Youth Throwing Elbow Injuries

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Abstract:

Youth elbow throwing injuries have been increasing among the pediatric population as more children participate in overhead sports, compete at high levels, and specialize in a single sport at an earlier age. The majority of these elbow injuries are attributable to overuse. In order to decrease the incidence of elbow injuries, recommendations and guidelines have been established and adopted by the Little League Baseball organization and other youth baseball organizations in America. There has been some success with these guidelines as they have been shown to decrease the risk of developing injury. Despite having guidelines, however, adolescents who compete in overhead sports remain at high risk of developing overuse injury, and the spectrum of injury is commonly seen in pediatric orthopaedic offices. In this review, we describe six different elbow injuries associated with overuse and their specific management and treatment strategies: medial epicondyle apophysitis, medial epicondyle fracture, capitellar osteochondritis dissecans, Panner's disease, UCL sprain, and olecranon stress injury. The purpose of this review is to highlight the spectrum of overuse elbow injuries seen in the pediatric population and briefly summarize the management of each injury.

Key Concepts:

- There is an increasing incidence of elbow overuse injuries associated with youth sports participation, specifically in throwing sports such as baseball and softball.
- Despite the existence of recommendations and guidelines for arm care, pediatric orthopaedists continue to see and treat a large number of overuse elbow injuries.
- Medial epicondyle apophysitis, medial epicondyle fracture, capitellar osteochondritis dissecans, Panner's disease, UCL sprain, and olecranon stress injury are some of the most common overuse elbow injuries treated.
- The majority of these injuries can be treated nonoperatively, however, for those that require surgical treatment, it is imperative for the orthopaedist to recognize it and treat adequately to prevent further complication.

Introduction

About 60 million children aged 6–18 years participate in some form of athletics each year.[1] Specifically, for baseball and softball, participation continues to increase among the adolescent age group,[2,3] with 2.4 million boys and girls playing baseball and softball through the Little League organization alone.[4] More importantly, the trend of early sports specialization has increased dramatically

as the number of sports per participant decreased to its lowest number ever to 1.84 in 2019.[5] Multiple studies have shown that early sports specialization increases the risk of injury and interestingly, lowers the lifelong sports participation rate and increases the risk of burnout.[6,7,8,9]

As more young athletes participate in overhead sports, compete at high levels, and specialize earlier, elbow

Table 1. MLB Pitch Smart Guidelines for Youth Pitchers

Age	Daily Pitch Max	0 Days' Rest	1 Days' Rest	2 Days' Rest	3 Days' Rest	4 Days' Rest	5 Days' Rest
7-8	50	1-20	21-35	36-50	N/A	N/A	N/A
9-10	75	1-20	21-35	36-50	51-65	66+	N/A
11-12	85	1-20	21-35	36-50	51-65	66+	N/A
13-14	95	1-20	21-35	36-50	51-65	66+	N/A
15-16	95	1-30	31-45	46-60	61-75	76+	N/A
17-18	105	1-30	31-45	46-60	61-80	81+	N/A
19-22	120	1-30	31-45	46-60	61-80	81-105	106+

injuries in the adolescent population continue to rise.[10,11] These injuries are often attributable to overuse, especially in youth baseball players.[12,13,14] Injury to the pediatric elbow occurs as a wide spectrum, and the patterns of injury are dependent upon age and developmental stage of the child. As the treatment and management of these injuries are dependent upon the type of injury and maturity level of the athlete, it is imperative to recognize that an injury exists. Unfortunately, many adolescent athletes will continue to play through pain, likely due to inexperience of the player or the coach.[15,16] When a pediatric patient initially presents with the complaint of elbow pain associated with activity, a careful history and exam must be obtained for accurate diagnosis.

