterior apprehension test, Jobe relocation test, anterior and posterior drawer test, and sulcus test. The anterior apprehension test is performed by having the patient lay supine on the examination table and slowly abducting and externally rotating the arm. Feelings of pain or instability are suggestive of anterior instability. The Jobe relocation test is then performed with the arm kept in the abducted and externally rotated position and applying a posterior-directed force on the humeral head. This test is positive if pain or feelings of instability resolve. Drawer testing is performed by placing the arm in line with the scapula and evaluating the amount of humeral head translation with force applied to the proximal humerus. Laxity is defined as grade 1 to 3 translation based on the amount of motion of the humeral head on the glenoid.

Imaging should begin with standard shoulder radiographs, including internal rotation, external rotation, and either axillary or scapular Y views. More specific imaging may include West Point view for anterior glenoid deficits or Stryker notch views for Hill-Sachs lesions. MRI with arthrography is recommended for imaging of the glenoid labrum, glenoid surface, and rotator cuff. Bankart and Hill-Sachs lesions have been noted in most first-time dislocations, with a smaller number of SLAP lesions (**Fig. 4**A, B).[33] Glenoid bone loss is common in adolescents and is a risk factor for recurrence.[34] Computed tomography (CT) may be performed to further delineate bone loss of the humeral head or glenoid.

Treatment

Caution should be used in initial closed reduction of presumed shoulder dislocation in young children. Many physeal fractures of the proximal humerus may appear similar to a shoulder dislocation, with swelling and internal rotation of the proximal arm.[35] Radiographs should be taken before any reduction maneuver in order to protect against iatrogenic injury to the proximal humeral physis. After initial closed reduction, a short period of immobilization is generally recommended, although there is no consensus regarding arm position.[36–38]

Because of the high risk of recurrence of instability, there is great debate regarding appropriate initial treatment of a first-time instability episode.[39] Factors that need to be taken into consideration include the patient's chosen sport, future plans in that sport, future career plans (ie, military or manual labor), history and/or success of previous treatment, medical and psychiatric history, and expectations regarding possible outcomes.

After a short period of immobilization, nonoperative treatment usually begins with cessation of sports and an initial course of physical therapy. Therapy usually consists of shoulder range-of-motion exercises, scapular and rotator cuff strengthening, and sport-specific therapy. If the patient has a pain-free shoulder with symmetric bilateral upper extremity strength and range of motion after 4 to 6 weeks of nonoperative treatment, an attempt may be made to return to sports. Abduction shoulder bracing may be attempted, but this is usually poorly tolerated in adolescents and has limited effectiveness.[40] Pain or continued instability symptoms even after conservative treatment is prognostic for recurrence.[41]

Operative treatment of shoulder instability is recommended in patients who have failed conservative treatment and in some first-time dislocations. Adolescent patients involved in collision sports, such as ice hockey and football, may be candidates for initial surgical treatment if the patients and their families are unwilling to modify their activities. Patients may also choose to be

