[Imaging]

A Segmental Approach to Imaging of Sports-Related Injuries of the Pediatric Elbow

Jerry R. Dwek, MD*†

Context: The imaging of pediatric sports injuries of the elbow requires an understanding of the interaction between biomechanical forces common in sports and the developing skeleton.

Evidence Acquisition: A PubMed search was performed using the terms *elbow, radiology*, and *sports* with the search limited to children up to 18 years of age. No limits were set on the range of years searched. Articles were reviewed for relevance with an emphasis of the changing nature of sports injuries about the pediatric elbow.

Results: A clear progression of injuries about the elbow can be identified as the skeleton matures. Sports most commonly associated with injuries in the pediatric age group were baseball and gymnastics.

Conclusions: Most pediatric sports injuries result from overhand throwing, especially in baseball or gymnastics. The manifestation of the injuries shifts as the physes progress toward closure.

Keywords: elbow, adolescent, injury, chronic

The elbow is a complex articulation comprising the radius, ulna, and humerus. The radius and ulna function in concert with the distal humerus to allow flexion and extension at the elbow, while the radius and ulna separately allow supination and pronation.

As a main transfer point of forces between the upper and lower arm, the elbow serves as the insertion site for a number of muscle tendons, all of which exert substantial forces at their attachment sites.

During infancy, the elbow's articular surfaces cannot be seen radiographically, as they are not as yet ossified. As the child grows, an ordered progression of ossification occurs at the secondary centers as the elbow joint gradually reveals its structure.

The capitellum is the first secondary ossification center to ossify, occurring at about 1 year of age. Next, the radial head ossifies at about 3 years of age, followed by the internal (medial) epicondyle at 5 years, the trochlea at 7 years, the olecranon at 9 years, and finally the lateral epicondyle at 11 years. The progression lends itself to an easy mnemonic ("CRITOE") with the ossification progressing approximately every 2 years in most cases. Some variability in the age of ossification of the various centers is common. When faced with an unusual pattern of ossification, views of the contralateral elbow can be very helpful. In truly difficult cases, advanced imaging may be needed, primarily ultrasound and magnetic resonance imaging (MRI).

The configuration of the various ligaments and tendons about the elbow is the same as in the adult. The ulnar collateral ligament (UCL) medially has anterior, posterior, and transverse bands of which the anterior and posterior bands are most important. The anterior band spans the gap from the medial epicondyle to the sublime tubercle (Figure 1A). The posterior band is the weaker of the two and extends from the medial olecranon to the posterior aspect of the medial epicondyle (Figure 1B). Laterally, the radial collateral ligament and the lateral band of the UCL are the main restraints to varus stress, with the latter being the primary support. Both arise from the lateral epicondyle. The lateral band of the UCL wraps along the underside of the radius, cradling it, and inserts on the lateral ulna at the supinator crest (Figure 1A). The annular ligament, as its name suggests, encircles the radial head with insertions on the posterior and anterior aspects of the ulna at the radial notch.

Given its varied appearance and multiple-tendon and ligamentous appearance, a multimodality approach to elbow imaging is best. Especially in pediatrics, radiographs remain the mainstay of initial investigation, since they are fast and inexpensive and usually include sufficient information to guide

From the †Rady Children's Hospital and Health Center, University of California at San Diego, San Diego, California

*Address correspondence to Jerry R. Dwek, MD, Rady Children's Hospital and Health Center, 3020 Children's Way, San Diego, CA 92123, CA 92075-1201 (e-mail: jdwek@yahoo.com).

DOI: 10.1177/1941738112448733

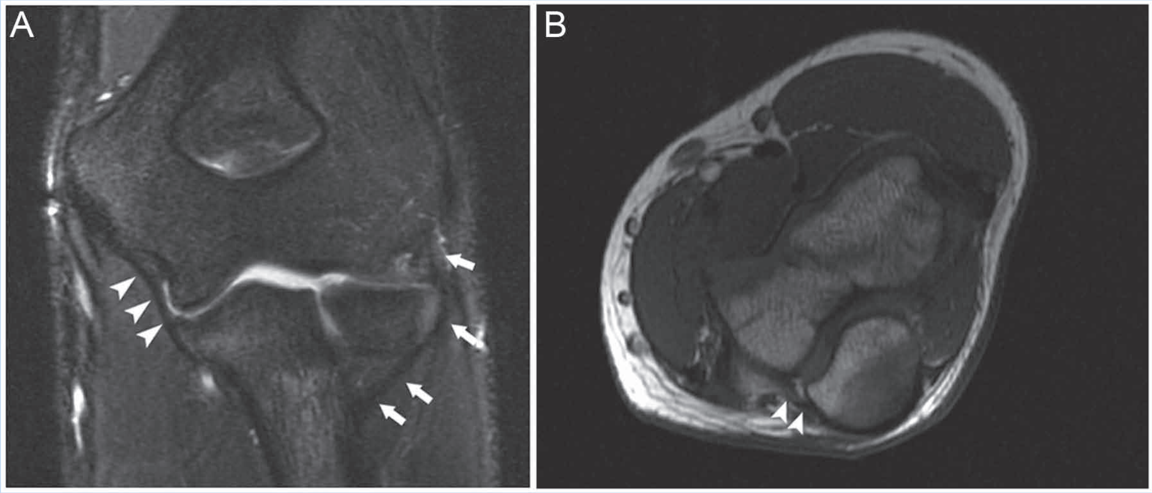

Figure 1. Twelve-year-old boy. A, coronal T2 fat-saturated magnetic resonance. The anterior band of the ulnar collateral ligament stretches from the underside of the medial epicondyle to the sublime tubercle (arrowheads). The lateral band of the ulnar collateral ligament arises from the lateral epicondyle, wrapping around the radial head to insert on the ulna (arrows). B, axial T1 magnetic resonance. The posterior band extends from the medial aspect of the olecranon inserting on the posterior aspect of the medial epicondyle (arrowheads).

therapy in the majority of cases. However, other modalities make substantial contributions to the diagnosis and care of both acute and chronic injuries about the elbow through childhood and adolescence. Computed tomography scanning with its multiplanar capability is adept at producing highly intelligible images with excellent resolution. Ultrasound has the advantage of not requiring ionizing radiation but tends to be a more focused examination without the ability to obtain a global picture of the joint. MRI is the primary advanced imaging modality, as it does not require ionizing radiation and can visualize bone as well as articular, physeal, and epiphyseal cartilage.