Steps have been made to help provide guidance and recommendations to decrease the incidence of overuse injuries, specifically for youth baseball pitchers. Major League Baseball (MLB), in association with their advisory committee, has developed specific guidelines for maximum pitch counts in a game and minimum days rest between outings for youth pitchers.[17] These guidelines are the same adopted by the Little League organization (Table 1).[17,18]

More importantly, other than providing maximum pitch counts and days' rest for youth pitchers, MLB Pitch Smart also provides the risk factors that lead to throwing injuries: pitching while fatigued, pitching year-round without dedicated rest for up to 4 months out of the year, playing for multiple teams at the same time, and radar gun use.[19] Knowledge of these risk factors can help prevent injuries in youth baseball. A recent survey of parents of youth pitchers revealed that those who are aware of and follow these Pitch Smart guidelines are significantly less likely to have a child with an injury compared to parents who are unaware of the Pitch Smart guidelines.[20]

As the rate of overuse elbow injuries continues to rise in the pediatric and adolescent population, it is important to recognize these types of injuries. In this review, we examine medial epicondyle apophysitis, medial epicondyle fracture, capitellar osteochondritis dissecans, Panner's disease, UCL sprain, and olecranon stress injury, specifically focusing on the diagnosis and management of each injury.

Medial Epicondyle Apophysitis

Medial humeral epicondyle apophysitis, also referred to as "Little Leaguer's Elbow," is a common upper extremity injury in adolescent overhead throwing athletes.[21] First described by Brogdon and Crow in juvenile baseball pitchers, this term has grown to represent a range of pathology involving lesions about the medial aspect of the elbow.[22,23] The prevalence of medial epicondyle apophysitis is not clearly defined, although several studies have described rates as high as 70–95% of medial elbow pain in adolescent and preadolescent pitchers.[22,24,25]

Repetitive valgus stresses to the elbow and forearm pronation during overhead throwing sports, such as seen during the late cocking and acceleration phase of throwing, places significant traction through the immature chondro-osseous junction of the epicondylar apophysis.[22] Figure 1 depicts the throwing phases for a pitcher during a routine delivery.[26]

Figure 1. Pitching phases—the most valgus stress is applied during the late cocking and acceleration phases of throwing.

Over time, such valgus overload can produce hypertrophy of the medial epicondyle or fragmentation/separation of the medial epicondyle apophysis, which is an area of weakness in younger athletes.[27] As a result, athletes may experience progressive, activity-related elbow pain that may adversely affect function and athletic performance.

The diagnosis of medial epicondyle apophysitis is generally made clinically. Patients will present with medial elbow pain worsened by overhead throwing activities and decreased throwing speed. Tenderness directly upon the medial epicondyle may be elicited during physical examination; however, it is important to note that several of the pathologies discussed in the current review could produce similar physical examination findings. Pain and/or instability with valgus stress of the elbow may also be present.

A complete radiographic evaluation of the affected elbow is recommended as the spectrum of apophysitis involves several potential pathologic changes and radiographic findings can dictate management.[28] Medial epicondylar changes, including widening, fragmentation, separation, irregularity, and hypertrophy have been noted to occur at a high rate in prior literature evaluating adolescent baseball players.[22,29] Hang et al. found that all Little Leaguers in a series of 343 had hypertrophic changes about the medial epicondyle, many without symptomatology, and proposed this to be a normal physiologic change in such athletes.[22] In an ultrasonographic evaluation of medial epicondylar changes in juvenile baseball players, Otoshi found varied morphology of the apophysis by age and noted the presence of
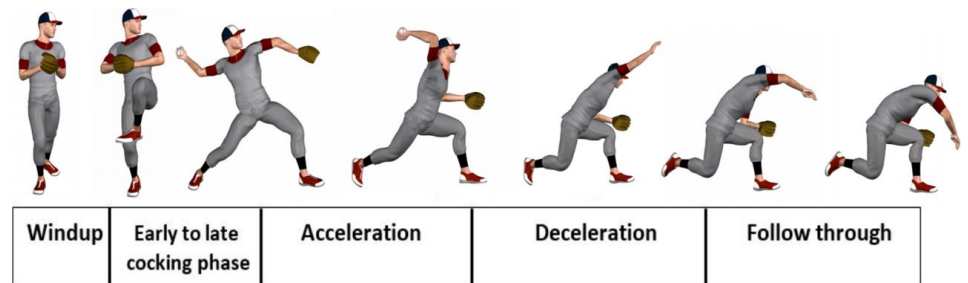
fragmentation to be a significant factor for the development of elbow pain in such players.[21] Radiographs may also diagnose a frank avulsion fracture of the medial epicondyle, which represents an extreme of the spectrum of Little Leaguer's Elbow and will be discussed in greater detail below. Magnetic resonance imaging (MRI) may also be considered to evaluate for stress fractures or ligamentous injury and will show edema of the medial epicondyle apophysis.[27]