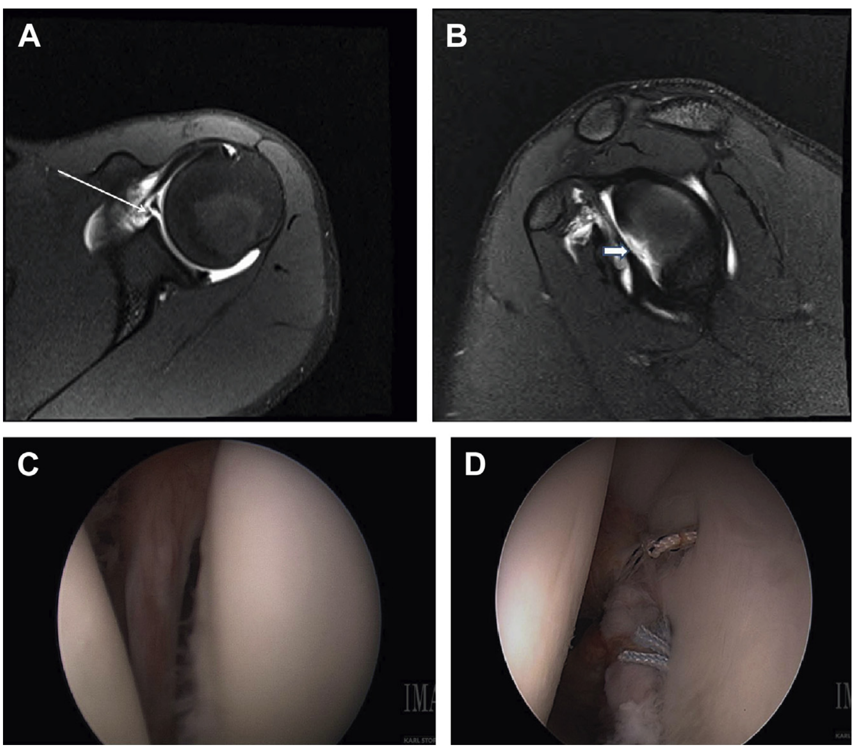

Fig. 4. (*A*) MRI of the left shoulder in a 13-year-old boy after dislocation from a bicycle crash. Arrow shows labrum separation from glenoid on axial view. (*B*) Full arrow shows labral detachment from glenoid on coronal view. (*C*) Arthroscopic appearance of torn labrum. (*D*) Suture anchors placed in anterior labrum.

treated with nonoperative therapies and delay surgery until after their sports season has finished.

Older studies in which open stabilization procedures were performed showed low recurrence rates and high rates of return to sports.[26,30,42] Arthroscopic methods of stabilization have also shown good results in the adolescent population (Fig. 4C, D). A large study of 32 shoulders treated with arthroscopic Bankart repair at an average age of 15 years showed a low recurrence rate of 15.6%.[43] A study of 65 patients with an average age of 16 years treated with arthroscopic repair found a recurrence rate of 21%. Overall, 81% of patients were able to return to their previous levels of activity.[44] Other studies in young patients have found similar results, with recurrence rates of 11% to 21%.[3]

MULTIDIRECTIONAL INSTABILITY

Approximately 5% of shoulder instability may be considered as multidirectional instability (MDI).[45,46] However, shoulder instability is difficult to classify. One large study of asymptomatic adolescents found a high rate of physical examination findings of shoulder instability without other signs of ligamentous laxity, with positive physical examination findings in 57% of boys and 48% of girls.[47] Symptomatic MDI is seen most often in patients participating in repeated overhead activities, most commonly gymnastics and swimming.[48]

As opposed to anterior shoulder instability, MDI is not typically caused by a single dislocation event. MDI may also be associated with generalized ligamentous laxity. Patients with Ehlers-Danlos syndrome and other connective tissue disorders may also present with instability symptoms. Practitioners should be aware of any medical history and make appropriate referrals to genetics if there is suspicion for underlying disorder.

History

In patients involved in overhead sports such as swimming or baseball, symptoms are usually gradual in onset. Symptoms may also correlate with a recent increase in training. A history of a traumatic dislocation may be seen in the presence of previous instability episodes. Many patients report a history of spontaneous reduction after these events. Patients may have a range of symptoms from subjective feelings of laxity with overhead activities to complete dislocations.

Caution should be used in the treatment of voluntary instability of the shoulder. Patients who are able to consciously subluxate or dislocate their shoulders may respond poorly to both surgical and nonsurgical treatment.[3,49,50] A full psychiatric history should also be obtained.

Physical Examination

Examination of the MDI shoulder involves the same tests as anterior instability. Apprehension, anterior and posterior drawer testing, relocation test, and sulcus sign should all be evaluated in both shoulders. The sulcus sign appears when downward traction is applied to the arm and a dimple appears between the humeral head and acromion, and is common in MDI.[33] Any signs of Sprengel deformity or scapular motion dysfunction should be noted. Patients with voluntary instability may also be able to dislocate or subluxate the shoulder on command. Testing for ligamentous laxity should also be performed by testing for hyperextension of the elbow and knee, thumb opposition to the forearm, and ability to place the palms flat on the floor with the knees extended.

