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Elbow injuries in overhead throwing athletes: clinical evaluation, treatment, and osteopathic considerations

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Abstract: Injury to the elbow is very common in the throwing athlete and can potentially lead to long absences from play and, in the most severe scenarios, medical retirement. The throwing motion is a highly complex series of movements through the entire kinetic chain that results in very high angular velocities and valgus forces at the elbow joint. The repetitive nature of overhead throwing in combination with the high levels of accumulated force at the elbow puts both pediatric and adult athletes at risk of both acute and chronic overuse injuries of the elbow. This review provides an update on common injuries in the throwing athlete and covers clinical presentation, diagnosis, and treatment of these injuries.

Keywords: baseball; elbow; musculoskeletal injury; overhead athlete

Injuries to the elbow in overhead throwing athletes are common due to the repetitive demand of the throwing motion and the extreme force accumulation at the joint during the throw [1–6]. Over one quarter of adolescent pitchers experience elbow pain during or after pitching. Further, an overall elbow injury rate of 0.86 per 10,000 athlete exposures has been reported in high-school baseball players [5, 6]. Elbow injuries are not only common in throwing athletes, but also frequently result in extended absence from play. Elbow injuries have been shown to more frequently result in removal from play for more than 3 weeks and/or medical disqualification than shoulder injuries in pitchers [6]. Moreover, the evolution of the game of baseball has led to an emphasis on coaching and training for increased pitch velocity [7]. High pitch velocity is one of the most well-established risk factors for injury to the medial ulnar collateral ligament (UCL) of the elbow [8–11]. The continued pursuit of increased velocity compounds the heavy burden that elbow injuries already pose to throwing athletes.

Throwing a baseball effectively requires a highly complex and coordinated delivery that produces extreme levels of force on the elbow joint [12, 13]. The complex anatomy of the elbow joint leads to a broad differential diagnosis for pathology as well as variable necessary treatments for throwing athletes. This paper provides an updated review of the underlying anatomy and biomechanics of the throwing motion and the evaluation and treatment for prominent elbow pathologies in throwing athletes.

Anatomy

The confluence of three bones – the distal humeral epiphysis, radial head, and the proximal ulnar epiphysis – articulate to form the hinge-and-pivot elbow joint complex [14]. The ulnohumeral joint and radio-capitellar joint allow for flexion-extension, whereas pronation-supination occurs at the proximal radioulnar articulation. Unlike the proximal radioulnar joint, the ulnohumeral and radio-capitellar joints play a role in elbow stability [1].

Major structures of clinical significance in the medial elbow of throwing athletes include the medial epicondyle of the humerus, the UCL, the origin of the flexor-pronator muscle group, and the ulnar nerve [15]. The UCL is the primary stabilizing structure of the medial elbow. The structure consists of three bundles: anterior, posterior, and transverse. The anterior bundle acts as the primary stabilizer against valgus and internal rotation stress, making it the most prone to injury in throwing athletes [14, 16–21]. The flexor-pronator muscle group includes the flexor carpi radialis, flexor carpi ulnaris (FCU), flexor digitorum

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superficialis, flexor pollicis longus, and pronator teres. Through concentric and eccentric contraction, the flexor-pronator mass serves as a secondary, dynamic stabilizer against valgus stress in the elbow during the overhead throwing motion [22].

The ulnar nerve provides motor innervation to most of the intrinsic muscles in the hand and sensory innervation to the dorsal and palmar aspects of the fourth and fifth digits as well as to the ulnar aspect of the hand. The ulnar nerve passes behind the medial epicondyle through the cubital tunnel bordered by: the posterior bundle of the UCL, joint capsular structures (including a retinaculum and Osborne's ligament laterally), the medial epicondylar groove, and the arcuate ligament [23]. The nerve then continues to pass through the interval between the humeral and ulnar heads of the FCU as it courses down the forearm to the hand [23].

The lateral structures of the elbow include the bony radio-capitellar joint, the lateral collateral ligament complex, and the extensor/supinator musculature of the forearm and hand [15]. The lateral collateral ligament complex consists of the annular ligament surrounding the radial head, the radial collateral ligament (RCL), and the lateral ulnar collateral ligament (LUCL). The lateral stability of the joint is composed of the radio-capitellar articulation in concert with the lateral ligaments. The LUCL provides a majority of the ligamentous stability to the lateral elbow, resisting varus and external rotatory forces [15].