As with many overuse injuries, the mainstay of treatment is nonoperative and involves activity modification, rest, and physical therapy. Once the diagnosis is made, attempts at reducing acute inflammation with ice, a short period of rest, and nonsteroidal anti-inflammatory medications is prudent.[28,30] A supervised strengthening and flexibility program targeting the flexor-pronator musculature with isotonic, isokinetic, and isometric strengthening should be initiated, followed by an interval-throwing program.[27] Surgical management is rare and is reserved for those who have failed nonoperative management or those with concomitant radiographic abnormalities such as symptomatic spurs, loose bodies, or persistent valgus instability.[27] The specific surgical management depends upon the underlying pathology and may involve arthroscopic or open debridement of osteochondral lesions, loose bodies, or ligamentous reconstruction as appropriate.

Medial Epicondyle Avulsion Fractures

Medial epicondyle fractures are relatively common injuries, representing approximately 12% of all elbow fractures in the pediatric population.[31] In overhead

throwing athletes, these fractures may occur by an avulsion-type mechanism in the setting of valgus tension stresses of the common flexor origin and the ulnar collateral ligament. Such injuries may result from chronic microtrauma (i.e., pitching, throwing) or may occur after an acute trauma such as an elbow dislocation.[28] Contrary to medial epicondyle apophysitis which typically affects slightly younger patients, avulsion fractures are more common in older adolescents as the apophysis ossifies.[28] Osbahr et al. discussed a series of male adolescent baseball players with a mean age of 13 years who all sustained acute medial epicondyle avulsion fractures.[32] Eighty-seven percent of patients presented with sudden pain and a distinct "pop" while throwing. High pitch counts in adolescent athletes has been implicated as a risk factor for this injury.[32] Importantly, prevention of such injuries in baseball players can be optimized when complying with the MLB Pitch Smart guidelines outlined in Table 1.[17]

A detailed physical examination should be performed to include assessment of elbow tenderness as well as stability. A thorough radiographic evaluation of the affected elbow is imperative to define fracture displacement and morphology. In the case of minimally displaced fractures, physeal widening or irregularity may be the only radiographic abnormality.[33] Following acute trauma such as an elbow dislocation, clinicians must pay close attention to the ulnohumeral joint, as incarcerated medial epicondyle avulsion fracture fragments may be present, and this finding necessitates surgical management.[34] In equivocal cases, it may be prudent to obtain contralateral elbow views for comparison. Other views such as the internal oblique view and distal humeral axial view may increase the accuracy in measuring the displacement.[35] Edmonds et al. showed that plain radiographs may underestimate the amount of fracture displacement, and CT scan may be more accurate in determining the true displacement in equivocal cases.[36]

While there are clear operative indications for certain medial epicondyle fractures, management of medial

Figure 2. *A) Radiograph of right elbow of a 14-year-old male right-hand dominant baseball player revealing displaced medial epicondyle fracture. B) Patient underwent open reduction internal fixation.*

epicondyle avulsion fractures which do not fall within absolute indications remains controversial. In addition to open fractures as previously mentioned, fractures incarcerated within the joint which are irreducible by closed means may be managed with open reduction and internal fixation.[37] Other commonly accepted operative indications include ulnar nerve symptoms, gross valgus instability, and displaced fractures in high-demand athletes.[38,39,40] In cases that do not meet the above indications, such as minimally displaced fractures (generally considered <2 millimeters) and non-athletes, closed management with casting and close radiographic follow-up may be the preferred management technique.[31,37] Open reduction and internal fixation can successfully be utilized using Kirschner wires in younger patients or screw fixation in higher-demand athletes.[37] Figure 2 shows a medial epicondyle fracture that underwent screw fixation.