Treatment

Most cases of MDI are treated with modification of activities and physical therapy. Therapy focusing on strengthening and stabilization of the rotator cuff and periscapular muscles is the centerpiece of treatment. Providing increased dynamic stability counteracts the deficiencies of the static stabilizers.

Overall good results have been reported with nonoperative treatment. One large cohort of patients with either anterior instability or MDI showed excellent results in 80% of patients with a diagnosis of MDI.[51] Kuroda and colleagues[52] followed 573 shoulders in 341 patients and found that there was a higher rate of spontaneous resolution in patients who were younger and who avoided overhead sports. They recommended avoidance of surgical treatment; however, no specific recommendations were made regarding physical therapy. In general, most patients who are treated with physical therapy report improvement in their symptoms; however, continued pain and instability are a common finding.[53]

For patients who continue to have pain and instability associated with MDI after nonoperative treatment, surgical stabilization is an option. Many practitioners advise a waiting period of 6 months of physical therapy and activity modification before surgery is recommended.[3]

Traditional methods of stabilization relied on open techniques that included an inferior capsular shift. Good results were reported with regard to elimination of instability symptoms and return to sports.[54]

Arthroscopic techniques of stabilization of MDI have increased in popularity as the rate of shoulder arthroscopy in general has increased. Advantages of arthroscopic treatment compared with open procedures include the ability to treat both anterior and posterior disorders as well as decreased surgical morbidity. Early arthroscopic techniques relied on capsular shift.[55] More recent advances in arthroscopic treatment have involved plication of the capsule with sutures through the labrum or tied to the capsule (**Fig. 5**).[56,57]

Results of arthroscopic treatment have been encouraging. Recurrence rates of instability have been reported from 2% to 12%. Return to sports, range of motion, and pain scores have also been good to excellent for most patients.[58]

TRAUMATIC INJURIES OF THE SHOULDER

Introduction

Many of the injuries of the shoulder in children and adolescents are acute fractures. Fractures of the proximal humerus in adolescents often involve the physis, but may also involve the metaphysis only. Most physeal injuries are Salter-Harris type I injuries, although type II or III injuries may also occur. Because of the large amount of humeral length arising from the proximal physis, remodeling potential is great. These injuries have traditionally been treated nonoperatively, but surgery may be indicated for severely displaced fractures, especially in older patients approaching skeletal maturity. The biceps tendon may be interposed between the fracture fragments, preventing adequate healing.[59] Injuries to the axillary and radial nerves have also been reported, but usually resolve spontaneously.[35]

The clavicle fracture is one of the most common fractures encountered in pediatric orthopaedics, accounting for 5% to 15% of all pediatric fractures.[60,61] Despite the commonality of pediatric clavicle fractures, most of the current literature cited is extrapolated from studies involving adult or older adolescent clavicle fracture.

Injuries involving the sternoclavicular (SC) and acromioclavicular (AC) joint are also seen in adolescents participating in high-energy activities such as football or motocross. AC injuries in children are often avulsion fractures wherein the distal clavicle separates from the periosteal sleeve, which remains attached to the acromion. True AC and SC dislocations are also seen, usually in more skeletally mature adolescents. Posterior SC dislocations are often from high-energy mechanisms and can present as a surgical emergency.

PROXIMAL HUMERUS FRACTURES

Proximal humerus fractures may occur because of falls, collisions, or acute fracture of a previously stressed proximal humeral physis.[59] Patients are likely to present similarly to a shoulder dislocation, with internal rotation and adduction of the arm. A complete neurovascular examination should be performed to rule out axillary nerve or brachial plexus injury. Any previous history of arm pain from pitching should be elucidated.