Throwing biomechanics

Throwing in a manner conducive to competitive success requires a highly coordinated delivery that sequentially transfers energy up from the ground, through the kinetic chain, and into ball release [24]. The kinetic chain describes the transfer of energy from larger and stronger structures of the lower extremities, pelvis, and trunk to the relatively smaller and weaker structures of the upper extremity [25]. Proper utilization of the kinetic chain during the overhead throwing motion is crucial for avoiding excess stress on the more injury-prone structures of the upper extremity [26]. Several well-established phases of throwing exist that are important to be aware of when evaluating throwing athletes [23]. The windup is the initiation of the throwing motion and is completed when the pitcher begins to remove his hand from his glove while his stride leg is at maximal knee lift. The stride (early cocking) phase is characterized by the pitcher gaining ground with his stride leg and ends when the stride leg contacts the ground. During this phase, the two arms separate and the distance between the pelvis and shoulder accumulates and stores force [27]. Energy is transferred up the kinetic chain during the cocking phase, which concludes when the throwing shoulder reaches the point of maximal external rotation. Peak angular velocities are produced during the acceleration phase, when the throwing arm powerfully internally rotates from the point of maximal external rotation. The acceleration phase concludes with ball release. Deceleration occurs following ball release and ends once the throwing shoulder has reached 0° of internal rotation. Follow-through is the last stage of the pitching delivery when the body moves forward in the direction of the target until it has caught up with the throwing arm. Through the throwing motion, the forces on the elbow and the anatomy impacted depends on the varus torque, valgus stress, and rapid extension at the joint [27]. There are tensile stresses that take place at the medial aspect of the elbow impacting the UCL, the flexor-pronator mass, and the medial epicondyle, as well as compressive forces at the lateral aspect of the elbow impacting the radiocapitellar joint, and shearing stress at the posterior compartment at the olecranon and the olecranon fossa [27].

Discussion of elbow pathologies

Medial elbow injuries

Little league elbow/medial epicondylar apophysitis

The term "little league elbow" classically refers to an apophysitis of the medial epicondylar growth plate, typically occurring in young athletes prior to growth plate fusion [28]. The injury is the result of microtrauma caused by repetitive throwing, compounded by inadequate rest. Accumulated forces preferentially cause injury at the apophysis in the pediatric athlete because the apophysis is an estimated five times weaker than the UCL in patients before reaching skeletal maturity [29]. Patients presenting with medial epicondylar apophysitis (MEA) are typically aged 6–15 years old. They commonly present during their throwing-sport season, reporting insidious onset of medial elbow pain and decreased throwing performance [20].

Evaluation

On examination, patients will commonly have tenderness to palpation over the medial epicondyle and medial elbow pain with valgus stress testing of the elbow including the "milking" maneuver and moving valgus stress test. However, valgus instability is not commonly present on examination [30]. Occasionally, patients will have swelling with mechanical symptoms and limited extension at the joint.

In patients with a clinical picture indicative of MEA, imaging should be pursued. Initial radiographs should include bilateral anteroposterior (AP) views, and lateral views, with an additional view with the elbow bent to 90° and valgus stress applied [28, 31]. If MEA is present, the medial epicondylar apophysis may appear ragged with sclerosis of the border of the ossification center [28, 29, 32]. For most athletes suffering from MEA, radiographs will be sufficient for clinical evaluation and advanced imaging will not be necessary [28]. Point-of-care ultrasound (US) can also be utilized as an extension of the clinical assessment. US has been found to have a high positive predictive value of medial epicondyle pathology, including for MEA [33]. In a previous study, cortical irregularity, discontinuity, fragmentation, or UCL abnormalities identified on US were all indicative of MEA [33].

Treatment

Treatment of MEA relies on cessation of throwing activity, followed by a modified return to play with gradual return to throwing. The athlete should refrain from throwing for 4–6 weeks. However, this period of rest can at times last 2–3 months. During this time, it is appropriate to continue generalized conditioning and physical therapy without throwing, with a focus on kinetic chain strengthening [29, 34]. If the patient is pain free at the end of the rest period, it is appropriate to begin a progressive throwing program over approximately 6 weeks. If there is recurrence of symptoms during the return-to-play process, then a longer period of rest is warranted. Widening of the physis >3 mm on imaging warrants referral for surgical consultation [34].

Medial epicondyle avulsion fractures

Medial epicondyle avulsion fractures are a more severe pathology of the medial epicondyle in skeletally immature athletes in which a bone fragment is avulsed from the epicondyle due to repetitive valgus loading, with subsequent lysis of the growth plate. While MEA is a chronic condition with insidious onset, medial epicondyle avulsion fractures typically occur acutely [35]. The fracture is a result of acute valgus stress and forceful muscular contraction of the flexor pronator mass during an individual throwing act, transmitting force through the apophysis resulting in avulsion [35, 36].

Due to the relative weakness of the apophysis at the medial elbow before skeletal maturity, pediatric and adolescent throwers are most at risk of avulsion injury as opposed to a UCL tear [29, 36]. Presentation of avulsion fractures traditionally consists of acute medial elbow pain following a single throw that the patient can identify, and occasionally the injury is accompanied by a cracking or popping sensation in the elbow at the time of injury [35, 36].