The key to understanding elbow injuries in the child is an appreciation of the weak links in the structure of the elbow. The physis is a mainly columnar aggregation of chondrocytes with scant intervening matrix. As such, it is always weaker than bone and is much more likely to fail in the face of acute or chronic repetitive trauma. Much of pediatric elbow imaging focuses on the evaluation of the multiple growth centers and their physes about the elbow. The distal humerus also includes a thin supracondylar portion, which, when exposed to the force of the olecranon, is much more likely to fracture compared with the more substantial physes at the larger portion of the distal humerus. Supracondylar fractures are common as an acute sports injury, as are lateral and medial condylar fractures. In many cases, after acute trauma no fracture will be noted on conventional radiographs. However, prominent anterior and posterior fat pads indicate a joint effusion and alert the physician of the likelihood of an occult fracture (Figure 2). The elbow can then be immobilized. Follow-up films done 10 to 14 days later will commonly show periosteal reaction, indicating that a fracture had indeed occurred.

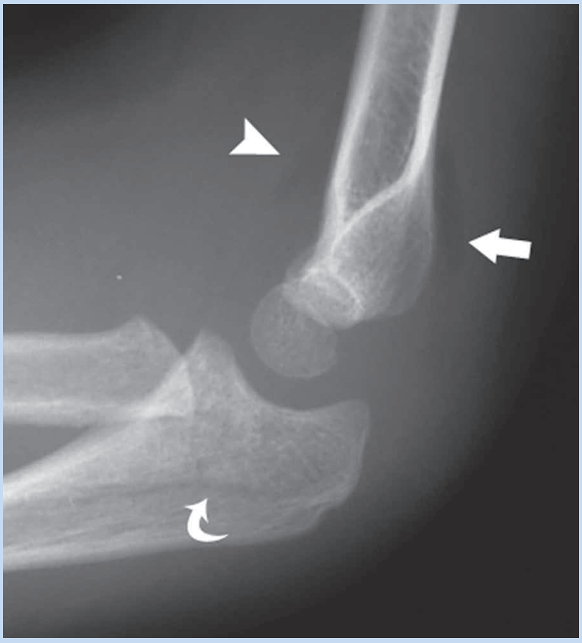

Figure 2. Six-year-old boy. Lateral view of the elbow demonstrates a prominent anterior far pad (arrowhead) and posterior fat pad (arrow). A fracture of the proximal ulna is present (curved arrow)

As children grow and mature, they participate in sports in a more goal-directed manner. In addition to a greater time actually playing sports, a greater amount of time is spent practicing. The greater load of repetitive motion leads to an increased incidence of overuse injuries about the elbow. As the ossification centers about the elbow develop and mature, the pattern of injury changes as well.

In the United States, sports-related injuries of the pediatric elbow mainly result from baseball and gymnastics.

During throwing, the arm is extended posteriorly, or “cocked,” and then accelerated forward to propel a projectile toward the target. During the late phase of cocking and early acceleration, a large hyperextension and valgus force is placed on the elbow. The result is a lateral compressive force centered on the developing capitellum laterally where the pattern of injury depends on the state of maturation of the capitellum.

A great tensile or distractive force is concurrently borne by the medial supporting structures. Here again, the injury changes with age as the skeleton goes through its predictive pattern of maturation. Although the actual mechanism of injury is identical to the syndrome of valgus extension overload common in adult professional baseball pitchers, the appearance changes since the skeletal structures are different.

A typical pattern of injury emerges. Laterally, Panner disease is seen first. This injury is thought to be an osteochondrosis of the capitellum seen in athletic individuals less than about 12 years old. In athletes older than 11 years, osteochondritis dissecans (OCD) occurs and is akin to OCD elsewhere in the body, as at the femoral condyles and talus. As can be seen, there is some overlap in the age ranges in the 2 syndromes reflecting to a certain extent their common etiologies. In skeletally mature individuals, true osteochondral fractures of the capitellum may occur.

Medially, injuries also progress in a fairly predictable manner. In younger adolescents, the medial epicondyle with its relatively weak physis is mainly affected. As physeal fusion nears, the focus of the injury shifts to the UCL as the main restraint to valgus forces is overcome. At the medial margin, many mixed forms are present such that partial tears of the UCL may coexist with chronic physeal injury at the medial epicondyle. Interestingly, chronic physeal injury at the medial epicondyle weakens it and may result in a complete avulsion of the entire medial epicondyle with displacement.

Posteriorly, the main injury is to the olecranon at the level of the physis. Here the triceps caused a chronic avulsive injury to the olecranon physis and persistence of the olecranon physis.

In addition to injuries related to throwing a baseball, elbow injuries related to gymnastics are also very common. The pursuit of excellence in gymnastics requires long hours of training in which the same routines and exercises are practiced repetitively such that the arms are subjected to a remarkable degree of repetitive stress. Injuries at the wrist are well documented and include a range on injuries whose manifestation depends on the skeletal maturation of the athlete. Elbow injuries are also common and include some of the same injuries that baseball players sustain especially laterally.

Apart from acute fractures, football injuries are underrepresented in the scope of injuries about the elbow. The reason for this discrepancy is related to the actual shape of the football as opposed to the baseball.

A baseball is small and round and fits easily into the palm of the hand. It is meant to be thrown, and indeed, all the players on the field, not just the pitcher, throw the baseball an enormous number of times. In contradistinction, the football is not a ball that is easy to throw. It is far heavier than a baseball and does not lie well in the hand. It is much more difficult to throw hard so that the throwing motion is far less extreme in terms of the acceleration of the arm and the extent of cocking that occurs during throwing. In addition, most of the players on a football team do not ordinarily throw the ball. In fact, most of the players on a team do not touch the ball at all during the course of the game.

THE LATERAL ASPECT

Panner disease involves in nearly all cases the dominant arm and usually affects boys rather than girls.[5]

Panner disease belongs to a poorly understood group of diseases termed *osteochondroses*. This group includes fairly common types, including Legg-Calve Perthes disease, which affects the femoral head of younger children. Findings in Panner disease closely parallel that of other osteochondroses.

The cause is theorized to be an injury to the tenuous vascularity of the capitellum. Haraldsson in 1959 noted that in the juvenile, the capitellum is supplied only by small posterior perforating end arteries.[2] These vessels must traverse a pliable and compressible epiphyseal cartilage, exposing them to injury. With significant vascular injury, disordered ischemia of the ossific nucleus occurs and is followed by disordered endochondral ossification.

Radiographically, the capitellum initially shows demineralization with loss of the sharpness of the cortical margins. This is followed by sclerosis and loss of volume. Subchondral linear lucency and frank fragmentation is common. In contradistinction to Legg-Calve Perthes disease of the femoral head, at the smaller capitellum the entire ossific center is usually involved.