Patients can usually expect good outcomes with treatment in a sling or hanging-arm cast. A hanging-arm cast is often recommended if there is angulation or shortening of a fracture (**Fig. 6**). Operative treatment may be indicated for open fractures or fractures with unacceptable angulation in older children, often caused by biceps entrapment.[59] Treatment options include percutaneous screw fixation, pin fixation, and retrograde flexible nails[62] (**Fig. 7**).

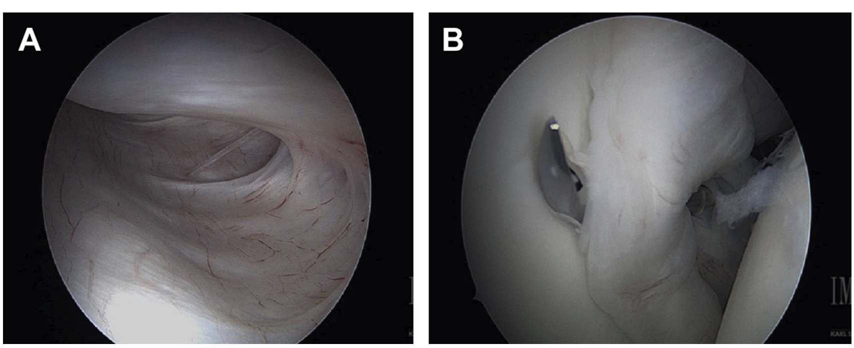

Fig. 5. (*A*) Patulous capsule with large inferior humeral recess in a 15-year-old softball player with symptoms of MDI. (*B*) Suture passer in anterior capsule and labrum. Additional sutures were placed posteriorly and inferiorly.

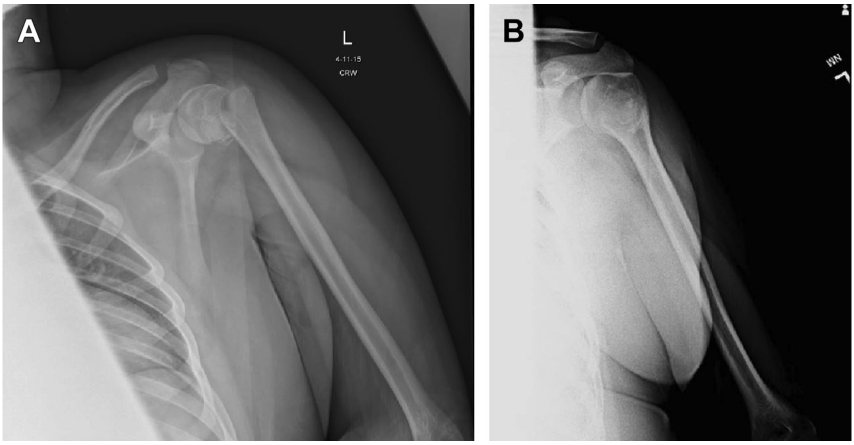

Fig. 6. (*A*) A 16-year-old boy with Salter-Harris II fracture of proximal humerus who fell while playing basketball. (*B*) Appearance of shoulder after 3 months of conservative treatment, including hanging-arm cast. Function was normal at final follow-up.

CLAVICLE FRACTURES

School-aged children often sustain fractures from a fall involving a lateral compression force to the shoulder, as opposed to a fall on an outstretched hand.[63] Typical activities include fall from bicycles, sporting activities, or playgrounds. Treatment is typically nonoperative, with immobilization for 4 to 6 weeks. Immobilization is typically performed in a sling, with little benefit seen with braces (Fig. 8).[64]

