Non-Medial Ulnar Collateral Ligament Elbow Pathology in the Thrower

Valgus Extension Overload, Osteochondritis Dissecans, Olecranon Stress Fracture, and Ulnar Nerve

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KEYWORDS

• Valgus extension overload syndrome • Osteochondritis dissecans
• Olecranon stress fracture • Ulnar nerve • Elbow • Overhead thrower

KEY POINTS

- The thrower's elbow undergoes significant repetitive forces that lead to distinct injury patterns.
- Non-medial ulnar collateral ligament (MUCL) elbow injuries in throwers are often overshadowed by the MUCL but significantly impact athletic performance and return to play capacity.
- Clinicians must recognize and address the multifaceted landscape of elbow injuries in order to adequately treat the overheard thrower.

VALGUS EXTENSION OVERLOAD SYNDROME

The complex motion of throwing places unique demands on the elbow that result in valgus forces and angular velocities reaching as high as 64 N-m and 5000 deg/sec.[1–8] As the elbow approaches terminal extension during deceleration, it undergoes a triad of forces seen as tensile stress along the medial elbow (medial ulnar collateral ligament [MUCL], flexor–pronator mass, medial epicondyle apophysis, and ulnar nerve), compression stress along the lateral radiocapitellar joint, and compression and shearing

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stress along the posteromedial olecranon and trochlea.[1,9,10] Over time, these repetitive forces result in predictable injury patterns discussed in this article.[1] Poor dynamic muscular control, throwing mechanic issues, and MUCL insufficiency can further amplify these forces and result in posteromedial pathologies to both the olecranon and trochlea such as symptomatic olecranon or trochlear stress reactions, transverse/proximal olecranon stress fractures, olecranon tip exostosis (with or without fragmentation), trochlear marginal exostoses, trochlear chondromalacia and osteochondral lesions (with subchondral insufficiency fractures and collapse), osteophytes, and loose bodies.[1,9–12] This constellation of repetitive force dissipation and resulting pathology is collectively referred to as valgus extension overload syndrome (VEOS).

With isolated VEOS, patients will typically present with elbow pain localized to the posteromedial olecranon after ball release.[1] Symptoms are typically preceded by decreases in pitch velocity, control, and early fatiguability.[1] Additional findings may include loss of terminal extension due to posterior osteophyte impingement, mechanical symptoms due to loose bodies/chondromalacia, history of prior MUCL/flexor–pronator injury, and ulnar nerve neuritis and/or subluxation.[1,13] A valgus extension overload test of repeatedly forcing a flexed elbow into rapid extension with a valgus stress will often reproduce pain with impingement of the posteromedial tip of the olecranon.[2] Understanding the intricacies of this condition is crucial for accurate diagnosis and effective management.

Lesions of the posterior compartment, olecranon osteophytes, and loose bodies have historically been the most common pathologies resulting from VEOS that require operative management in throwers.[2] Andrews and Timmerman[14] reported posteromedial olecranon impingement, which is a term that describes the compression of structures on the posteromedial side of the elbow, to be the most common diagnosis requiring surgery in baseball athletes, while Reddy and colleagues[15] reported it to be the most common diagnosis requiring arthroscopic treatment in athletes overall. Plain radiographs of the elbow may reveal these posteromedial osteophytes or loose bodies, typically best seen on a modified anterior–posterior (AP) humerus fully flexed elbow film with 40° of external rotation (**Fig. 1**).[16,17] Radiographs may also demonstrate calcification/ossification of the MUCL, possibly indicating prior injury or MUCL insufficiency.[2,11] MRI can further assess injury to the soft tissues and chondral surfaces, MUCL, and is also useful in evaluation of loose bodies, osteophytes, and neurologic pathologies/complaints.[2,11]

Initial conservative treatment of VEOS consists of activity modification and throwing rest, nonsteroidal anti-inflammatory medication, intra-articular corticosteroid and/or

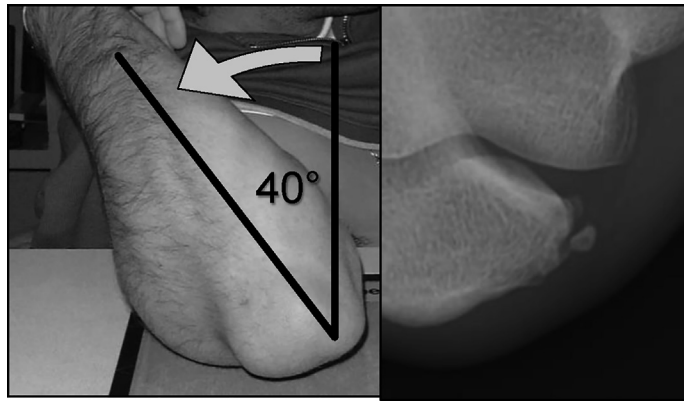

Fig. 1. Plain radiograph view depicting a loose body in 40° external rotation oblique anterior–posterior (AP) of humerus with the elbow fully flexed.

platelet-rich plasma injections, detailed assessment of pitching mechanics, and a progressive return to throw program.[1] However, minimal evidence-based literature is available on the outcomes following conservative care for posteromedial impingement, especially in those without overt compromise of the articular cartilage, subchondral bone, or MUCL.[3] Piraino and Davis[3] demonstrated a case report of conservative treatment in a 15 year old baseball player with VEOS, highlighting the capabilities and importance of a systematic movement examination and comprehensive rehabilitation program to address specific kinesiopathology.