On MRI, the affected chondroepiphysis is usually low signal on T1. It is variably very low signal on T2 or high signal on T2 depending on the viability of the underlying tissue and the stage of disease progression. Although the stages of the disease have not been described for Panner disease as they have been for Legg-Calve Perthes disease, one might assume that the ossific nucleus goes through the same progression of ischemia and necrosis, followed by revascularization and reossification. Generally, the early necrotic phase would be indicated by low signal on T1 and T2 sequences, whereas high signal on T2 later might indicate revascularization (Figure 3). Dynamic contrast imaging may be helpful, as enhancement is consistent with revascularization, although again no controlled studies are available.

The prognosis in Panner disease is excellent, with full recovery of the spherical shape of the capitellum being the

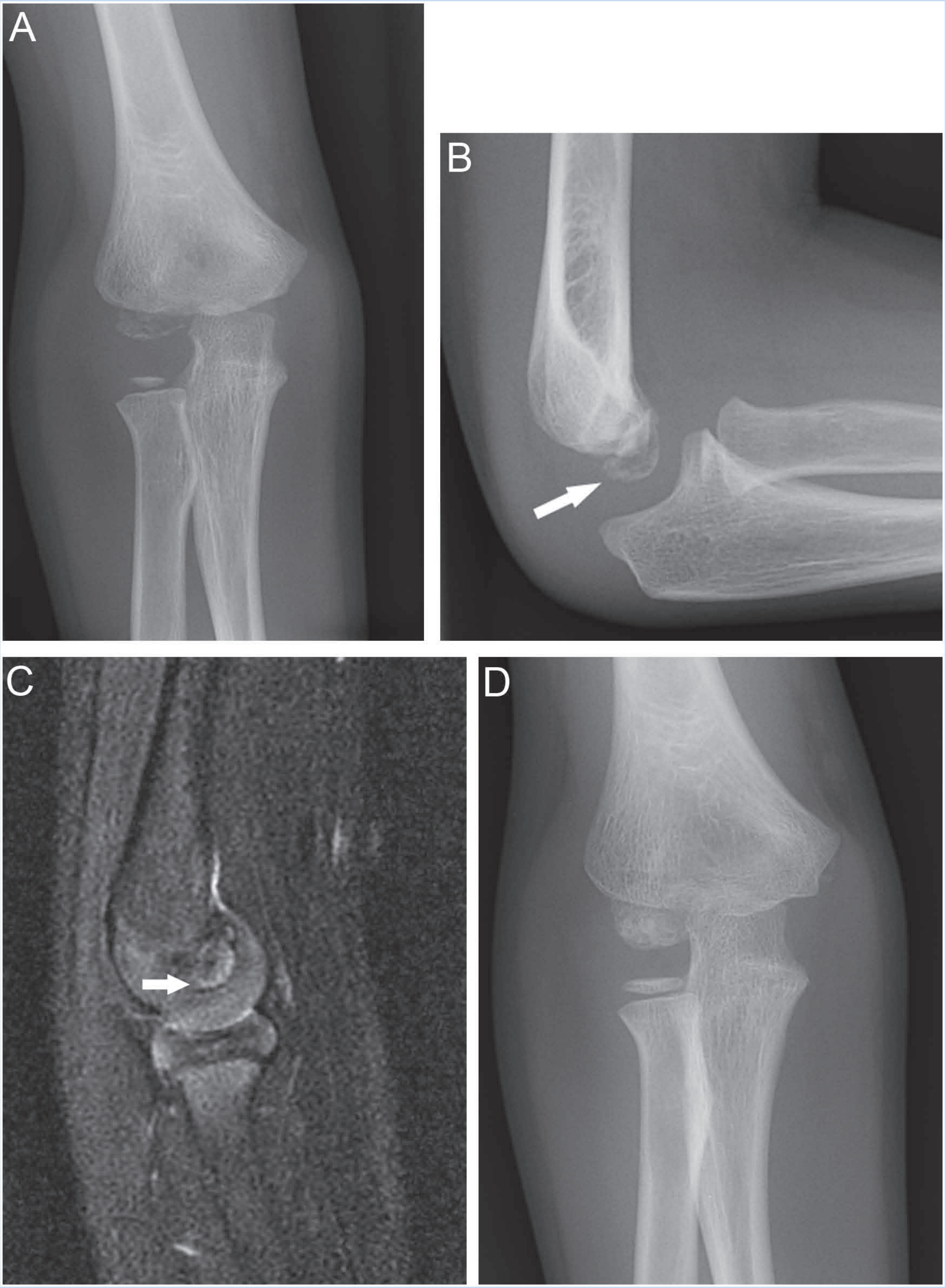

Figure 3. Eight-year-old boy. A, anteroposterior elbow. The capitellum is fragmented although it retains its shape. B, lateral view. Arrow indicates the fragmented capitellum. C, sagittal T2 fat-saturated magnetic resonance. T2 hyperintensity is apparent in capitellum (arrow). D, anteroposterior elbow. Eighteen months later, the capitellum is reossifying with some mild fragmentation remaining.