Evaluation

Patients will exhibit focal tenderness to palpitation of the medial epicondyle upon physical examination [36, 37]. Patients will typically exhibit valgus instability and a reduction in elbow extension range of motion (ROM) [36, 38, 39]. The milking maneuver and moving valgus tress test will typically be positive. If there is concern for medial epicondyle avulsion injury, radiographs of the elbow should be pursued. The age of medial epicondyle apophysis fusion is variable in adolescent throwing athletes; therefore, radiographs of both the injured and contralateral limb are necessary for determining if imaging findings are from potential anatomic variation or an acute injury [40]. A combination of bilateral AP, lateral, and 45° of internal-rotation oblique radiographs should be obtained and compared to determine the presence and maximal displacement of the fracture [40, 41]. This series of radiographs should be sufficient for diagnosis of an avulsion fracture in most patients [28, 40]. Similar to patients with MEA, patients thought to be suffering from an avulsion fracture can also benefit from point-of-care US as an extension of the clinical assessment [33].

Treatment

The decision of whether to treat avulsion fractures conservatively or operatively is a controversial topic depending on several factors. Nondisplaced or minimally displaced fractures can generally be treated conservatively. Absolute indications for surgical intervention include open fractures, incarcerated fragments, and ulnar nerve entrapment due to the avulsed fragment [39, 40, 42]. Relative indications for surgical intervention include elbow instability and significant fracture displacement [39, 40]. Additionally, the demands of repetitive valgus loading upon return to play may be an additional relative indication for surgical management in overhead throwing athletes with moderately displaced fractures [1, 42–44]. Although there is no general consensus regarding exactly what level of fracture displacement qualifies as severe enough for surgical intervention, most physicians recommend open reduction and internal fixation (ORIF) for >5 mm of fragment displacement [45, 46]. However, in throwing athletes, most physicians recommend surgical consultation for any displacement >3 mm. Nonoperative management consisting of splint immobilization followed by progression to early motion has been shown to produce satisfactory results when surgical indication is not present [44, 45].

Similar outcomes and return-to-play rates have been reported for both surgical and conservative management [35, 47]. Return-to-sport time varies from 3 to 7 months, and a recent study by Axibal et al. [47] on matched operative and nonoperative moderately displaced fractures in adolescent throwing athletes found that nonoperative patients tended to return to sport sooner than operatively managed patients (3 vs. 5.5 months, respectively) [35, 39, 47–49].

Posteromedial impingement (valgus extension overload)

Symptomatic posteromedial impingement, also known as valgus extension overload syndrome, is characterized by reactive bone and osteophyte formation at the posteromedial olecranon tip, the potential for chondromalacia within the olecranon fossa and posterior medial trochlea, and the potential for loose body formation [50–52]. Terminal extension of the elbow during the deceleration phase of the throwing motion leads to the dissipation of excess kinetic energy through the structures of the posterior olecranon and the olecranon fossa [18, 50]. The repetitive shear and compressive forces imparted on these structures by the dissipation of the combined valgus force and angular moment at the elbow for each throw can lead to the development of posteromedial impingement over time [16, 50].

Patients with posteromedial impingement will typically report localized pain to the posteromedial aspect of the olecranon occurring immediately after ball release as the elbow reaches terminal extension. The presence of loose bodies or chondral injuries can also produce symptoms of catching, locking, or crepitus within the joint [50, 51]. Posteromedial impingement frequently occurs concomitantly with valgus instability and/or ulnar nerve pathology [51, 53].

Evaluation

Tenderness over the posteromedial olecranon and an associated loss of extension of the elbow may be present upon physical examination. Both the elbow extension impingement test and the arm bar test should be performed on patients for which posteromedial impingement is within the differential diagnosis [50]. The elbow extension impingement test consists of placing the elbow in 20–30° of flexion and then quickly and repeatedly thrusting it into terminal extension [50]. The test is considered positive if the patient experiences pain as the elbow enters terminal extension. The arm bar test is conducted by placing the patient's hand on the examiner's shoulder with the elbow extended and the shoulder flexed and internally rotated [50]. The examiner then pulls down on the olecranon to simulate forced extension. A positive finding on the arm bar test is characterized by the reproduction of posterior elbow pain associated with posteromedial impingement. Patients suspected to have posteromedial impingement should also be evaluated for UCL injuries given the association between valgus instability and posteromedial impingement.

Imaging should include radiographs of the elbow including AP, lateral, oblique, and a modified AP radiograph with 140 degrees of external rotation to best image the posterior medial olecranon for osteophyte formation [50, 51]. Computed tomography (CT) imaging can be useful for identification of loose body and surgical planning [50]. Magnetic resonance (MR) arthrogram can be useful in evaluating surrounding structures for concomitant pathology. Additionally, dynamic US can be useful in evaluating for related valgus instability and ulnar nerve instability [50].