Surgical intervention for VEOS is indicated when throwers fail to obtain symptom relief after a trial of conservative management. Arthroscopic posteromedial debridement and osteophyte excision have ultimately become a safe and reliable method to treat VEOS in throwers, with many results demonstrating high patient satisfaction and high rates of return to play (RTP).[1,14,15,18,19] Andrews and colleagues[14] first demonstrated an RTP rate of 70% at 24 months in 56 professional baseball players with posterior osteophyte excision; however, 41% required reoperation for repeat debridement. Five years later, Reddy and colleagues[15] showed an RTP rate of 85% in baseball players undergoing arthroscopic treatment of posterior impingement. More recently, Koh and colleagues[18] and Matsuura and colleagues[19] both demonstrated RTP rates as high as 97% and 100% in 36 and 15 throwers, respectively, undergoing elbow arthroscopy with posteromedial olecranon osteophyte resection. It is important to note, however, that olecranon spurs are routinely found in asymptomatic throwers (especially professional baseball players), and thus posteromedial decompression is only indicated in patients with positive provocative testing.[1]

Historically, the goal of surgical management for posteromedial impingement was to resect the olecranon tip in its entirety. However, modern thought and techniques now advocate against the removal of any portion of the normal olecranon margin (**Fig. 2**). Kamineni and colleagues[20] first demonstrated that sequential partial resection of the posteromedial olecranon resulted in a stepwise increase in valgus angulation as the amount of resection increased in 12 cadaveric elbows, challenging the rationale of removing any amount of normal olecranon in throwing athletes. In a follow-up study, Kamineni and colleagues[21] demonstrated increased strain on the MUCL with olecranon resections greater than 3 mm, supporting MUCL insufficiency as a relative contraindication to posteromedial decompression in fear of exacerbating valgus instability. Paul and colleagues[22] validated this fear by reporting that 18% of 28 baseball pitchers that underwent isolated arthroscopic posteromedial osteophyte resection for posteromedial impingement went on to require MUCL reconstruction surgery.

While RTP after arthroscopic debridement alone has been validated and studied, there is a paucity of literature regarding RTP after combined medial ulnar collateral

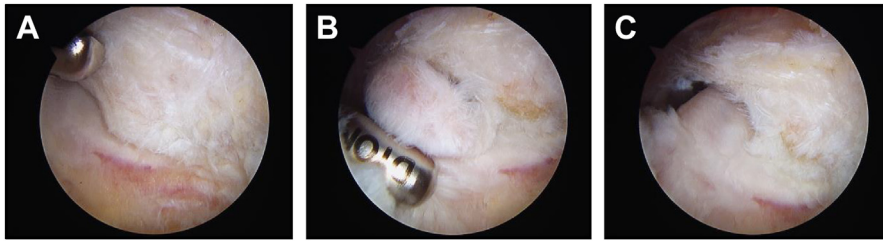

Fig. 2. Arthroscopic photographs of the posterior medial compartment and posterior medial olecranon tip margin with a mobile posterior medical olecranon tip fracture fragment (*A*), cleared of overlying soft tissue (*B*), and further mobilized for removal (*C*).

ligament reconstruction (MUCLR) and arthroscopic debridement for VEOS. Osbahr and colleagues[23] reviewed 29 baseball players who were treated for combined posteromedial chondromalacia and MUCL injury, demonstrating a lower RTP rate of 76% when compared to players with isolated MUCL injuries. However, Heaps and colleagues[24] showed an RTP of 83% in throwers undergoing MUCLR with concomitant arthroscopic posterior compartment debridement, additionally demonstrating no difference in statistical performance in pitchers before or after surgery. They concluded that the addition of an arthroscopic posterior impingement procedure does not diminish an athlete's ability to successfully return to sport (RTS) or perform at their prior level.[24]

Overall, the goal of arthroscopic debridement in throwers with VEOS should be restoration of the normal contour of the posteromedial compartment without removal of any portion of the normal olecranon margin, along with concomitant procedures of MUCL reconstruction or ulnar nerve transposition as indicated. It is critical to work up and recognize MUCL injury and valgus laxity in these patients in order to not worsen medial-sided pain and instability in the future. Advances in instrumentation and arthroscopy technique continue to improve the safety and efficacy of elbow arthroscopy in throwers. Surgeon's experience, knowledge, strategic preoperative planning, and expectation management remain paramount in the treatment of these athletes.

OSTEOCHONDRITIS DISSECANS

Osteochondritis dissecans (OCD) of the elbow is a localized disorder of articular cartilage and subchondral bone that results in a loss of structural support.[25,26] While the exact etiology is unclear and likely multifactorial, the widely accepted theory is that of repetitive microtrauma from excessive valgus creates stress along the radiocapitellar joint during development and throwing.[1,25,26] This stress manifests as compressive and shear forces, likely compromising an already tenuous blood supply, and resulting in separation between cartilage and bone beneath the epiphyseal cartilage, most commonly in the capitellum. This in turn leads to inflammation, edema, and ossification arrest of the articular fragment with subsequent fibrocartilage formation and eventual subchondral bone and articular cartilage fracture/fragmentation.[25,26] Because of this proposed mechanism, the overhead athlete is often affected. The general incidence of elbow OCD is reported as 2.2 per 100,000 (6.8 times greater in male individuals),[27] with reported incidences ranging from 1% to 7% in youth baseball players.[27–31]

Patients with OCD will initially present with an insidious onset of activity-related, poorly localized lateral elbow pain, decreased range of motion, mechanical symptoms (suggestive of intra-articular loose bodies), and tenderness of the radiocapitellar joint.[31] It is important to note that in 82 baseball players with an OCD lesion, Kida and colleagues[30] reported that only 32.9% reported elbow pain at diagnosis, but 81.7% had a history of prior elbow pain. The active radiocapitellar compression test will often be positive, eliciting lateral elbow pain upon rotation of the forearm with the elbow extended.[32]