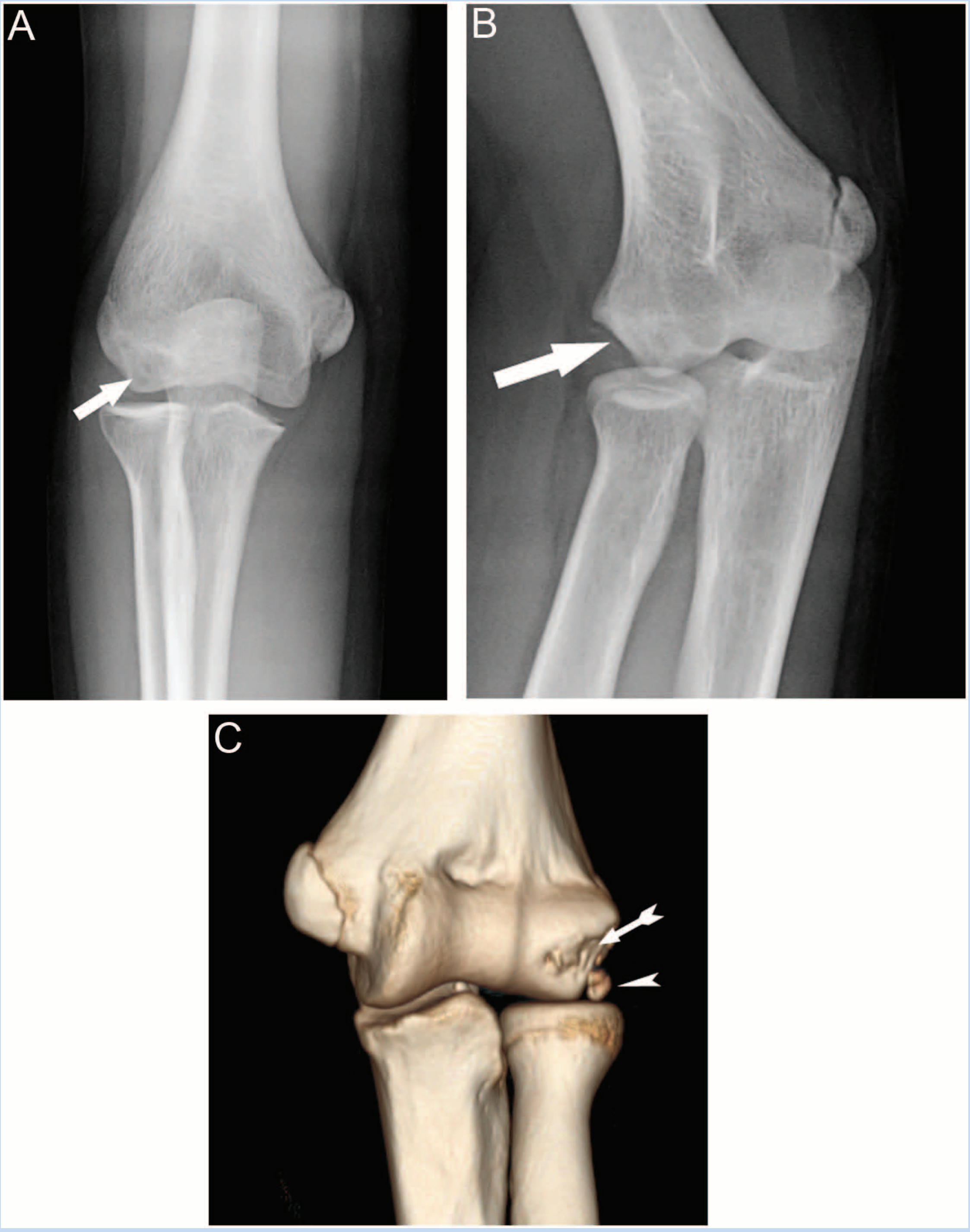

Figure 4. Fourteen-year-old boy. A, anteroposterior elbow. Focal lucency is seen in capitellum (arrow). B, oblique 45° semiflexed image. Flattening and loss of cortex is seen in the capitellum. Note faint ossific fragments (arrow). C, 3-dimensional computed tomography reconstruction. Note osseous defect in capitellum (arrow) and displaced osseous body (arrowhead).

norm.[5] This may be related to the fact that the capitellum, as opposed to the femoral head, does not bear weight. Even so, residual flattening of the capitellar articular surface may occur. Accelerated maturation of the radial head epiphysis is also seen.[9]

As the child ages, the capitellum becomes larger and more completely ossified. The remaining epiphyseal cartilage thins, leaving only a thin layer surrounded by the articular cartilage along the articular surfaces. With this development, after the age of 11 and 12 years old, OCD is the main manifestation of

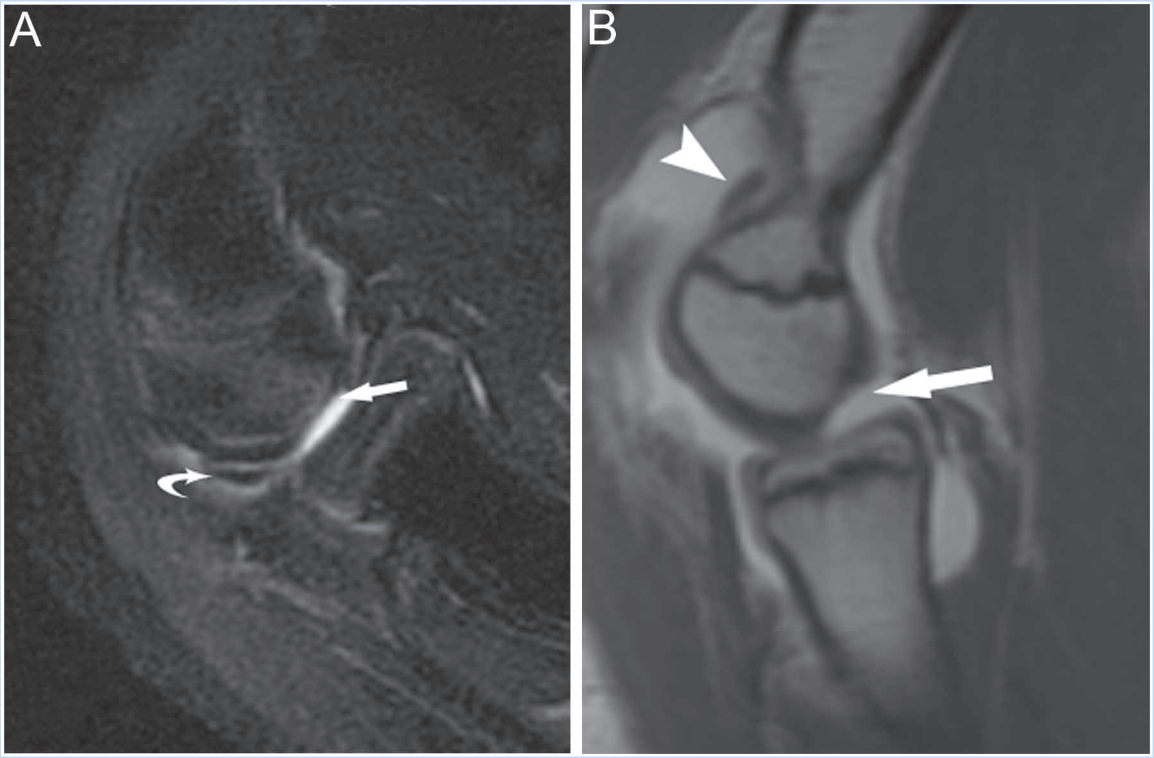

Figure 5. A, 13-year-old boy baseball catcher, sagittal T2 fat-saturated magnetic resonance. Osteochondral defect is seen at the articular surface (arrow) with edema seen in the donor site. Note loose body posterior to capitellum (curved arrow). B, 14-year-old shortstop, sagittal proton density image. Arrow indicates defect in articular surface with loss of articular cartilage. Note loose body in olecranon fossa posterior to humerus (arrowhead).

lateral compression injuries at the elbow. This lesion is thought to be akin to OCD seen at the femoral condyles and the talus.