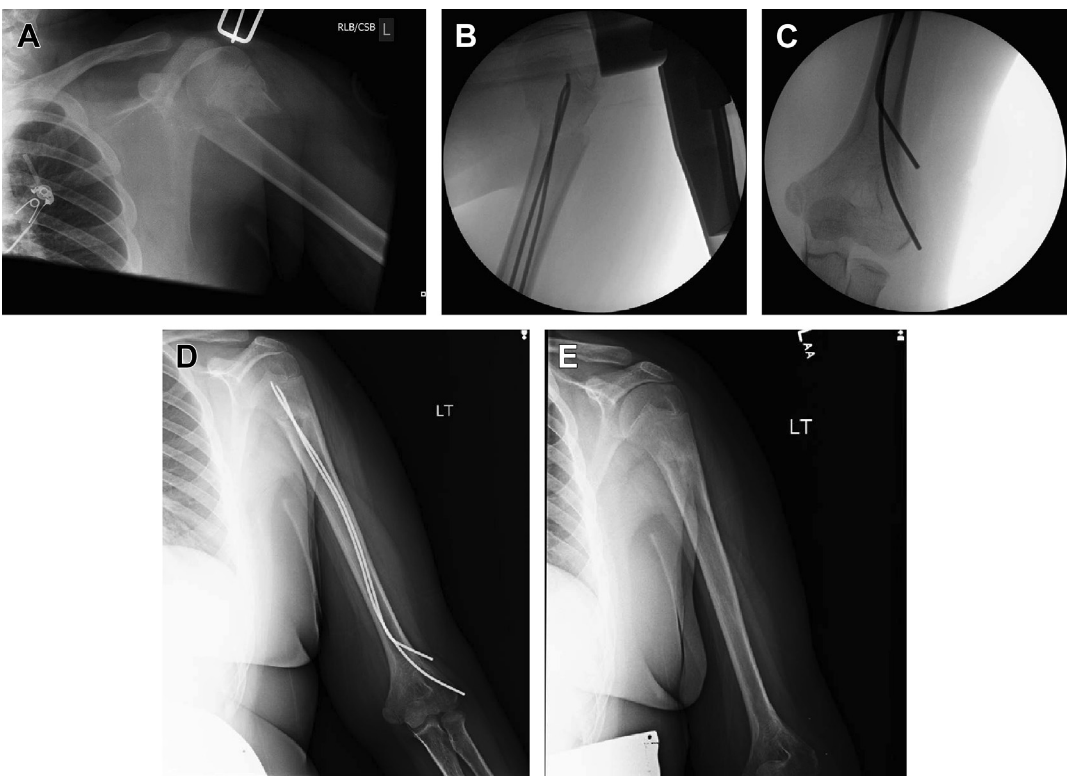

Fig. 7. (*A*) A 13-year-old boy with shoulder pain after a fall during motocross. Radiographs show a displaced fracture of the proximal humeral metaphysis. (*B*) Fluoroscopic image of the proximal humerus taken during closed reduction and elastic nail fixation. (*C*) Appearance of the elbow during elastic nail placement. (*D*, *E*) Appearance of the proximal humerus at 6 months and after nail removal. The patient had regained full function and returned to sport.

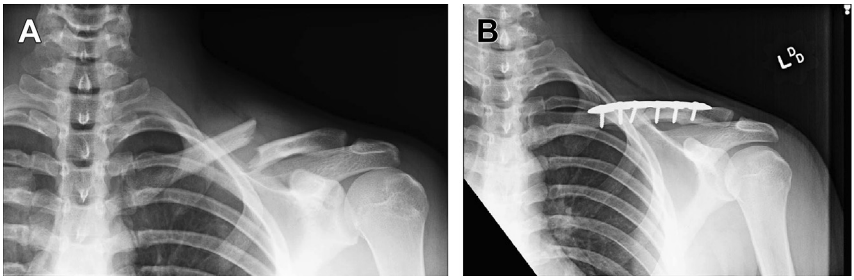

Fig. 8. (*A*) A 17-year-old boy with left clavicle fracture from football. Radiographs show a 100% displaced and minimally shortened fracture. After discussion with family, he elected operative fixation. (*B*) Appearance of clavicle fracture 3 months after plate fixation.