Standard orthogonal radiographs have been reported to miss up to half of all OCD lesions and are less than 50% sensitive when compared to MRI.[31,33–35] Thus, routine radiographs are not typically useful for treatment planning or follow-up imaging. First described by Takahara and colleagues[26] and Conway,[36] the 45° flexed AP "capitellum view" is widely accepted as the standard of care for initial imaging workup in these patients as it is better able to visualize the capitellum.[37] In baseball players, it is our recommendation that flexed views are obtained at 40° and 60° in throwers as they have been found have larger lesions with higher inclination angles.[38] Advanced

imaging modalities such as computed tomography (CT) and MRI have been shown to be more valuable in not only identifying lesions but also evaluating and characterizing their stability.[34] MRI scans are almost always performed with intra-articular contrast with a high spatial resolution magnet, narrow slices (2–3 mm) with 3 dimensional reformats. It is our recommendation that MRI scans are performed with "40° up-oblique" sequences, allowing slices to be appropriately aligned with the OCD lesion (**Fig. 3**). CT scans are typically only useful for complex, late-stage reconstruction planning, and recent studies have begun to suggest that ultrasonography may even provide an improved screening tool capable of detecting asymptomatic lesions.[28,29]

The treatment of OCD is still largely evolving but is mainly predicated on the stability of the overlying cartilage, the size and location of the lesion, and the lesions capacity to heal (often related to age).[32] Many classification systems exist for a multitude of imaging modalities seeking to grade these lesion characteristics to guide treatment; however, they are typically unreliable and difficult to apply.[38–40] Overall, general signs of instability on imaging include fluid beneath the lesion, increased T2 signal at the fragment/bed interface, sclerosis, and fragmentation of the cartilage or subchondral plate with associated loose bodies (**Fig. 4**).[31,38,41]

Conservative management mainly involves rest from throwing with occasional immobilization. Some have advocated for bracing (including a range of motion brace or activity cast) as well as follow-up imaging at 6 to 12 week intervals to evaluate healing.[42] Takahara and colleagues[42] in particular advocates for immobilization with casting (mean: 3.7 weeks) followed by splinting (mean: 7.3 weeks) which was shown to enable earlier RTS (mean: 4.4 months) along with faster and more complete healing. This is our recommended first-line treatment of choice for young throwers with open physes. Evidence-based indications for nonoperative care include younger age and an open lateral epicondylar physis (more growth remaining healing potential), smaller, stable, and central grade I lesions, and the absence of radial head migration.[43,44] In a retrospective review of 93 elbows, Niu and colleagues[43] demonstrated a healing rate of 53.8% at a mean of 8.3 months, concluding that over half of "stable" OCD lesions have the capacity to heal with activity restriction. Smaller lesions and the absence of cysticlike lesions were independent predictors of healing.[43] In one of the only studies to report on RTP in nonoperative OCD management, Sakata and colleagues[44] reported a RTP rate of 70.4% in 81 youth baseball players at a mean time of 6.3 months. Proximal radial translation length on AP radiographs was significantly greater (less proximal migration) in the RTS group. Funakoshi and colleagues[45] performed a multivariate regression on 245 elbows with OCDs concluding that radial

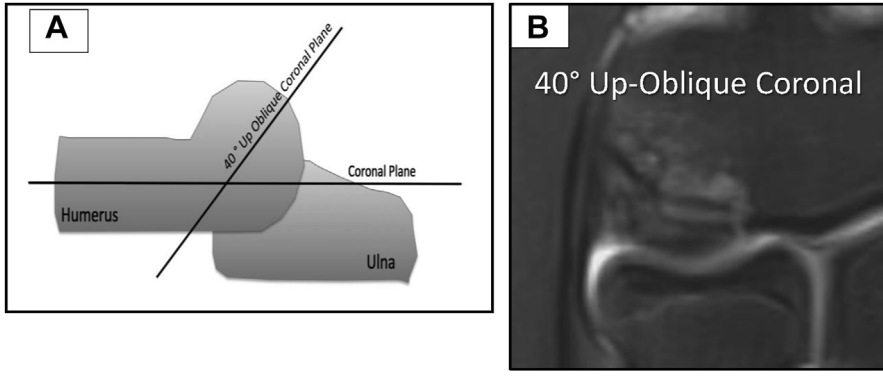

Fig. 3. 40° up-oblique coronal plane sequencing (*A*) for MRI detection (*B*) of OCD lesions.

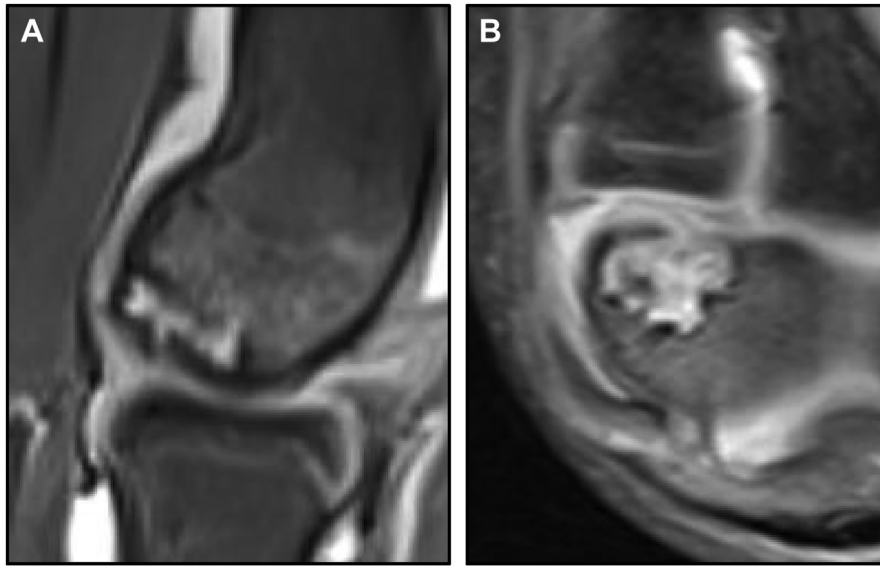

Fig. 4. Sagittal (*A*) and axial (*B*) MRI showing an unstable OCD.

head enlargement and asymmetrically advanced skeletal age were significant predictors of lack of healing and advanced stage lesion. This study suggests that a history of radiocapitellar joint stress (such as from repetitive throwing) may lead to OCD and thus cause a more advanced skeletal age in the involved elbow.