In OCD of the femoral condyles, the injury is at the periphery of the developing epiphysis. An injury to the developing spherical physis possibly vascular in nature has been theorized.[7] In the same vein, the injury at the capitellum in juvenile OCD is at the level of the peripherally ossifying portion of the epiphysis, as opposed to a shear injury at the articular surface of the capitellum, as is the usual case in the skeletally mature.

The distinction is not inconsequential. In the adult form where the injury is at the articular surface, the fragment is more likely to be unstable and treated surgically. The prognosis is worse. In the adolescent or juvenile form, however, given that the lesion is deep to the articular surface, the fragment may be stable and the treatment, conservative.[10]

Initial anteroposterior radiographs may show subtle flattening and sclerosis of the articular surface. Anteroposterior images with the elbow in 45° of flexion can be more helpful[11] (Figure 4). Cortical irregularity and subchondral lucency may ensue. Loose intra-articular bodies can result, and an assiduous search should be made on all images. Loose bodies are likely to lie in natural recesses within the joint, particularly the olecranon and condylar fossae, or immediately posteroinferior to the capitellum.[3]

Since the articular surface of the capitellum is, to a large degree, exposed to the sonographic beam, sonography can be used to directly image the articular surface, noting any articular cartilage defects.[12] Performed through anterior and posterior windows, the articular surface is carefully inspected for contour abnormalities and discontinuity. A displaced fragment is identified by an echogenic density displaced from the articular surface of the capitellum and is good evidence for instability.[12]

MRI allows a more complete assessment of the capitellum, as well as ancillary findings such as loose bodies and related ligamentous injuries. Coronal and sagittal sequences are the most helpful since the lesion is usually anterolaterally placed. The defect is usually low intensity on T1 and low on T2 as well, although the T2 signal is variable. Correlation to plain film is very helpful. Bright T2 signal is usually present in much of the capitellum to a varying extent (Figure 5).

An assessment of the stability of the lesion is important for prognosis. The original Desmet criteria were revised by Kijowski et al[4] as they apply to the pediatric age group. In the adult, a fluid intensity interface surrounding the body, multiple cysts at the donor site, and a tear of the articular cartilage are all unequivocal indicators of instability. In the adolescent, however, these criteria occurring singly are not very sensitive.

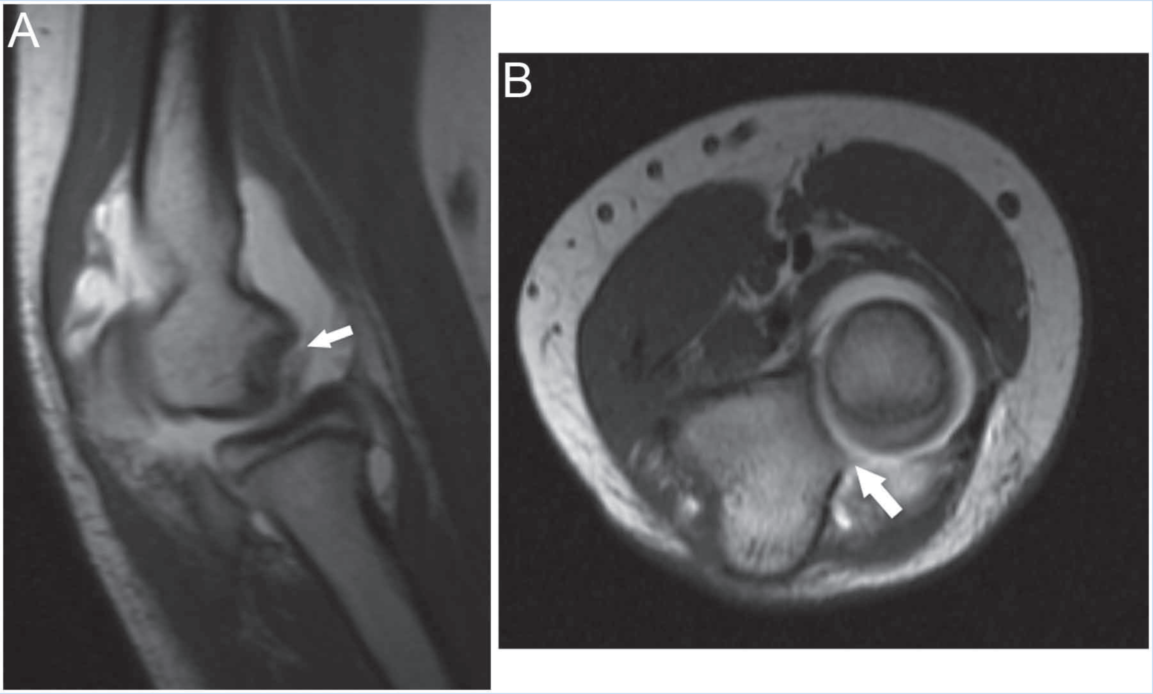

Figure 6. Fourteen-year-old boy. A, sagittal T1. An osteochondral defect is seen at the anterior articular surface of the capitellum (arrow). B, axial T1. The annular ligament is torn off of its posterior ulna attachment (arrow).

Only when occurring together are they 100% sensitive. This was confirmed in part by Jans et al in 2010.[3]

The most important of the above criteria is disruption of the articular cartilage. This criterion had the highest sensitivity for indicating an unstable lesion. More important, however, is that the status of the articular cartilage has the greatest influence on clinical management. If the articular cartilage is intact, rather than violate an otherwise intact articular cartilage, the lesion is drilled from the humeral metaphysis rather than through the articular surface. This has the advantage of not injuring otherwise healthy articular cartilage, which cannot regenerate.

To that end, high-resolution cartilage imaging is essential for accurate diagnosis and planning. Generally, the sagittal plane is preferred, as it portrays the lesion, concomitant flattening, and loss of cartilage best. Recently, high-quality 3-dimensional isotropic sequences have become available, which afford a view of the articular surface in any plane. Appropriate sequence planning is necessary to ensure that an isotropic voxel is acquired in which the measurements of the voxel are equal in the axial, sagittal, and coronal planes. In addition to basic mathematics, an understanding of the way in which sequences are optimized is very helpful to keep the sequences short and practical. A veritable alphabet soup of cartilage sequences are available from the different vendors, which, when used well, are capable of producing

Figure 7. Thirteen-year-old female gymnast. Coronal inversion recovery. Edema is seen throughout the radial neck. A focal stress fracture was seen on other imaging.