Treatment

Nonoperative management should begin promptly following a diagnosis of posteromedial impingement. Importantly, patients should be held from throwing and activities that might forcefully place the elbow into terminal extension should be avoided or modified for a period of 2–6 weeks [16]. During this time, the athlete should begin physical therapy exercises that work to strengthen and stretch the dynamic stabilizers of the elbow. Furthermore, physical therapy should address the kinetic chain and throwing mechanics. Additionally, the use of nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, and possible administration of orthobiologics should be considered to address the patient's pain [50]. At the rest period's completion, the athlete should gradually return to throwing through a progressive throwing program. The athlete can return to play if they are able to complete the progressive throwing program without a recurrence of symptoms.

Operative management is indicated when conservative treatment fails. Options for surgical intervention include arthroscopic posteromedial osteophyte removal and a limited incision arthrotomy Caution must be taken in patients with concurrent UCL insufficiency as isolated arthroscopic treatment with posteromedial osteophyte resection is contraindicated due to the risk of developing valgus instability [50]. Additionally, over resection of the posteromedial olecranon can create UCL instability. Several studies have shown that careful arthroscopic debridement produces excellent clinical outcomes and high return to play rates in athletes with posteromedial impingement [54–56].

Flexor-pronator mass injury

The flexor-pronator mass is the musculotendinous bulk of the anteromedial forearm. The structure acts as a dynamic stabilizer against valgus stress during the throwing motion. The flexor-pronator musculature eccentrically contracts to provide medial stabilization during the acceleration phase of throwing and then concentrically contracts to flex the wrist during ball release [26, 57]. The repetitive dynamic action of the structures during the throwing act can predispose the flexor-pronator mass to injuries such as tendonitis, tendinopathy or even acute musculotendinous tears [58]. Injuries to the flexor component of the forearm predispose throwers to significant injury including UCL tear [59].

Evaluation

Flexor-pronator mass injury is an adult throwing athlete injury and is quite rare in skeletally immature populations as injuries of the medial epicondylar physis are far more likely due to the relative underlying weakness of the growing bone [60]. The primary differential diagnosis in skeletally mature populations involves injury to the UCL [37]. Athletes with an injury to the flexor tendon will commonly complain of pain during the acceleration phase of throwing and demonstrate tenderness just distal to the medial epicondyle and sublime tubercle. Location of tenderness on exam can be of assistance in determining the diagnosis, as athletes with an injury to the UCL will demonstrate pain in a more distal and posterior location corresponding to the anterior band of the UCL [16, 37]. Additionally, magnetic resonance imaging (MRI) and US are recommended to assist in clinical differentiation between the two pathologies [18, 61].

Treatment

Common flexor-pronator tendon injuries typically respond well to nonoperative management [62]. Treatment should include rest from throwing and physical therapy focused on active ROM and the kinetic chain. Anti-inflammatory medication can also be useful for pain relief in certain situations. Caution is warranted when considering corticosteroid injections into the flexor pronator mass or common flexor tendon due to the proximity of the UCL as well as the risk for weakening the tendon [16, 37, 62]. Given the extent of the injury, orthobiologics with platelet-rich plasma (PRP) for tendon injury or platelet-poor plasma (PPP) for muscle injury can be considered [63–65]. For a partial tendon tear treated with a PRP injection, progression of return to throwing and full return to play would be similar to that for nonoperative treatment of a partial UCL tear with targeted rehabilitation without throwing for 6–8 weeks, followed by initiation of an interval throwing program, and then a progression to full return to play at approximately 12 weeks [66]. Therefore, depending on the in-season status of the athlete, the extended timeline needs to be of consideration for treatment with a PRP injection. If the injury is identified as muscular tissue, PPP injection can be considered. After a PPP injection, the athlete will undergo rehabilitation, return to throwing, and full return to play similar to what would occur without an injection. The primary goal of a PPP injection for muscle injury is for hastened muscular healing and faster progression through rehabilitation to full return to play [67]. Surgical intervention is rarely necessary but can be considered if conservative treatment fails [18, 62].

Ulnar neuropathy

The ulnar nerve is susceptible to injury in throwing athletes due to the traction and compressive forces to the nerve through its course around the medial elbow joint during the throwing motion. The valgus moment during the late cocking and acceleration phases of the throw and the rapid extension of the elbow in the later phases of the throwing motion particularly impact the ulnar nerve [23, 68]. The nerve can be further compromised by pathology of the surrounding structures, such as osteophytes, intraarticular loose bodies, hypertrophy of the triceps, and/or calcification of the UCL. Ulnar neuropathy is frequently present concomitantly with other elbow pathologies such as UCL injury and/or common flexor tendinopathy [69].