Numerous authors have concluded that many capitellar OCD lesions lack innate healing potential and thus conservative care may lead to poor outcomes especially in high-risk, overhead athletes trying to RTS.[2,41] Surgical management of OCD is largely guided by size and location of the lesion.[32] Predictors of poor outcomes with nonoperative care are unstable lesions, older age, longer duration of symptoms, closed lateral epicondylar physes, higher stage lesion classification findings, larger lateral lesions (especially uncontained lesions—lesions extending lateral to the radial head center line and including the lateral margin[46]; **Fig. 5**), as well as radiocapitellar incongruity and radial head hypertrophy/migration.[41,43–45] Surgical options include arthroscopic debridement, drilling/microfracture and loose body (LB) removal for smaller lesions, and fragment fixation and open complex reconstruction procedures for larger lesions.

Multiple studies have demonstrated mixed results with regard to arthroscopic debridement with or without drilling. Lewine and colleagues[47] reported a return to primary sport rate of 66.7% in 21 adolescents with Grade IV OCD lesions (defined in this study as detachment of the lesion and intra-articular LB formation) treated with LB removal and drilling/microfracture. Bexkens and colleagues[48] reported a lower rate of 55% in 77 patients treated with debridement and LB removal, citing open physes and shorter duration of symptoms as being correlated with improved outcomes. More recently, Matsuura and colleagues[49] and Rothermich and colleagues[50] reported RTS rates of 87% (only 20% in pitchers) in Grade IV and V lesions and 93% in lesions ranging from “small, moderate and large” in size, respectively. While many of these results support non-reconstructive surgical care, they also demonstrate that while debridement and drilling can be effective for some, it is not successful for all, especially overhead throwers.

Fig. 5. Radiograph that demonstrates a large lateral uncontained osteochondritis dissecans capitellum lesion that extends beyond the radial head midline (black *line*) and the lateral third line (white *line*). The prognosis for healing with conservative care is limited with increasing lateral involvement.

With the high demand of the throwing athlete and the average-to-moderate outcomes of arthroscopic debridement and drilling, complex cartilage reconstruction and restoration procedures may be the preferred option for large unstable lateral lesions. At the forefront of these procedures is osteochondral autograft (OAT) and allograft transplantations (Fig. 6). Autograft harvest sites have included the ipsilateral or contralateral elbow and knee (lateral trochlea, notch, costochondral), and allograft donors have ranged from precut fresh osteochondral plugs or knee condyle/trochlea to multiple other sources such as the humeral head, distal humerus, femoral head, and

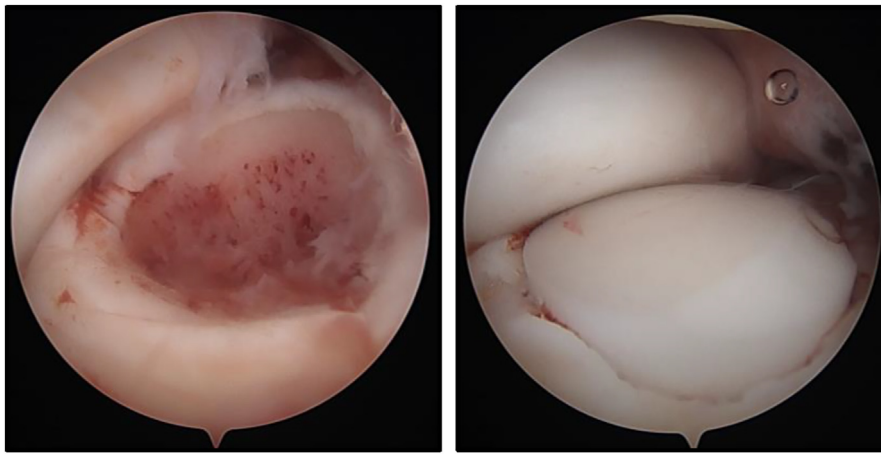

Fig. 6. Osteochondral autograft transplantation surgery in the management of OCD. One 10 mm medial trochlea graft was used in the reconstruction.

talar head. In a systematic review from 2016 comparing RTS rates in athletes (primarily baseball players and gymnasts) undergoing OCD debridement, fixation or OAT procedures, Westermann and colleagues[51] found that the return to the highest preoperative level of sport was most common after OAT (94%). They also demonstrated that fragment fixation had a lower RTS and higher reoperation rate than both debridement and OATS. Since that time, multiple other systematic reviews and studies have also supported high (>90%) successful RTS and graft incorporation rates, as well as reliable outcomes with few complications and low donor-site morbidity.[31,52–55]

OCD lesions of the elbow remain a difficult and controversial pathology to treat. To date, no controlled prospective studies that consider lesion stage or standardized therapy exist, and there are few studies that prospectively compare OCD treatment options. Overall, we recommend using an evidence-/algorithm-based approach in the treatment of these athletes. Conservative care has the potential to be successful in young, premature, stable, small, central, short duration lesions, while operative management is typically indicated in larger, more mature, unstable lesions with indications for OATS for large lateral lesions. Nonoperative progress can be followed with selective, flexed AP radiographs and specific OCD sequence MRI scans; however, they should not be followed for more than 3 months without considerable concern and discussion of operative intervention. Arthroscopic debridement/drilling and fragment fixation may be acceptable for smaller, shallow-contained lesions without evidence of radial head pathology. However, there is growing evidence that these procedures may not work as well or as predictively as OATS procedures and have lower RTS and higher reoperation rates.