Adolescents sustain clavicle fractures from injuries that involve similar mechanics to those in school-aged children, as well as high-energy mechanisms such as motor vehicle and all-terrain vehicle accidents or competitive sports. Although less common, stress fracture can also be incurred secondary to repetitive, high-intensity training in sporting activity such as rowing or gymnastics.[65]

For acute, traumatic fracture with no or mild displacement, nonoperative management is typically the recommended treatment, with previous studies reporting union rates from 95% to 100%.[66,67] Most nondisplaced fractures have significant union by 6 to 8 weeks, with displaced fractures taking longer, reported at 10 to 12 weeks.[66] Historically, nonoperative treatment has been the preferred treatment modality with the expectation of bony union without adverse effects from a functional standpoint.[68,69] There is a risk of refracture after nonoperative treatment, reported at 18%.[70]

Absolute indications for operative treatment include open fractures and significant skin tenting/compromise. Over the last 10 years there has been an overall increase in operative management for displaced midshaft clavicle fractures, specifically in the 15 to 19 years age group (see Fig. 8).[71] Recent studies published have suggested that open reduction and internal fixation (ORIF) for displaced fractures in skeletally immature patients is safe and effective,[72,73] including a randomized clinical trial that favored operative treatment (ORIF) for acute, displaced clavicle fractures.[74] Other studies have concluded that nonoperative treatment can be safely used for midshaft fractures in pediatric patients without risk of clinically meaningful loss of shoulder range of motion or strength.[75,76] The studies showing successful nonoperative management with good outcomes suggest that favoring operative fixation may lead to over-treatment and excessive cost.[67,77,78]

DISTAL CLAVICLE AND ACROMIOCLAVICULAR INJURIES

The distal aspect of the clavicle articulates with the scapula via the AC joint. Ligamentous attachments include the AC and coracoclavicular ligaments, both of which are firmly attached the clavicle's thick periosteal sleeve. True AC injuries are rare during skeletal immaturity compared with fractures of the distal clavicle (Fig. 9). Often the clavicle displaces out of the periosteal sleeve, leaving the periosteum attached to the coracoclavicular and AC ligaments, leading to high remodeling potential (Fig. 10).[5,79,80]

Physical examination should include notation of any deformity, swelling, ecchymosis, or skin tenting. Palpation over the AC joint should elicit significant discomfort. A thorough neurologic examination to assess for brachial plexus or cervical spine injury should also be performed.

Initial imaging should include anteroposterior and axillary lateral views of the shoulder to help determine diagnosis. A Zanca view is also recommended as part of the initial radiographs

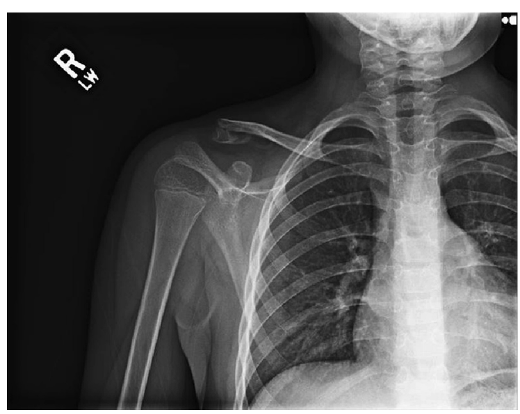

Fig. 9. An 11-year-old boy after a fall in gymnastics. Radiographs at presentation show fracture of the distal clavicle with elevation of the proximal fragment.

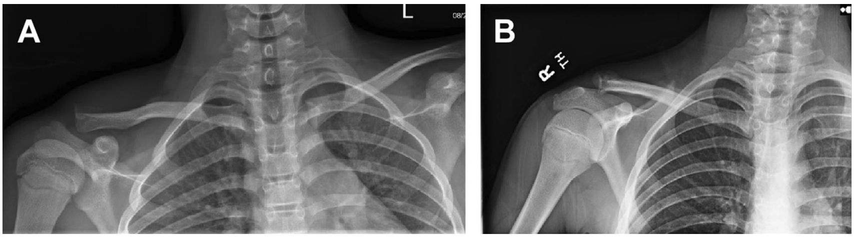

Fig. 10. (*A*) A 12-year-old boy with a distal clavicle fracture from a fall during soccer. (*B*) Appearance of the clavicle 2 months later with abundant fracture callus.

when AC dislocation is suspected.[5] The Zanca view is obtained with the patient upright, the injured arm hanging with gravity, and the x-ray beam 10° to 15° cephalad.