Symptoms of decreased performance (decreased velocity, accuracy, and endurance) commonly precede neuropathic symptoms of pain and paresthesia [23, 70]. As damage to the nerve progresses, patients may develop the symptoms at rest.

Evaluation

If ulnar neuropathy is within the differential diagnosis for a thrower, the nerve should be palpated along its course from the region proximal to the medial epicondyle to the mass of the FCU distal to the medial elbow [23]. Tinel's sign can also be evaluated along this course. Signs of nerve subluxation should be assessed as the elbow is ranged into flexion and extension. US can also be utilized in the assessment of the ulnar nerve at the elbow to evaluate for compression of the nerve by various surrounding structures as it passes through the cubital tunnel and exits through the interval between the two muscle bellies of the FCU [71]. Morphological changes of the ulnar nerve can also be assessed including changes in the nerve cross-sectional area relative to normative values and the contralateral side and changes to the fascicular architecture of the nerve [71, 72]. Dynamic US evaluation of the nerve at the medial epicondyle can evaluate for subluxation of the nerve during flexion-extension movements [23, 73]. However, subluxation is not uncommon in throwing athletes and frequently can be asymptomatic [23, 73]. Therefore, care must be taken not to erroneously attribute medial elbow symptoms to nerve subluxation. If nerve compression from a neighboring pathologic structure is of concern, MRI may be included in the workup to better characterize the injury and determine appropriate treatment [23]. Electrodiagnostic studies can be a useful adjunct in the workup of ulnar neuropathy; however, they are commonly inconclusive in injured throwing athletes with known ulnar neuropathy and may not show any electrophysiologic changes until later stages of the injury process [23, 74].

Treatment

The treatment algorithm should start with conservative management characterized by rest from throwing, with the possible additions of NSAIDs, physical therapy, US-guided injections, and nighttime splinting. This treatment should last approximately 3–6 months, with a progressive return to throwing commencing once the thrower is asymptomatic [72]. Surgical intervention is considered when nonoperative management does not resolve ulnar nerve symptoms or if there is concomitant elbow pathology that would require invasive intervention [72]. Earlier surgical intervention is indicated in athletes who are developing sensory loss or weakness in the ulnar nerve distribution [23, 75]. There are multiple surgical options, including simple *in situ* decompression with neurolysis or surgical decompression with subcutaneous or submuscular transposition. Subcutaneous transposition is the preferred surgical option for throwing athletes due to the risk of iatrogenic instability with *in situ* decompression and due to the risk of flexor pronator mass injury with submuscular transposition [23, 70].

UCL sprain/tear

Injuries of the UCL are among the most common and well-publicized pathologies affecting overhead throwing athletes. The UCL acts as the primary stabilizer against valgus stress at the elbow joint during the throwing motion [37, 76, 77]. The repetitive stresses on the UCL during throwing can lead to weakening and microtrauma of the ligament, and the extreme valgus forces produced by the late cocking and acceleration phase of throwing can exceed the failure strength of the UCL [37, 78, 79]. This can lead to elbow valgus instability or complete rupture. Injuries of the anterior bundle of the UCL are the primary UCL injuries in throwers [1, 69, 80]. Athletes with an acute UCL injury routinely report a popping sensation accompanied by a sudden onset of pain during one individual throwing act [62]. Throwing with higher levels of velocity, high overall throwing volume, and fewer rest days between outings are factors that have been shown to increase the likelihood of injury [11, 79].

Evaluation

Patients will typically report isolated pain during the late cocking and acceleration phase of throwing [62]. Athletes with suspected UCL injury should undergo a thorough physical examination and advanced imaging. The physical examination should include palpation of the UCL, the moving valgus stress test, the milking maneuver, and a full evaluation of bilateral upper-extremity ROM and strength [81]. The moving valgus stress test is the most useful special test to evaluate for UCL injury. This test is executed with the patient seated and the elbow flexed to 20–30° [82]. The examiner should stand beside the patient, place one hand on the patient's wrist, and place the other hand on the patient's elbow. The examiner should apply valgus stress to the elbow while stabilizing the wrist with the other hand. The elbow should then be moved into flexion and extension. Medial elbow pain with valgus stress is considered a positive finding [82]. The milking maneuver is executed with the patient seated and the forearm fully supinated [82]. The examiner grasps the patient's thumb and applies a valgus stress to the elbow joint. Medial elbow pain and/or excessive opening of the joint with valgus stress would be considered a positive finding [82].