OLECRANON STRESS FRACTURE

Olecranon stress fractures (OSFs) are a rare upper extremity fractures that primarily impact the overheard thrower.[56] As the olecranon is repeatedly driven into the fossa during the throwing motion, shear and impaction forces are created along the medial tip/fossa leading to the development of stress reactions, fractures, and osteophytes.[2,10,13] Typically deemed an injury of overuse, the olecranon is the site of injury for 58% of stress fractures in baseball players with pitchers being the most at-risk position.[56,57] Athletes will typically present with an insidious onset of vague, activity-related posterior elbow pain that is progressive over the course of weeks, often occurring with elbow extension at ball release.[56,58] Point tenderness to palpation over the posteromedial or posterolateral olecranon is a key physical examination finding.[56,58] In throwers specifically, repetitive valgus loads on the elbow can cause additional attenuation of the MUCL with increased reliance on the posterior elbow for stability and a compensatory increase in posteromedial compression during the throwing motion.[56,58]

Initial workup begins with plain radiographs. While often initially normal and nondiagnostic, characteristic findings can include new periosteal bone formation, enthesopathy, endosteal thickening, cortical radiolucency and sclerosis, and even late fracture lines.[58,59] Early detection and diagnosis of OSF is imperative as prior literature has demonstrated a statistically significant difference in return time to sport in athletes when the stress injury was diagnosed within 3 weeks of symptom onset (return time 10.4 vs 18.4 weeks).[60] Lateral radiographs with the humerus internally rotated 20° ("hand down lateral") may enhance visualization of the posteromedial olecranon (**Fig. 7**).[56,59] If stress injury is suspected but radiographs appear normal, advanced imaging with CT, MRI, and 3 phase bone scan may be helpful with early diagnosis. CT scan is often useful in identifying cortical abnormalities and early signs of fatigue

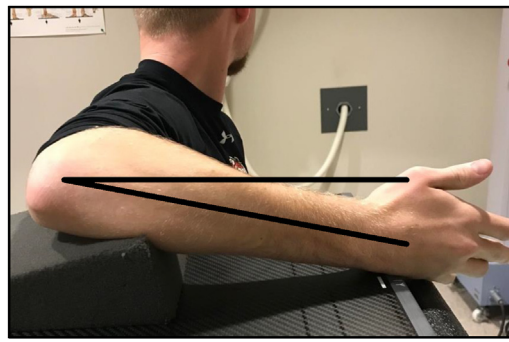

Fig. 7. Suggested positioning for hand down lateral radiographic imaging for the detection of posteromedial olecranon stress fractures.

damage.[61] It should be performed on a minimum 128 slice scanner with true axial, sagittal, and coronal alignments and may also be used to follow stress reaction healing postoperatively.[59] Bone scintigraphy is quite sensitive for early detection of stress reactions within 3 to 5 days after symptom onset due to its capacity to detect areas of subtle osseous turnover and stress remodeling.[62] However, MRI has remained the gold standard for diagnosis due to its enhanced sensitivity and specificity.[63] With its sequencing-dependent capacity to detect early bone edema, it also provides a more comprehensive evaluation of the bone and surrounding soft tissue, making it especially critical in throwers when considering and evaluating the relationship between olecranon stress injury and MUCL damage.[56,62] However, it is also important to note that MRI may provide a delayed positive or false negative especially in olecranon tip and sublime tubercle fractures.[58,59]

Treatment of OSF requires a thorough understanding of the origin of injury and subsequent fracture plane characteristics.[64] Furushima and colleagues[64] sought to classify OSF in baseball players. Retrospectively reviewing 200 baseball players, they identified 5 types of OSF: (1) physeal (mean age of onset [MAOO], 14.1 year); (2) classic (MAOO, 18.6 years); (3) transitional (MAOO, 16.9 years); (4) sclerotic (MAOO, 18 years); and (5) distal (MAOO, 19.6 years). The physeal type was subclassified into 4 stages based on the severity and was the most common pediatric OSF, while the classic type was the most common adult OSF where the fracture line originates from the ulnar articular surface and develops into an oblique fracture due to the closure of the epiphyseal plate. The authors postulated that the different types of OSF depend on the presence or absence of remnants of the epiphyseal plate and the age of onset. Additionally, they found a concomitant MUCL injury and/or medial epicondyle avulsion fracture in 71% to 95% of cases.[64] Subsequent authors have expanded upon this classification, namely by separating fractures of the immature skeleton into proximal extra-articular and distal intra-articular (more common in baseball players) variants, as well as describing 4 fracture patterns in the mature skeleton: the diffuse proximal ulna and olecranon stress reaction, the mid-oblique OSF, the transverse proximal OSF, and the olecranon tip stress fracture (**Fig. 8**).[58,65,66]

Conservative management typically begins with throwing cessation, rest, rehabilitation exercises, progressive throwing programs, and possible bone growth stimulators.[2,56] Furushima and colleagues[64] reported that nonsurgical management is typically indicated for sclerotic OSF, but may also be attempted in the physeal, classic, transitional, and distal patterns for a duration of 3 months, especially when diagnosed early. Papaliodis and Conway[58] reported that in general, conservative care is reserved