Fractures that are comminuted or primarily cartilaginous in nature can be fixed utilizing alternative methods such as suture anchor fixation.[41] Outcomes are generally favorable regardless of management strategy, with one comparative study highlighting similar outcomes between either nonoperative or operative management in isolated fractures 5 to 15 millimeters displaced.[42] Patients generally have successful return to play within 1 year when following these general treatment approaches.[32,43]

Capitellar Osteochondritis Dissecans

Dr. Franz König first characterized osteochondritis dissecans (OCD) of the capitellum in 1888 as he described three cases in which elbow pain and swelling were resolved after removal of loose bodies.[44,45] The etiology of the disease process is not completely understood, and multiple factors likely play a role.[46,47] Essentially, it is presumed that disruption of the blood flow to the pediatric elbow leads to fragmentation of the developing capitellum. Multiple studies have suggested that young overhead athletes are at increased risk for developing OCD.[48,49,50,51,52] Patients are often greater than 10 years of age and will present with lateral elbow pain and swelling associated with activity. They can often lose full elbow extension, and mechanical symptoms such as clicking or locking is a late sign indicating the presence of loose bodies.

Radiographs are the initial imaging study to identify capitellar OCD and imaging may reveal lucency or flattening of the capitellum in early stages. Kijowski et al. retrospectively reviewed a group of 15 patients with OCD confirmed by surgery or MRI and found that only 7 patients had the OCD lesions detected by initial interpretations of routine radiographs.[53] In fact, ultrasound may be a better screening tool for asymptomatic or minimally symptomatic lesions.[54] Because lesions can be subtle on these initial imaging studies, it is not uncommon for OCD to be identified late in the course of the disease or for patients to present with years of pain.
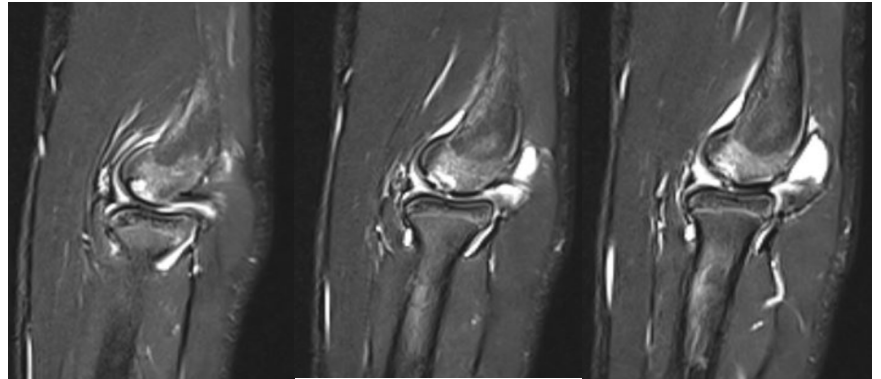

Figure 3. MRI of a 14-year-old pitcher with capitellar OCD lesion.

Ultimately, after the diagnosis is made, CT or MRI (Figure 3) is used to determine the stability of an OCD lesion.[55,56]

OCD lesions are classified based on their stability, which corresponds to their management strategies. Table 2 summarizes the International Cartilage Repair Society classification system developed in 1997 which uses arthroscopic findings to stage cartilage lesions.[52,57] Despite the usefulness of this system, management of capitellar OCD lesions in the youth population remains controversial.

It is generally accepted that stable lesions can be treated nonoperatively with a trial of rest. In a retrospective review of 106 cases of OCD of the capitellum, Takahara et al. demonstrated that stable lesions that healed completely with elbow rest had an open capitellar growth plate, localized flattening of the subchondral bone, and good elbow motion. Patients with stable lesions that continued activity, however, had worse outcomes in terms of radiographic findings and formation of loose bodies.[58]

For unstable lesions, surgical treatment includes debridement, microfracture, fixation, or reconstruction with an osteochondral graft. Indications differ for each option, and outcomes are variable. Fixation appears to provide good outcomes with healing and return to sport. Specifically, Hennrikus et al. showed good to excellent functional outcomes for patients who underwent internal fixation of unstable in situ OCD lesions of the capitellum,

Table 2. International Cartilage Repair Society (ICRS) Classification System for OCD Lesions

Stage	Description
I	Stable with continuous but softened area covered by intact cartilage
II	Partial discontinuity that is stable when probed
III	Complete discontinuity but not yet dislocated
IV	Empty defect or dislocated fragment (loose bodies)

particularly in those who were younger and had lesions <13 mm in sagittal width.[52] Reconstruction or osteochondral autograft transplant surgery (OATS) is gaining popularity, especially for larger (>10 mm) unstable lesions (Figure 4).