Plain-film radiographs should be obtained to rule out any concomitant injuries of the elbow osseous structures [62]. The MRI arthrogram has a high level of sensitivity and specificity for diagnosing UCL injuries and is considered the gold-standard imaging technique [1, 62, 78, 83, 84]. The MRI arthrogram can show pathology in asymptomatic throwing athletes and must be correlated clinically [78, 85]. Dynamic stress ultrasonography can also be utilized to make a UCL injury diagnosis based on ulnohumeral joint gapping with valgus stress when compared to the asymptomatic contralateral elbow. Additionally, bone marrow edema present at the sublime tubercle has been found to be a better indicator of symptomatology than tear grade [86]. US may also show heterogeneity, calcifications, thickening, or tears of the UCL in an injured patient [62, 78, 87]. For athlete's undergoing revision UCL surgery, a preoperative CT scan may be useful for surgical planning by allowing for determination of the anatomy of tunnels from the primary operation [81].

Successful surgical vs. nonsurgical treatment of UCL injuries is highly dependent upon determining the severity and type of UCL tear, as well as the location of the tear [78, 79]. There are several nomenclature categorization systems for evaluating UCL tears based upon MRI imaging. In one categorization system, grade 1 is an intact ligament with or without edema, grade 2a is a partial tear, grade 2b is a chronic healed injury, and grade 3 is a complete rupture [78, 85]. A newer categorization system utilizes six stages to evaluate UCL tear severity based on MRI imaging, with the stages being based upon tear location (proximal, midsubstance, distal) and whether the tear was partial or complete [78, 83].

Treatment

Treatment of UCL lesions is dependent on the grade and location of the damage to the ligament as well as the sporting position of the injured athlete [88]. In some situations, UCL injury can be definitively managed with conservative care in the form of physical therapy in conjunction with possible PRP injection. In general, nonsurgical treatment can be attempted in patients with partial tears located at the proximal/humeral aspect of the ligament. This treatment should include a comprehensive physical therapy program including ROM, possible blood-flow restriction exercise programs, and plyometrics. Frequent clinical reassessments should take place to monitor for a lack of healing or regression. PRP may also be indicated in these cases. For throwers with partial proximal UCL injuries, appropriately dosed PRP injected under US guidance in combination with rehabilitation has been shown to lead to satisfactory return to play rates, MRI-confirmed healing of the UCL, and decreased opening of the joint space with valgus stress under US imaging [66, 89, 90]. Furthermore, this nonoperative protocol with PRP injection followed by rehabilitation has been shown to be effective after initial failure of 6–8 weeks of rest and physical therapy alone [66]. Following US-guided PRP injection, athletes perform dedicated rehabilitation for approximately 6–8 weeks followed by initiation of an interval throwing program. Full return to play occurs for these athletes at approximately 12 weeks from the date of injection [66, 89]. In sum, the available body of evidence indicates that patient selection is key for deciding on operative vs. nonoperative treatment of UCL tears, with proximal partial tears being most amenable to nonsurgical management.

Relative indications for surgical management of a UCL injury include complete/high-grade tears, distal tears, tears with a concomitant flexor muscle avulsion, and partial tears that have failed nonoperative management [81]. There are two options for surgical intervention of a UCL injury: the gold-standard UCL reconstruction (UCL-R, “Tommy John Surgery”) and the more novel UCL primary repair surgery. UCL-R has great clinical outcomes historically with return-to-play rates of 80–90 % [79]. However, the full recovery process to return to competition following UCL-R takes 12 months or greater [78, 79]. The major advantage of UCL primary repair compared to UCL-R is that the return-to-competition time of UCL primary repair is significantly shorter than that of UCL-R [91]. However, there is a lack of long-term results available on the outcomes of UCL primary repair, and very little data are available on the outcomes of elite athletes who receive UCL primary repair [78, 79]. Additionally, there are strict eligibility criteria for UCL primary repair. Indications for UCL primary repair over UCL-R are partial-thickness tears, isolated acute avulsion type tear of the proximal or distal end of the ligament, in addition to patient preference of UCL primary repair over UCL-R [81].

Lateral elbow injuries

Osteochondritis dessicans of the capitellum (OCD)

OCD of the capitellum is a disease of pediatric throwers due to the highly metabolic bone that is present in the region. The condition is a result of injury to the subchondral bone, leading to loss of support for the overlying articular cartilage and eventual breakdown of the cartilage and destruction of bone of the capitellum [92]. The condition is believed to be the result of repetitive microtrauma in combination with ischemia of the region [93, 94]. During the acceleration phase of the throw, valgus stress at the elbow exposes the capitellum to compressive and shear force [93, 95]. Due to the vascular anatomy at the bony structure, the blood supply can be interrupted from repetitive trauma leading to regional ischemia [93, 94]. There is believed to be a genetic predisposition to the condition [93].