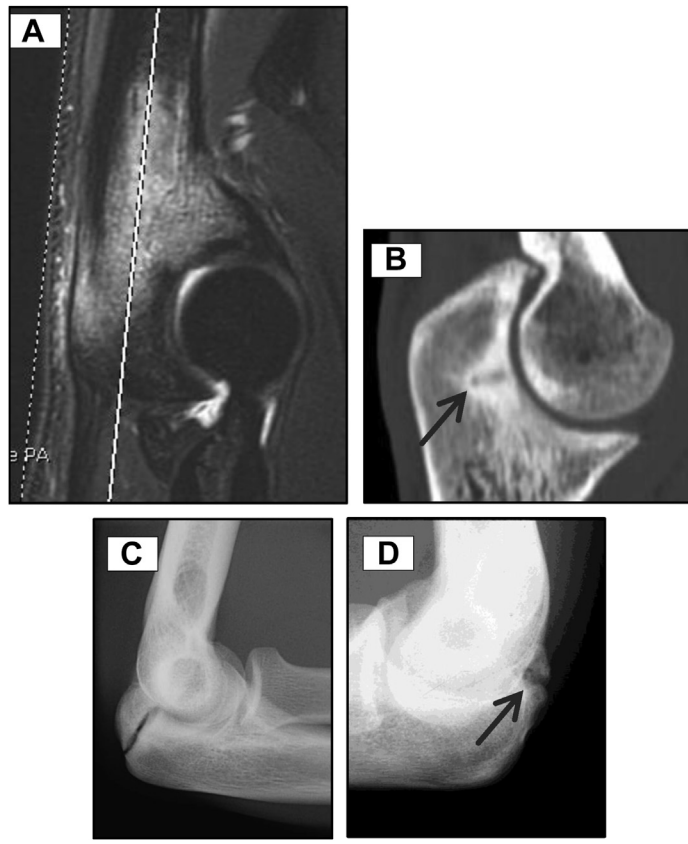

Fig. 8. Imaging findings of different types of olecranon stress fractures in the mature skeleton (*A*) the diffuse proximal, (*B*) the mid-oblique, (*C*) the transverse, and (*D*) the olecranon tip.

for athletes 13 years and younger, while surgical management is indicated for those 16 years and older. Athletes within the middle 14 to 15 year old range are indicated for surgical management if the involved physis is fully open while the contralateral physis is closed or if the involved physis is surrounded by marked sclerosis.[58] Surgical management is rarely necessary for adult-type diffuse proximal ulna/olecranon stress reactions, but conservative care is typically less successful for the mid-oblique and transverse proximal OSF patterns, especially when there is a clear radiographic fracture line.[58]

While multiple authors have demonstrated successful treatment of OSF with nonoperative management, many OSFs in the competitive thrower often fail to adequately respond to conservative care and require surgical fixation in order to successfully return the athlete to sport in a timely manner.[2,67,68] According to a systematic review by Smith and colleagues,[67] up to 77% of patients do opt for a surgical procedure. Many surgical options have been described, including tension band wires, headed and headless compression screws, washers, and compression plating.[58,69–72] In the senior author's experience, a single 6.5 mm for apophyseal fractures or two 4.0 mm partially threaded, countersunk, noncannulated headed compression screw(s) for adult fracture oriented perpendicular to the fracture plane is the optimal surgical

treatment of choice (Fig. 9).[58,59,66] For adult fractures, the screw(s) should be placed as close to the subchondral plate as possible (fluoroscopic imaging parallel to guide pins confirms the proximity to the subchondral plate), typically from a proximal-posterior-lateral to distal-anterior-medial direction.[59] Arthroscopic-assisted fracture reduction may be useful for displaced fractures, and tapping of drill tunnels is especially important when sclerosis is present to avoid implant failure during insertion.[58] Complications may include nonunion, refracture, trochlea chondromalacia, hardware complications, and persistent triceps pain.[59]

Paci and colleagues[73] reported 17 of 18 (94%) athletes with OSF treated with cannulated screw fixation after failed conservative management returned to sport at an average time of 29 weeks. Of note, 6 patients did undergo subsequent hardware removal at a later date.[73] Similarly, Fujioka and colleagues[74] reviewed 6 adolescent overhead throwers who underwent fixation of OSF with a single headless cannulated screw and reported that all 6 were able to RTS. Recently, Erickson and colleagues[75] reviewed all professional baseball players who underwent surgical management of OSF between 2010 and 2016, reporting that among 52 players (75% pitchers), the majority sustained a primary OSF treated with one screw and the overall RTS rate was only 67.5%. Those who sustained an acute OSF had an overall RTS rate of 83.3% at an average time of 282 days. This study suggests that a lower RTS rate in professional throwers may be expected, likely due to the higher demands placed upon the elbow in these elite athletes.[75] Interestingly, this study reported only 3 pitchers who subsequently required MUCL reconstruction, suggesting that MUCL procedures are largely unnecessary in throwers with isolated OSF in the absence of medial-sided symptoms.[75]

Finally, the olecranon tip stress fracture is a common pattern that typically results from VEO and posteromedial impingement with olecranon tip exostosis and tip fragmentation as described in the VEOS section.[58] Throwers may present with posteromedial trochlea osteochondral injury, loose bodies, and MUCL insufficiency.[58,66] It is important to note, however, that olecranon tip exostosis is a common, asymptomatic finding in many professional baseball players.[59] When symptoms are present and do not respond to conservative care, arthroscopic fragment excision is the treatment