Bae et al. reported on 28 patients who underwent single-plug OATS, and of the 13 patients who had >6 months follow-up, 9 patients (69%) returned to their primary sport and 100% returned to general sports participation.[51] Despite success from multiple studies, failures with surgical treatment are not uncommon. Chen et al. reviewed multiple studies and found similarities in those who had treatment failure: older patients with closed physes, patients with longer preoperative duration of symptoms, and those involved in higher risk upper extremity sports (baseball/gymnastics).[50] Ultimately, OCD of the capitellum in young, active patients continues to be a difficult clinical challenge for orthopaedic surgeons to address and further studies with longer follow-up are needed for better characterization of treatment strategies.

Panner's Disease

Panner's disease, or osteochondrosis of the capitellum, was first described by the Danish orthopaedic surgeon Dr. Dane Panner in 1927 as he noted radiographic changes of the elbow capitellum similar to that of osteochondrosis of the hip epiphysis known as Legg-Calve-Perthes disease.[59] Though some authors have grouped Panner's disease and OCD of the capitellum together, the two diseases are distinct pathologies with different management and outcomes.[60,61] There exists debate over the etiology of Panner's disease, and several theories have emerged. The prevailing belief is that stress or microtrauma over a period of time disrupts the chondrogenesis, and osteogenesis that occurs at the epiphysis and interference of the blood supply leads to sclerosis and fragmentation of the capitellum.[62,63] The mechanism is very similar to that of OCD of the capitellum and likely exists
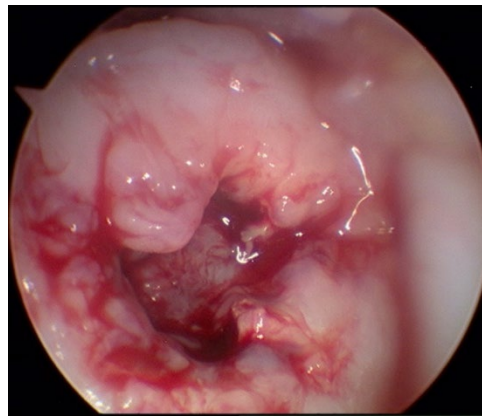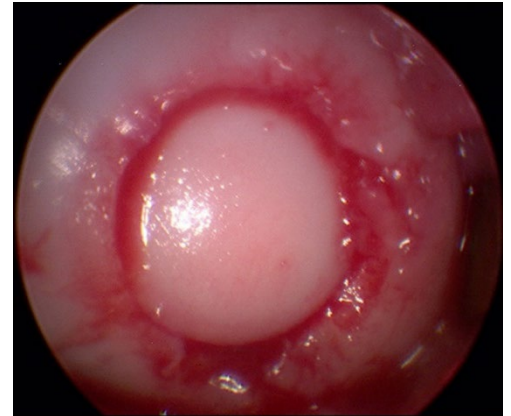
| Capitellar OCD | s/p OATS plug |

Figure 4. *Arthroscopic images of capitellar OCD that underwent single-plug osteochondral autograft transplant surgery.*

on a spectrum of the same disease process with patients less than 10 years of age developing Panner's disease and patients greater than 10 years of age developing OCD. It should be noted, however, that in Panner's disease, the entire ossific nucleus of the capitellum is affected, but in OCD, only a localized area of the capitellum is affected.[61]

Panner's disease is often seen in the dominant arm of boys during their first decade. Patients present with lateral elbow pain and stiffness with a history of mild trauma and overuse valgus force (i.e., throwing). Claessen et al. performed a literature review of Panner's disease and found that of the 29 patients whose symptoms were described, 19 patients (66%) had pain and 25 (86%) had limited elbow range of motion.[64] They also reported an association with sports including baseball, gymnastics, and handball.[65,66,67] Panner's disease is relatively rare compared to the other elbow injuries discussed in this review but still exists among young throwing athletes.