Evaluation

Typical presentation will be a young thrower (11–15 years old) who has been throwing for a few years with an insidious onset of poorly localized pain [92]. Later in the course of the condition, patients may report mechanical symptoms of catching and locking, related to the formation of a loose body [92]. Diagnosis of OCD of the capitellum ideally involves a combination of X-ray (XR), CT, and MRI [96]. On examination, there will commonly be poorly localized tenderness. Loss-of-extension ROM is common. Examination maneuvers that may reproduce pain include the “active radiocapitellar compression test,” which has the patient pronate and supinate with the elbow in full extension. Manual compression across the joint may also cause symptoms [92]. XR evaluation should include AP and lateral views with the addition of an AP view with the elbow in 45 degrees of flexion [96]. The disease can be identified on XR with flattening of the capitellar subchondral bone, rarefaction of bone, or isolation of the OCD fragment [92]. Early in the disease process, XR may not be sensitive enough to indicate a lesion [92]. MRI has become the next imaging modality in the diagnostic algorithm, because it assesses the surface of the articular cartilage with better sensitivity for early lesions when compared to XR [96]. Early in the condition, T1-weighted images will demonstrate an increased signal within the lesion even though the T2 images may remain normal [96]. CT is helpful in identifying the extent of the lesion and stability with better osseous detail than other modalities [96]. The use of US has been evaluated; however, the capitellum is obscured by the radial head in some planes making it a technically difficult scan and highly dependent on the location of the lesion [97]. Classification of OCD is dependent on imaging modality, and it assists in determining stable vs. unstable lesions [98]. Minami classification is utilized for XR, Itsubo for MRI, and Clanton and DeLee for CT [98].

Treatment

Treatment depends on characteristics of the OCD lesion including size, location, and stability. Stable lesions are usually managed with nonoperative management [97]. This includes rest/sports restriction with reduction of repetitive stress on the elbow, strengthening of the surrounding musculature of the elbow joint, NSAIDs, and a possible short course of immobilization [97]. Full recovery with rest alone is associated with an open capitellar growth plate, localized flattening or radiolucency of the subchondral bone, and good elbow ROM [92]. This rate decreases if the growth plate is closed [92, 97, 99].

Operative treatment is indicated for OCD lesions that do not respond to conservative treatment and for unstable lesions [96]. The most common procedure is arthroscopic debridement in combination with microfracture of subchondral bone for bone marrow stimulation and removal of loose fragments [97]. Open surgery may be indicated for failed arthroscopic procedures, internal fixation for large OCD fragments, or osteochondral autograft transfer [97]. Postoperative recovery is quicker for arthroscopic treatment [100]. Rehabilitation is initially focused on restoring pain-free ROM, which can be progressed to tolerance for patients who had arthroscopic repair [97]. For autografted patients, elbow flexion ROM is limited in the first 6 weeks [97]. Strengthening is initiated at 8 weeks for arthroscopic and 12 weeks for open treatments [97]. When the patient has no pain and a normal ROM, a gradual return to throwing is started [100].

Panner's disease

Osteochondrosis of the humeral capitellum, known as Panner's disease, is a lateral compression injury of the elbow that typically impacts adolescent patients less than 10 years old [101]. Panner's disease occurs due to the compression and shear forces placed on the capitellum during the acceleration phase of the throwing motion [102–104]. The vascular supply of the epiphyseal cartilage can become insufficient under the repetitive compressive loads created by overhead throwing, leading to ischemia in the area [1]. A key differentiation in working up the pediatric thrower with lateral elbow pain is that Panner's disease occurs in athlete's during the period of active ossification of the capitellar epiphysis, whereas OCD occurs after the epiphysis is almost completely ossified [105, 106]. Panner's disease is a benign and self-limiting pathology given the elevated healing capacity of the elbow prior to ossification, making the differentiation from OCD key due to the different treatment algorithms for the two disorders [1, 105, 106].

Evaluation

Patients with Panner's disease will typically present with pain, decreased ROM, and localized tenderness over the lateral epicondyle of the elbow [107]. On physical examination, the radiocapitellar compression test can be utilized to confirm the presence of Panner's disease [1]. The elbow is placed into full extension and then pronated and supinated. Pain is indicative of a positive result. The benign clinical course of Panner's disease means that afflicted patients rarely require advanced imaging; however, MRI is the most sensitive diagnostic imaging tool for detecting pathology [105].

Treatment

Outcomes of nonoperative management for patients with Panner's disease are excellent due to the regenerative capacity of the elbow prior to ossification [1, 101, 104, 106]. Nonoperative management should include rest and cessation of throwing for up to 6 months as well as activity modification and physical therapy [108]. Consideration of surgical intervention is very rare for patients with Panner's disease [101]. Return to throwing should occur through the introduction of an interval throwing program after the pain has subsided [101].