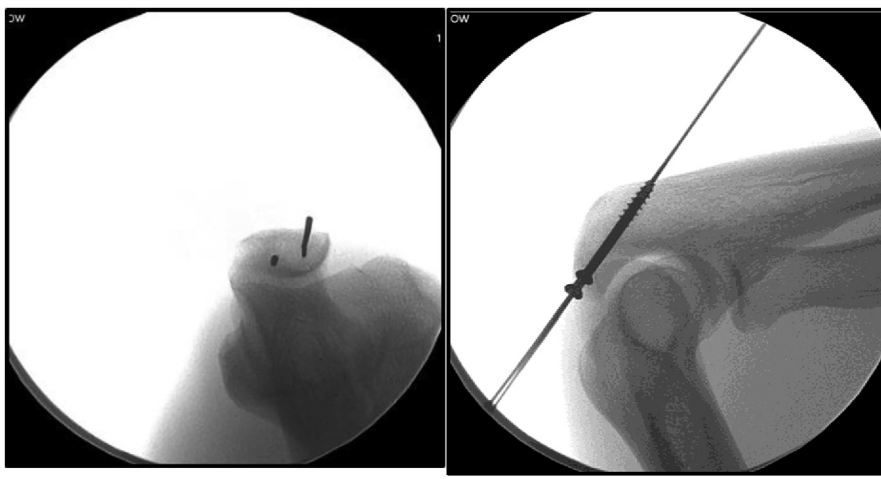

Fig. 9. Axial and lateral fluoroscopic images of the elbow demonstrating appropriate guide pin and subsequent cannulated screw placement for fixation of a transverse proximal olecranon stress fracture. Alignment of the guide pin with the fluoroscopy imaging beam will confirm proximity to the subchondral plate and avoid joint penetration.

of choice along with careful assessment of the need for concurrent MUCL procedures.[56,58,66] The normal olecranon should again be preserved with resection reserved only for pathologic bone.[58]

Overall, the insidious onset of OSF can make timely diagnosis and treatment difficult, leading to a significant source of morbidity in the overhead throwing athlete.[75] Clinical suspicion should always remain high when evaluating the thrower, along with a detailed history, physical examination, and appropriate and expeditiously obtained imaging.[58,66] While nonoperative management with close follow-up can be successful, operative management remains the gold standard in the throwing athlete secondary to increased risk for delayed union and nonunion.[56,58,66] Successful treatment of OSF and optimizing RTS in the overheard thrower is possible and largely dependent upon early diagnosis and individualized, evidence-based management.

ULNAR NERVE

Ulnar nerve injury is an uncommon but consequential condition seen in the overhead throwing athlete that creates a significant amount of morbidity and treatment complexity. Extreme valgus forces placed upon the medial elbow during the throwing motion combined with the subcutaneous nature of the ulnar nerve throughout the cubital tunnel make ulnar neuropathy the second most common neuropathy of the upper extremity and the most common neuropathy in the thrower's elbow.[2,76–78] While it may occur in isolation, ulnar nerve injury is often associated with other pathologic processes of the elbow, including MUCL insufficiency.[77,79] Up to almost half (42%) of pitchers with MUCL injuries have been reported to have concomitant ulnar neuritis, further complicating the treatment algorithm.[80] Using a cadaveric study, Mihata and colleagues[81] confirmed that MUCL injury and attenuation cause significant strain and elongation of the ulnar nerve at 60° and 90° of flexion. Aoki and colleagues[82] reported an increase in movement of the ulnar nerve during all throwing phases and a 13.1% increase in strain on the nerve during the acceleration and late cocking phases, placing the nerve close to its elastic and circulatory limits. Recently, Looney and colleagues[83] reported the prevalence of bilateral ulnar nerve subluxation in professional pitchers to be 26.4%; however, none were symptomatic or associated with pathologic findings. Additional secondary causes of ulnar nerve injury include compression at other known anatomic sites of the elbow and arm, aberrant musculature, anconeus epitrochlearis (**Fig. 10**),

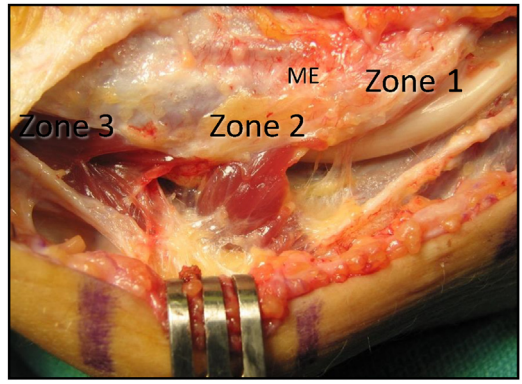

Fig. 10. Medial elbow demonstrating ulnar nerve and 3 zones of the cubital tunnel. There is a small anconeus epitrochlearis muscle in Zone 2. ME, medial epicondyle.

flexor muscle hypertrophy and osteophytes, as well as direct trauma, repetitive friction from subluxation as previously mentioned, and the subsequent formation of perineural adhesions, scarring and entrapment after MUCL surgery.[76,79]

Ulnar nerve symptoms can imitate many other upper extremity pathologies, making complete and detailed histories and physical examinations of utmost importance. Typical symptoms include paresthesia in the small and ulnar half of the ring finger, intrinsic hand weakness often affecting ball grip, vague medial elbow and arm pain, ulnar nerve distribution paresthesias at night and while throwing, throwing clumsiness, and loss of command.[76,79] Snapping or popping sensations may occur in cases of ulnar nerve subluxation, and players may complain of decreased velocity, pain with throwing, and decreased pitch counts and innings pitched.[77] Of note, it is important to consider and rule out potential upstream diagnoses of thoracic outlet syndrome and cervical radiculopathy, as well as concurrent MUCL insufficiency. Physical examination must include the entirety of the ulnar nerve throughout the arm and may be significant for focal posteromedial tenderness, positive Tinel's sign/percussion test asymmetric to the contralateral side, neurotension signs, palpable nerve subluxation during flexion and extension, altered light touch and pinprick sensation, and more chronic late findings of hand atrophy and intrinsic weakness.[77,79] Ultrasound evaluation has been demonstrated to useful in detecting the ulnar nerve subluxation; however, physical examination is still highly specific.[84]