Radiographically, Panner's disease has been described similarly to Legg-Calve-Perthes, as previously mentioned.[59] Findings on imaging can be subtle and easily missed. In a case study of a nine-year-old baseball player who initially presented to the ED with elbow pain and decreased range of motion, Stoane et al. presented radiographs that revealed "sclerosis, cortical irregularity, and

subtle fragmentation of the capitellum."[68] They also described the MRI findings of Panner's disease (decreased signal intensity of the capitellum on T1 sequences) for the first time in the literature and recommend its utilization for the early detection of Panner's disease as MRI is more sensitive to the early changes than plan radiographs.

Diagnosing Panner's disease is critical because it dictates treatment and parental counseling. Whereas OCD of the capitellum can require surgery, Panner's disease almost never requires surgical intervention.[61,64] Claessen et al. described in their review that of the 17 case reports that included treatment, only one reported surgery which included arthroscopic debridement with application of a postoperative cast for 4 months.[69] Most authors agree that conservative measures including rest and immobilization are appropriate for treating Panner's disease, though specific timetables for return to sport are not agreed upon.[61,64,70,71] Cessation of all throwing activities should be encouraged in those diagnosed with Panner's disease with a gradual return to sport after pain has resolved and elbow range of motion has returned to baseline, which can be within a few months.

UCL Injury

Injury to the ulnar collateral ligament (UCL) in the elbow, first characterized in javelin throwers by W. Waris in 1946, is now an increasingly common injury in youth baseball players.[72] UCL injuries in overhead athletes received considerable attention in popular news as well as scientific literature approximately 30 years later when Dr. Frank Jobe completed the first UCL reconstruction on professional baseball player Tommy John in 1974. After a revision procedure to reposition the ulnar nerve and remove scar tissue growing over it, John returned to the mound in 1976 and went on to excel as a professional pitcher for another 13 years. Jobe's pioneering UCL reconstruction procedure, which he first described in 1986, became colloquially referred to as "Tommy John surgery."[73] Today, the number of youth and high school pitchers requiring UCL reconstruction is rapidly increasing and considered by many to be an

Figure 5. *The milking maneuver is performed by creating a valgus stress on the elbow by pulling on the patient's thumb with the forearm supinated and elbow flexed at 90 degrees. Pain, instability, or apprehension is a positive sign for UCL injury.*

'epidemic.'[74] For example, while youth and high school pitchers accounted for only 10% of UCL surgeries at the American Sports Medicine Institute in Birmingham, AL in 1995, they accounted for approximately 40% of the Center's UCL reconstruction surgical caseload in 2020.[11,75] Similar to the elbow injuries previously discussed, this drastic increase in incidence is attributed primarily to overuse.

The UCL complex is comprised of anterior, posterior, and transverse bundles. The anterior bundle, composed of anterior and posterior bands, is the primary restraint to valgus stress in the elbow and the most commonly injured portion of the UCL. Injuries to the anterior bundle frequently occur during the late cocking and early acceleration phases of the overhead throwing motion when valgus forces often exceed the intrinsic tensile strength of the UCL.[73,76–80] Figure 1 demonstrates the throwing motions for a pitcher during a routine windup and pitch.

The primary pathology of UCL injury is a degenerative process from overuse, but injury may also occur as a result of acute tears or acute-on-chronic injuries. Specifically, repeated valgus stress leads to hypertrophic changes and degeneration of the UCL associated

with increased laxity and medial instability.[30,81,82] At the time of acute UCL tears, patients commonly experience a "pop" while throwing, followed by intense pain and either a total inability to throw or severely reduced velocity and loss of ball control. Following injury, patients present with symptoms that may include medial elbow pain, swelling/bruising, elbow instability on valgus stress test, positive milking maneuver (Figure 5), elbow stiffness and resistance to extension, ulnar neuropathy characterized by a positive Tinel's sign at the ulnar nerve and intermittent paresthesia in the fourth and fifth digits, and reduced grip strength.[83–85]

Radiographic images are generally obtained for patients with these symptoms, although it should be noted that radiographs are normal in approximately 40-50% of patients later confirmed to have a UCL tear. In patients with abnormal radiographic findings, however, the most common abnormality is olecranon osteophyte formation.[84] Although advanced imaging is widely used to diagnose UCL injuries, as discussed below, ultrasound and, specifically, stress ultrasound studies have been shown to be effective to diagnose complete UCL tears.[86] As with injuries discussed above, first-line treatment for suspected UCL sprain is conservative and includes ice, rest, and as-needed nonsteroidal anti-inflammatory medications. Physical therapy, with a focus on range of motion of forearm flexors and pronators, is often recommended.[77] In patients who fail exhaustive attempts (usually over the course of at least 3 months) at these conservative treatment options, advanced imaging is often indicated.