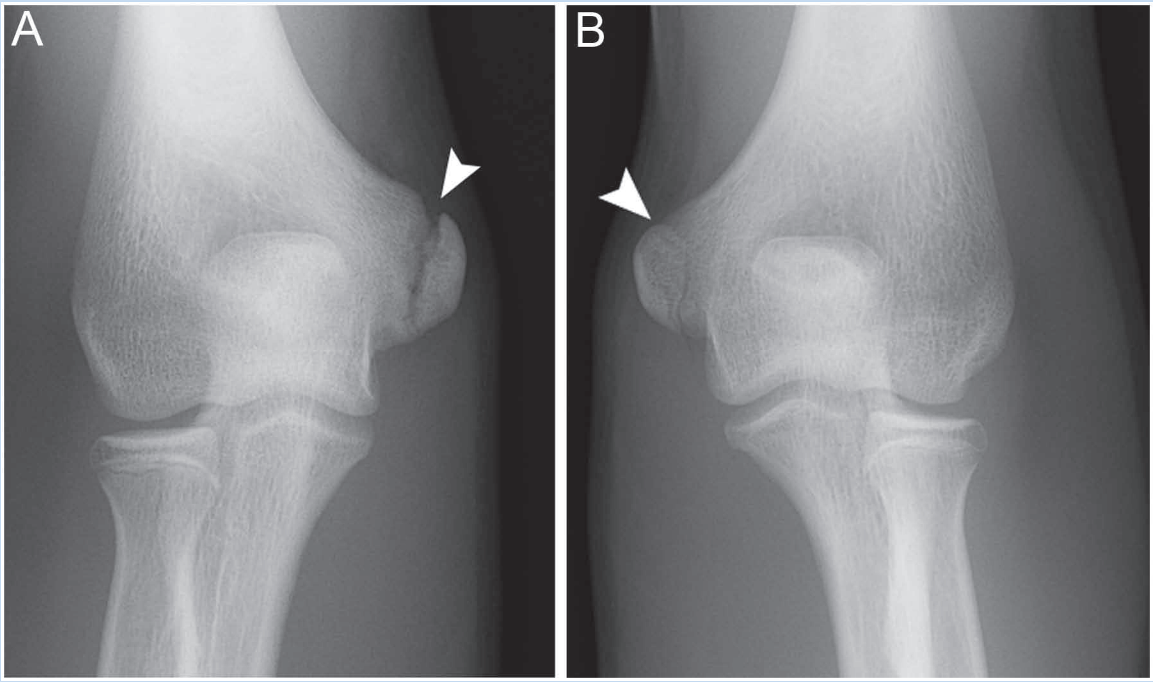

Figure 8. Fourteen-year-old boy. A-B, anteroposterior elbow shows a wide medial epicondylar physis, which is also slightly irregular (arrowhead). Contrast with normal contralateral elbow (arrowhead indicates normal physis).

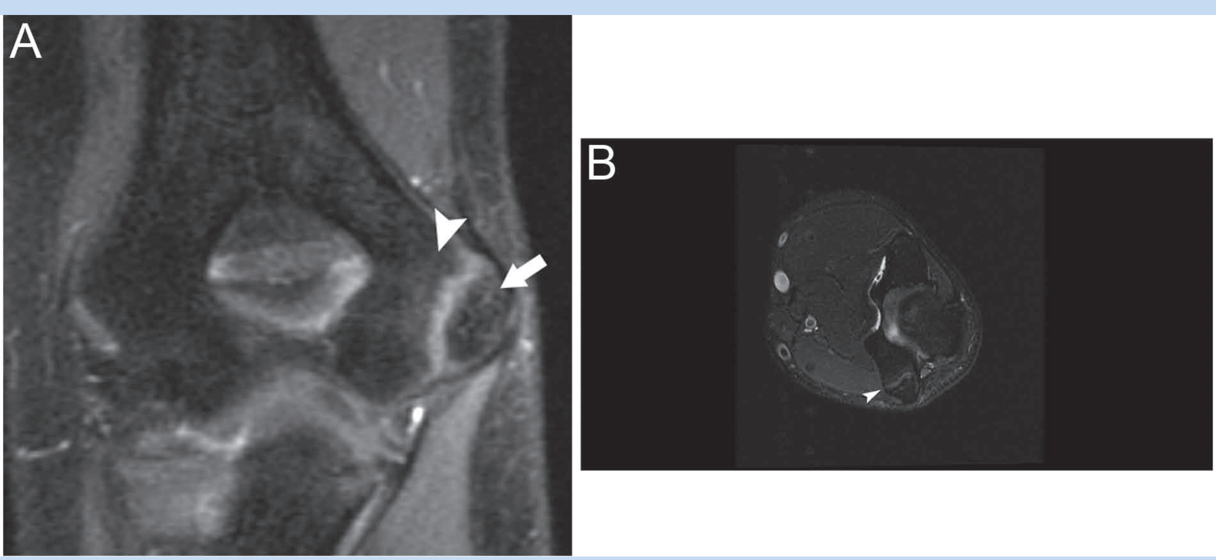

Figure 9. A, 15-year-old boy. Coronal T2 fat saturated. Edema is present on both sides of the medial epicondylar physis (arrow, epiphyseal side; arrowhead, metaphyseal side). B, 12-year-old boy. Axial T2 fat-saturated image shows a normal physis (arrowhead) of the medial epicondyle.

excellent diagnostic images.[13] MERGE sequences on GE MRI scanners (GE HealthCare, Waukesha, Wisconsin), LAVA, and basic 3-dimensional SPGR sequences are quite good at an accurate depiction of the articular surface. As opposed to the more medial trochlea, which ossifies from multiple fragmented centers, the capitellum ossifies from a single center so that the ossific nucleus is usually smooth. Confusing an OCD with a normal variant of ossification is usually not a problem.