Standard radiographs may demonstrate olecranon osteophytes, MUCL calcifications, or other bony degenerative changes that may cause diminished cubital tunnel volume and compression on the ulnar nerve.[77,79] This is often seen with VEOS as previously mentioned. MRI can be used to evaluate the MUCL and ulnar nerve appearance, and electrodiagnostic studies may be useful to confirm the diagnosis and locate the site of compression.[79] Comprehensive nerve conduction studies should always be requested with above elbow and below elbow nerve conduction velocity (NCV) tests. Short-segment incremental NCV studies may be significantly more sensitive for localizing the site of conduction delay.[85,86]

Initial management typically begins conservatively with rest from throwing, anti-inflammatory medication, and physical therapy.[77,79] Nighttime extension splinting to immobilize the ulnar nerve may be beneficial, as well as avoidance of elbow flexion, active release therapy, and nerve glide exercises/techniques.[87,88] Extension splinting may be especially useful in throwers experiencing nerve subluxation.[2,77,88] However, while conservative management is typically successful in lower demand or nonthrowing patients, the elite thrower that places high demand on the elbow may not respond as well and ultimately require surgical intervention.[78]

Surgical indications for ulnar neuropathy include failure of conservative management, persistent nerve subluxation, and concomitant MUCL injury requiring repair or reconstruction.[77] Treatment should be based on careful history and physical examination, response to conservative care, specific cause of entrapment/compression, as well as patient-specific factors and surgeon's training/experience. Options include simple decompression with neurolysis or transposition (submuscular vs subcutaneous [**Fig. 11**]) with the goal being to decompress points of constriction along the nerve allowing it to rest without tension and return athletes to nonpainful throwing.[76,77]

Pizzo and colleagues[89] initially treated ulnar nerve entrapment with anterior submuscular transposition, demonstrating successful RTS in 9 of 15 (60%) baseball players between 3 and 58 months. Of note, 6 players quit altogether due to continuing elbow symptoms. Today, controversy remains regarding simple decompression

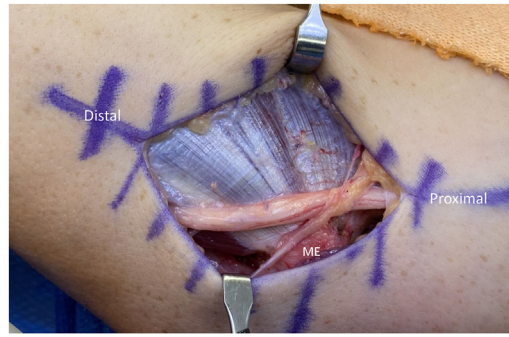

Fig. 11. Open ulnar nerve subcutaneous transposition.

versus decompression with submuscular versus subcutaneous transposition.[77] While simple decompression provides the advantages of minimal morbidity and the avoidance of ulnar nerve vascularity disruption, it provides no reduction in nerve strain and does not treat subluxation.[2,77] Given the extreme traction forces placed upon the nerve during the throwing motion, simple decompression is typically not recommended in the overhead thrower.[90,91]

While submuscular transposition can protect the nerve from additional direct trauma, subcutaneous transposition is favored in high-level throwers due to its preservation of the flexor–pronator musculature and decreased rates of postoperative ulnar neuritis symptoms.[14,77,92,93] Erickson and colleagues[76] identified anterior subcutaneous transposition as the most common procedure performed in professional baseball players experiencing ulnar neuritis (92% among 52 players [83% pitchers, 14 with prior MUCL reconstruction]). Historically, the authors such as Rettig and Ebben[94] and Petty and colleagues[95] have demonstrated successful results and RTS rates with subcutaneous transposition; however, Erickson and colleagues[76] found that only 62% of players were able to successfully RTS, leaving questions regarding the optimal surgical treatment in these athletes.

Overall, there are several available methods for the treatment of ulnar neuritis without a clear consensus on the best. Regardless of the method chosen, the principles remain the same: successful identification of the cause of nerve entrapment, adequate exposure and mobilization of the nerve, preservation of the vascular supply and motor branches, and avoidance of late compression and tethering. Clinicians must remain aware of all nerve compression etiologies and successfully diagnose concurrent medial laxity in order to best treat these athletes and provide the best possibility of successful RTP.

SUMMARY

The thrower's elbow and throwing motion represent a synergistic combination of strength, dynamic mobility, and complexity where repetitive valgus forces can lead to distinctive injury patterns.[77,78] While much of the literature focuses on the MUCL, this article highlights the importance of the array of non-MUCL elbow injuries in the overhead thrower that can significantly impact performance and RTS. By recognizing and addressing these often subtle yet potentially debilitating injuries, clinicians can not only optimize athletic performance but also mitigate long-term complications and help ensure career longevity of the overhead thrower.

CLINICS CARE POINTS

- The normal contour of the posteromedial compartment without removal of any portion of the normal olecranon margin should be the goal of arthroscopic debridement in throwers with VEOS.
- When considering OCD lesions, conservative care has the potential to be successful in young, pre-mature, stable, small, central, short-duration lesions, while operative management is typically indicated in larger, more mature, unstable lesions with indication for OATS for large lateral lesions.
- Successful treatment of OSF and optimizing RTS in the overhead thrower is possible and largely dependent upon early diagnosis and individualized, evidence-based management.
- Regardless of the method chosen to treat ulnar neuritis, one must consider the following: successful identification of the cause of nerve entrapment, adequate exposure and mobilization of the nerve, preservation of the vascular supply and motor branches, and avoidance of late compression and tethering.

DISCLOSURE

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