Advanced imaging such as MRI is important for diagnosing and assessing the severity of UCL sprains. However, while MRI detects full-thickness UCL tears with a reported sensitivity of 100%, it is less reliable for detecting partial tears (14% sensitive).[87,88] Because of its ability to detect partial-thickness tears (86% reported

Table 3. Classification of UCL Sprains by Features on MRI

Type (grade of tear)	Description
Type I (low-grade partial tear)	Edema in UCL only
Type II (high-grade partial tear)	Evidence of partial tearing; no extravasation of arthrogram fluid
Type III (complete tear)	Complete UCL fiber disruption; extravasation of arthrogram fluid along humerus or ulna ("T-sign," pathognomonic for UCL tears as seen in Figure 6)

Figure 6. The "T-sign" depicts extravasation of fluid at UCL insertion on ulna, suggestive of a complete type III UCL tear.[83] Figure adapted with permission from Joyner et al.

sensitivity) and high interobserver reliability, MR arthrography (MRA) with intra-articular gadolinium injection is considered the gold standard for imaging-based diagnosis of UCL sprains.[81,89] Computed tomography arthrography (CTA) offers similar but slightly inferior sensitivity and specificity in detection of UCL tears compared to MRA. The MR-based classification system for UCL sprains of the elbow, proposed by Joyner et al. in 2016, is summarized in Table 3 above.[81] Injuries which show imaging consistent with Type II or III UCL sprain are often treated surgically.

UCL reconstruction relies on securing a tendon graft to the ulna and medial epicondyle to mimic the attachment of the native UCL and ultimately reconstruct the anterior bundle of the UCL. Surgical techniques for UCL reconstruction are varied, with differences primarily in graft type, type of ulnar and humeral bone tunnels, ulnar fixation, humeral fixation, flexor pronator mass manipulation, ulnar nerve management, graft configuration, and fixation methods to the ulna and medial epicondyle. Ipsilateral palmaris longus tendon autografts are the most common graft type, harvested in approximately 50-74%

Table 4

OSF Type	Fracture line origination (lateral radiographic view)	Fracture line course (lateral radiographic view)	Characteristics
Physeal (stages 1-4, less severe to more severe)	Olecranon articular surface	Dorsal-distal direction of epiphyseal plate	Delayed closure or nonunion along epiphyseal plate
Classic	Olecranon articular surface	Dorsal-proximal direction	Large opening on origin of articular surface and ulnar side (MR); stress increased on articular surface and ulnar side
Transitional	Olecranon articular surface	Dorsal-proximal direction	Fracture line in line with epiphyseal plate; stress increased on articular surface and ulnar side
Sclerotic	N/A	N/A	Fracture line not obvious on radiograph, sclerotic change visible; T2-W MR: low intensity area on articular surface (recovering stress fracture)
Distal	Olecranon articular surface	Distal-dorsal direction	Sclerotic change on olecranon distal ulnar side, Dx difficult by radiograph

Five types of olecranon stress fractures (OSFs) in adolescent and young adult baseball players as proposed by Furushima et al. AP, anteroposterior; Dx, diagnosis; T2-W, T2-weighted MR image.[106]

of cases. Other possible graft sources include the contralateral gracilis tendon (~23% of cases) or ipsilateral toe extensor tendon (~1-3%). Further autograft options include the plantaris (~2%), triceps (~1.5%), Achilles, and patellar tendons.[73,77,78,84,90–92] Some studies have shown that utilizing allograft tissue for UCL reconstruction yields surgical outcomes similar to those of procedures using autografts.[93] In general, studies comparing techniques for UCL reconstruction have not clearly demonstrated one technique to be more effective than others.[77] Surgical complications include graft re-rupture or attenuation, ulnar nerve symptoms, or residual medial elbow pain and weakness, likely resulting in reduced performance or an inability to continue competitive play in overhead sports.[83,94]