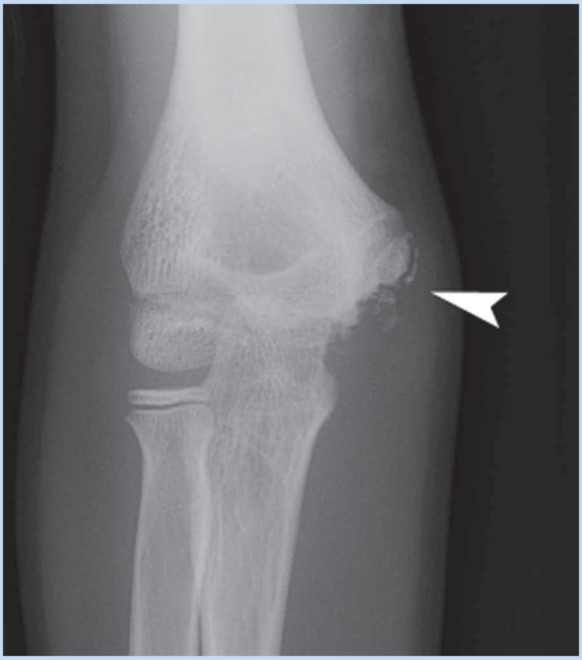

Figure 10. Twelve-year-old girl. Anteroposterior elbow shows multiple fragments of bone avulsed from the inferior surface of the medial epicondyle (arrowheads).

Figure 11. Sixteen-year-old boy. Coronal T2 fat saturated. Edema is seen at the ulnar collateral ligament insertion on the sublime tubercle. The periosteum (arrow) is elevated and partially stripped with bright signal (curved arrow) between it and the cortical surface of the ulna.

In addition to characterizing the OCD lesion accurately, note should be made of the ligamentous structures about the elbow. Because lateral compressive forces coexist with abnormal medial tensile forces, complex ligamentous abnormalities may be seen in the face of an otherwise straightforward OCD lesion. Laxity and high signal in the UCL or medial epicondyle may be seen.[6] Laterally, tears of the annular ligament and lateral band of the UCL are not uncommon (Figure 6).

Aside from injuries to the capitellum, stress fractures of the radial neck are another example of lateral compressive injuries. This injury is seen primarily in gymnasts who put large compressive loads on their arms repetitively (Figure 7). Gymnastic maneuvers are distinctly unusual from a biological standpoint. It should be understood that humans are not meant to walk on our hands. It is not surprising that the thin radial neck is prone to fracture in the gymnast.

Lateral epicondylitis is not uncommon in adolescents but is essentially an adult-type injury because it occurs on a skeletally mature bone with a mature tendon attachment. The lateral epicondyle ossifies last among the multiple ossification centers of the elbow. However, its physis fuses much earlier than the physis of the medial epicondyle and olecranon.

MEDIAL ASPECT

Excessive repetitive tensile forces typically cause injuries to the medial side of the elbow in children and adolescents. The chronic traction affects the various supporting structures of the elbow to varying extents depending on the skeletal maturity of the individual. In younger adolescents, traction injuries affect the medial epicondylar physis, as that is the weakest link along the medial elbow. The still immature UCL insertion on the sublime tubercle is also commonly affected. Later, as the physis progresses toward full maturity and closure, the nexus of injury shifts to the UCL proper and the common flexor tendon insertion.

Conventional radiography may reveal widening of the medial epicondylar physis. The physis in more severe cases may have a somewhat ragged appearance (Figure 8). Comparison to the contralateral elbow is invaluable in cementing the diagnosis. Many patients and their parents are loathe to discontinue the offending sporting activity in question, and it frequently helps the discussion when the abnormal side can be compared with the normal side.

A normal physis on MRI using fluid-sensitive sequences is depicted as a fairly thin moderately hyperintense line. Some mild hyperintensity is also seen in the immediate subphyseal areas. More pervasive bright signal, especially when seen on both sides of the main medial epicondyle, is indicative of pathologic edema (Figure 9). In Little League elbow, the entire medial epicondyle is frequently hyperintense on T2 fat-saturated sequences. The medial epicondyle is an apophysis

Figure 12. Fourteen-year-old male pitcher. Coronal T2 fat saturated. Edema is seen on both sides of the medial epicondylar physis and throughout the medial epicondyle (arrow). Edema is also present at the ulnar collateral ligament insertion on the sublime tubercle (curved arrow).

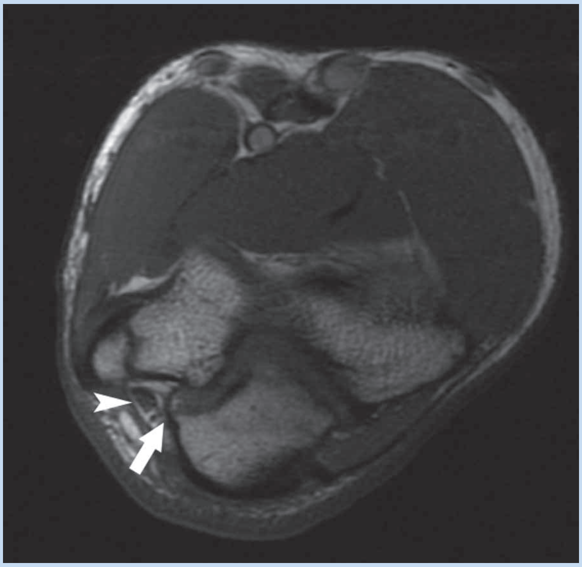

Figure 13. Fourteen-year-old pitcher. Coronal T1 magnetic resonance. A small osteophyte at the medial aspect of the olecranon (arrow). Note proximity of the ulnar nerve (arrowhead) to osteophyte, which may lead to impingement and neuritis.

Figure 14. Seventeen-year-old weight lifter. Sagittal computed tomography reconstruction. The olecranon physis is still patent with widening and irregularity.

that, like other secondary centers of ossification (epiphyses), is composed of uniformly fatty marrow. In normal adolescents, the medial epicondyle is not bright on T2 fluid-sensitive sequences, as it is mostly fatty.

Chronic injury to the physis may ultimately result in a complete avulsion in the face of relatively minor trauma. However, more commonly, small pieces of bone are avulsed from the underside or inferior surface of the medial epicondyle by the UCL (Figure 10). While it may not be immediately obvious, this too is a physeal injury. A spherical physis or growth plate surrounds the entire medial epicondyle, which allows for normal circumferential growth. These small avulsions involve that inferior portion of the physis, which is not apposed to the distal humerus. Since these avulsive injuries involve the physis with its growth potential, they may grow and be surprisingly large on initial presentation.

Avulsive injuries at the sublime tubercle are also common. The UCL may be completely avulsed or may remain attached to periosteum, which is stripped distally. The periosteum in the growing skeleton is highly vascular, active, and thick.[1] It is not as tightly attached to the cortical surface so that in the pediatric population, periosteal stripping of the sublime tubercle may be a more common injury than UCL avulsion (Figure 11).