Posterior elbow injuries

Olecranon stress injuries

Stress injuries of the olecranon can be caused by repetitive microtrauma from the stresses of competitive overhead throwing and by extensive tensile stress from the triceps tendon [18, 109]. It has been hypothesized that this repetitive loading may lead to tensile failure of the trabecular bone in the posteromedial olecranon, which can in turn progress to stress fracture of the bone without proper rest [109]. Stress fractures of the olecranon can be transverse, most commonly seen in the skeletally immature population or oblique as seen in the adult population [110]. Transverse-type fractures occur as a result of dominating extension forces and triceps traction, whereas oblique-type fractures are associated with increased valgus and extension forces [16]. Stress injuries of the olecranon typically present with an insidious onset rather than a specific event [18].

Evaluation

Athletes will typically present with decreased and painful elbow extension, pain with resisted triceps testing, and tenderness over the posteromedial olecranon [16, 62]. Pain with percussion of the proximal ulna may also be indicative of the presence of a stress injury [109]. Plain radiographs are useful for evaluating remodeling of the fracture site or any widening of the physis [16, 62]. Advanced imaging can be pursued if early radiographs are inconclusive. Schickendantz et al. [109] found that MRI was useful for identifying olecranon stress injury before progression to a complete stress fracture.

Treatment

Conservative management typically produces successful results for athletes with an olecranon stress injury [18, 109, 111]. Athletes should avoid any valgus stress for a minimum of 6 weeks and avoid full extension for the first 4 weeks [18]. Full ROM is allowed at 4 weeks and sport-specific rehabilitation is initiated at 6 weeks. Athletes will typically return to throwing with an interval throwing program starting at week 8. While there are not any studies specifically evaluating throwing athletes, extracorporeal shockwave therapy (ESWT) has been shown to be an effective treatment modality for bone stress injuries in athletes. Therefore, ESWT treatments may be a reasonable consideration for throwing athletes with olecranon stress injuries in order to hasten recovery and healing [112, 113]. Athletes with a complete olecranon stress fracture may require surgical fixation. Athletes undergoing ORIF of a complete olecranon stress fracture have been shown to have high rates of fracture union and return to play [114].

Osteopathic considerations

Osteopathic manual treatment (OMT) can be considered for the throwing athlete presenting with elbow pain. If the diagnosis is certain, the relevant anatomy and pathophysiology can be utilized to select the relevant manual therapy for the condition. One example is counterstrain for injury to the flexor-pronator mass [115]. If the diagnosis is not yet known, diagnosis and treatment of somatic dysfunction can still be pursued. The osteopathic evaluation and treatment of the throwing athlete should mirror the traditional osteopathic assessment for somatic dysfunction by identifying Tenderness, Asymmetry, Restricted range of motion, and Tissue texture changes (TART) [116]. When evaluating asymmetries in throwing athletes, clinical context must be taken into account with other findings on osteopathic examination because many changes will occur as a function of dominant hand throwing. These changes may not be clinically relevant and may not require treatment. Treatment will commonly be targeted at the area of symptomology, in this case the elbow. However, the entirety of the kinetic chain involved in the overhead throwing motion should be considered for evaluation of these findings. This includes not only the cervicothoracic spine, shoulder, periscapular region, elbow, wrist, and hand but also the lumbar spine, pelvis, sacrum and in some cases the lower extremity [24, 116]. Limitations in other joints of the kinetic chain may result in symptoms at the elbow joint [24]. Care should be taken in the presence of structural damage in an unstable joint such as in the case of a UCL tear or an osteochondral defect to not apply force that may further damage the joint; however, gentle techniques may still be utilized for symptomatic relief in this circumstance. Treatment targeted at somatic dysfunction has the goal of symptom reduction, improved ROM, and/or improved performance if the athlete is not currently sidelined [116]. When OMT is applied in the setting of conservative treatment for a condition, it is most effective when combined with active modalities such as guided strengthening exercise in a physical therapy program [116].

Conclusions

The extreme force produced by the overhead throwing motion places overhead throwing athletes at high risk of elbow injury. Elbow injuries can have negative, long-term impacts on performance, sideline the athlete for long periods during the season, or potentially be career-ending. Athletes, coaches, parents, and clinicians should be aware that overuse and improper throwing mechanics are linked to many of the most common pathologies of the elbow. Placing the proper emphasis on following pitch counts, avoiding unsupervised weighted ball programs, throwing with proper mechanics, and taking adequate rest (including absolute rest and throwing with decreased intensity) can help mitigate the risk of elbow injuries in throwing athletes.

Clinicians should be cognizant of when injuries can be treated conservatively and when surgical referral is appropriate. In the correct patient, OMT can be a useful adjunct for treatment.

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