UCL reconstruction outcomes are generally favorable. In a study by Cain et al. reporting long-term follow-up results from 743 patients who underwent UCL reconstruction with subcutaneous ulnar nerve transposition between 1988 and 2006, 617 patients (83%) returned to

competition at or above the preoperative level an average of 11.6 months postoperation. Complications to some degree occurred in 20% of patients, but only 4% were considered major.[84] Smaller studies also reported similar outcomes. In a report of UCL procedures performed on a cohort of 67 professional, collegiate, and high school baseball players, 53/67 (79%) experienced successful outcomes allowing for return to play at or above the preoperational level. The average time to return to competition for these players was 9.8 months.[83] Similarly, Petty et al. followed 27 high school baseball players post-UCL reconstruction and reported 20/27 (74%) returned to competition at or above their previous level, on average 11 months after surgery.[94]

Olecranon Stress Fracture

Although stress fractures in general are common injuries in athletes, they primarily occur in the lower extremity such as the tibial shaft or metatarsal bones and are relatively rare in the olecranon, which is the most common site of stress fracture in baseball players.[95–97] As with

UCL sprains, olecranon stress fractures (OSFs) were also first described in a javelin thrower by Waris in 1946.[72] However, this injury was not implicated in baseball players until 1977, when Torg and Moyer published a case report on a 16-year-old baseball pitcher with a surgically treated stress fracture nonunion through the olecranon epiphyseal plate.[24] In addition to reports describing similar injuries in baseball players and javelin throwers, OSFs have since been described in case reports featuring gymnasts, weightlifters, softball players, tennis players, wrestlers, and a tower-diving swimmer.[98–105]

Olecranon stress fractures are the result of overuse. Although there is debate regarding the mechanism of onset, OSFs are believed to be caused by valgus extension overload, excessive triceps tensile stress, or olecranon posteromedial impingement. However, the general consensus is that OSFs in adults are commonly a result of valgus extension overload or olecranon impingement, whereas OSFs in adolescents are more likely to be a result of triceps traction force.[24,106–111] Patients with OSFs present with a chief complaint of posterolateral elbow pain, often gradual in onset and refractory to analgesia and rest. On physical exam, there may be tenderness to palpation over the olecranon, normal to slightly reduced elbow extension with otherwise normal range of motion, and pain elicited by resisted supination.[105,109,112,113]

Based on a case series of 200 baseball players, Furushima et al. proposed a classification system in which they categorized OSFs in youth and young adult baseball players into one of five types based on fracture lines: physeal, classic, transitional, sclerotic, and distal.[106] The five types and their characteristics are summarized in Table 4.

While radiographs may appear normal without any evidence of interosseous abnormality, especially in sclerotic OSF types, many show a fracture line with a characteristic origin and course.[104,106] Diagnosis is best made with the use of both MRI and CT.[105,106,107]

Primary treatment for OSFs is approximately 2 months of rest with overhead throwing cessation. If symptoms

Figure 7. A) Radiograph of incomplete olecranon stress fracture of right elbow with lucency and sclerosis at olecranon in a 15-year-old right-hand dominant pitcher. Fracture was confirmed with MRI. B) Radiograph of right elbow of same patient after undergoing open reduction internal fixation.

persist following nonoperative treatment, surgical intervention is indicated. Most authors report surgical treatment via open reduction and internal fixation (Figure 7), often with favorable outcomes.[105,107] In a case series of five youth athletes between 13–17 years old, Rettig et al. reported good outcomes using an open reduction and internal fixation approach with cannulated cancellous compression screws with or without 18-gauge figure-of-8 tension banding. These athletes were clinically asymptomatic an average of 11 weeks postoperatively and all five returned to their previous level of competition, although the time to return to sport postoperatively was highly variable, with a mean of 29.4 weeks but a range of ~19-40 weeks.[112]

Summary

Overuse elbow injuries in the young throwing athlete are becoming more common. A young athlete complaining of elbow pain associated with activity should never be casually dismissed. As some of these injuries may require surgical intervention, an accurate diagnosis must be made. With a thorough history and exam, along with adequate imaging studies, appropriate management of the injury can be made. This review helps to highlight the spectrum of overuse elbow injuries in the youth population and provides a brief summary of the treatment strategy for each injury.

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