As the physis of the medial epicondyle closes, the focus of the injury shifts to the UCL proper and the overlying common

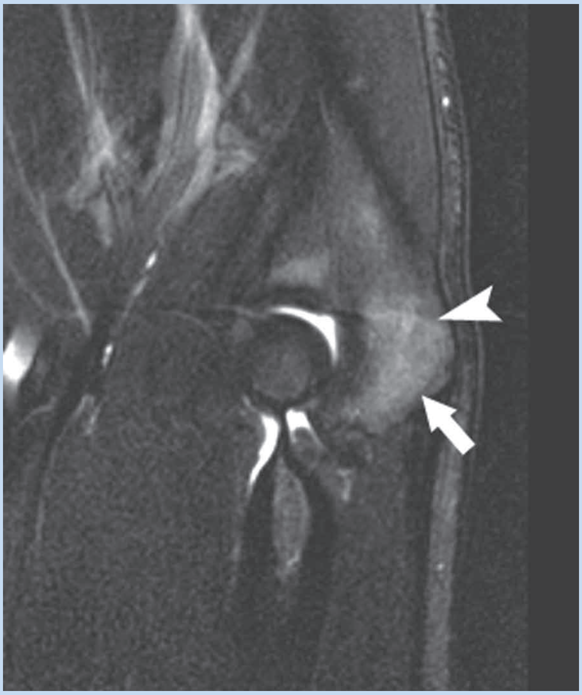

Figure 15. Sixteen-year-old male pitcher. Sagittal T2 fat-saturated magnetic resonance. Edema is seen throughout the olecranon (arrow) running up to the physeal scar (arrowhead) and slightly beyond it.

flexor tendon. An adult type of injury is seen with complete or partial tears of the tendon and ligament. Mixed lesions are common with physeal edema, edema at the sublime tubercle, and tears of the ligament occurring together depending on the level of skeletal development (Figure 12).

Subtle early osseous changes of valgus extension overload may be seen at the posteromedial olecranon where an osteophyte may form (Figure 13). A detailed analysis of this area is helpful to identify subtle cartilage lesions due to the chronic impaction of the medial olecranon on the articular surface of the humerus due to medial ligamentous laxity and instability.

POSTERIOR ASPECT

Posteriorly, a similar adult vs pediatric paradigm of injury can be seen. In the adult, avulsive triceps injuries are common. The pediatric analogue of this injury is avulsion of the olecranon epiphysis (Figure 14). In the acute avulsion, the entire olecranon apophysis may detach. Probably more common is the chronic injury to the olecranon physis causing the physis to remain open. The injury is in fact termed *persistence of the olecranon physis*.[8] The injury can be thought of as an epiphysiolysis similar to Little League shoulder. As was seen in the medial epicondyle, the physis of the olecranon widens and becomes irregular (Figure 14). It commonly remains patent with an otherwise unremarkable appearance. Comparison views are helpful, as the contralateral physis is frequently completely or nearly closed. By MRI, edema is present on both sides of the physis frequently involving the entire olecranon ossific center. Even during or after physeal fusion, a chronic traction injury may re-create similar patterns of edema as would occur before physeal closure. Edema may suffuse the recently matured olecranon apophysis running up until the nascent physeal scar and beyond it (Figure 15).

CONCLUSION

By considering the forces placed on the elbow during sports and the state of skeletal development, a predictable pattern of injury may be seen. Laterally, compressive injuries in younger adolescents and preadolescents manifest as Panner disease, while in the older adolescent, OCD is seen. Medially, physeal avulsive injuries both chronic and acute occur in younger patients with adult-type tears of the UCL and common flexor tendon being common as skeletal maturity nears. Posteriorly, a persistent olecranon physis represents the adolescent equivalent of triceps avulsions.

REFERENCES

1. Dwek JR. The periosteum: what is it, where is it, and what mimics it in its absence? *Skeletal Radiol.* 2010;39(4):319-323.
2. Haraldsson S. On osteochondrosis deformas juvenilis capituli humeri including investigation of intra-osseous vasculature in distal humerus. *Acta Orthop Scand Suppl.* 1959;38:1-232.
3. Jans LB, Ditchfield M, Anna G, Jaremko JL, Verstraete KL. MR imaging findings and MR criteria for instability in osteochondritis dissecans of the elbow in children [published online ahead of print February, 24 2011]. *Eur J Radiol.*
4. Kijowski R, Blankenbaker DG, Shinki K, Fine JP, Graf BK, De Smet AA. Juvenile versus adult osteochondritis dissecans of the knee: appropriate MR imaging criteria for instability. *Radiology.* 2008;248(2):571-578.
5. Kobayashi K, Burton KJ, Rodner C, Smith B, Caputo AE. Lateral compression injuries in the pediatric elbow: Panner's disease and osteochondritis dissecans of the capitellum. *J Am Acad Orthop Surg.* 2004;12(4):246-254.
6. Kooima CL, Anderson K, Craig JV, Teeter DM, van Holsbeeck M. Evidence of subclinical medial collateral ligament injury and posteromedial impingement in professional baseball players. *Am J Sports Med.* 2004;32(7):1602-1606.
7. Laor T, Wall E, Zbojniewicz A. Juvenile osteochondritis dissecans (JOCD): is it a growth disturbance of the secondary physis of the epiphysis? Paper presented at: International Skeletal Society; 2011; San Diego, CA.
8. Lowery WD Jr, Kurzweil PR, Forman SK, Morrison DS. Persistence of the olecranon physis: a cause of "little league elbow." *J Shoulder Elbow Surg.* 1995;4(2):143-147.
9. Smith MG. Osteochondritis of the humeral capitulum. *J Bone Joint Surg Br.* 1964;46:50-54.
10. Takahara M, Mura N, Sasaki J, Harada M, Ogino T. Classification, treatment, and outcome of osteochondritis dissecans of the humeral capitellum. *J Bone Joint Surg Am.* 2007;89(6):1205-1214.
11. Takahara M, Ogino T, Takagi M, Tsuchida H, Orui H, Nambu T. Natural progression of osteochondritis dissecans of the humeral capitellum: initial observations. *Radiology.* 2000;216(1):207-212.
12. Takahara M, Ogino T, Tsuchida H, Takagi M, Kashiwa H, Nambu T. Sonographic assessment of osteochondritis dissecans of the humeral capitellum. *AJR Am J Roentgenol.* 2000;174(2):411-415.
13. Winalski CS, Rajiah P. The evolution of articular cartilage imaging and its impact on clinical practice. *Skeletal Radiol.* 2011;40(9):1197-1222.