Many of these injuries are treated nonoperatively with a sling and rest. Although some investigators recommend nonoperative treatment of all pediatric AC injuries, operative management is frequently advocated for athletes or patients with more severe injuries.[5,80,81]

STERNOCLAVICULAR INJURIES

SC joint injuries are uncommon, representing less than 5% of all shoulder girdle injuries.[80,82,83] Dislocation/fractures are classified based on the direction of displacement (anterior or posterior) and the chronicity of the injury (acute or chronic). Most cases of anterior SC instability are atraumatic and associated with ligamentous laxity.[5]

The SC joint is well stabilized by the numerous ligamentous and muscular attachments, typically requiring a significant amount of force to disrupt it. Adolescents landing on their lateral shoulder during football or other sports may cause a posterior SC dislocation.[84]

On physical examination there may be significant swelling and ecchymosis present, sometimes making determination of the direction of dislocation more challenging. Careful evaluation for concomitant injury such as rib fractures, brachial plexopathy, or associated chest wall injuries should be performed.

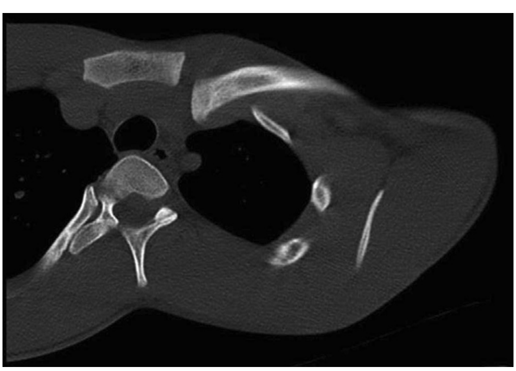

Fig. 11. CT scan of a posterior SC dislocation sustained from a fall during an equestrian event.

Plain radiographs are the preferred initial imaging modality. The serendipity view described by Wirth and Rockwood[83] is performed by angling the x-ray beam 40° cephalad while it is centered on the sternum, providing a view of both SC joints. In the serendipity view, the affected side appears superiorly displaced in cases of anterior dislocation; conversely the affected side appears inferiorly displaced in cases of posterior dislocation. The easiest method to evaluate the SC joint in cases of suspected fracture or dislocation remains CT (**Fig. 11**).

It is recommended that atraumatic anterior dislocation be treated nonoperatively.[5] Nonoperative management of a nondisplaced injury typically consists of sling immobilization for 3 to 4 weeks followed by gradual return to activities. A closed reduction of an anterior dislocation can be performed; however, recurrent instability is common. Posterior fracture-dislocations are usually treated operatively, with some investigators advocating performing closed reduction maneuver because of potential stability of reduction and remodeling of the medial clavicle.[5,83,84]

SUMMARY

Pediatric and adolescent athletes are at risk for both chronic and acute injuries to the shoulder and surrounding structures. Overuse injuries are the most common injuries in overhead athletes, with potential consequences to the physis and developing structures of the glenohumeral joint. Most overuse injuries may be treated with a period of rest and rehabilitation, with gradual return to activities. Patients who have sustained anterior dislocations of the shoulder during sports may require operative stabilization. Patients with MDI are often treated nonoperatively, but may require surgery if symptoms persist. Although falls may occur with any activity, children and adolescents participating in high-energy sports such as football, rugby, and motocross are at higher risk of fractures of the osseous structures of the shoulder. Treatment of these injuries is usually patient and fracture dependent.

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